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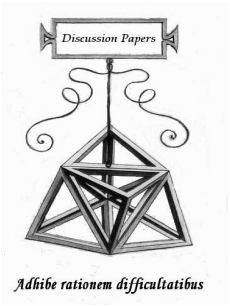

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The determinants of inter-firms R&D cooperation and partner selection. A literature overview.

Abstract

Firms which want to augment their technological capabilities can do it through in-house efforts or external R&D activities, such as R&D contracting or R&D cooperation. In this paper I focus on R&D cooperation, developing an originally structured and detailed review of its main determinants with a particular attention to the selected cooperation partners. The main contribution of this paper is to highlight points in which literature has not still achieved clear cut conclusions on the factors affecting firms' propensity to engage in R&D cooperations with other firms or science institutions, suggesting open fields of research.

Classificazione JEL: O31; O32; L22
Keywords: R&D cooperation, Innovation

Contents

I. Introduction

When speaking of cooperation, interest essentially resides in four large areas: (i) The motives which cause firms to form the alliances; (ii) the selection of partners; (iii) the management of the alliances, and (iv) the measurement of alliance performance (Bayona *et al.*, 2001). In this literature review I focus on the first two research fields and I restrict the analysis mainly on cooperations in R&D.

Firms which want to augment their technological capabilities can do it through in-house efforts or external R&D activities, such as R&D contracting or R&D cooperation[1].
Hagedoorn (1993, pp.378) presenting an insightful overview of major motives for strategic alliances, asserted that "[...]cooperation has to be understood in the light of attempts made by companies to cope with the complexity and interrelatedness of different fields of technology and their efforts to gain time and reduce uncertainty in joint undertakings during a period of growing technological intricacy". In this paper I focus on R&D cooperation, developing an originally structured and detailed review of its main determinants with a particular attention to the selected cooperation partners. The main contribution of this paper is to highlight points in which literature has not still achieved clear-cut conclusions on the factors affecting firms' propensity to engage in R&D cooperations with other firms or science institutions, suggesting open fields of research.

Since the 1980's an increasing variety of cooperative arrangements between innovating firms has emerged (Mariti and Smiley, 1983[2]). Scholars highlighted how innovation increasingly derives from a network of companies interacting in a variety of ways (Free-

[1]Schmiedeberg, 2008 using data from the Mannheim Innovation Panel (MIP), found a complementarities between internal R&D and R&D cooperation, obtaining similar results to Becker and Peters, 2000. On the other hand, Fritsch and Lukas, 2001 observed that R&D cooperations are a substitute of internal R&D.

[2]See also: Caloghirou, Ioannides and Vonortas, 2003 for an insightful review of different approaches to study different types of research joint ventures; and Hagedoorn, 2002 for an historical overview of 40 years of R&D partnerships, since 1960.

man (1991) and Veugelers (1997))[3]. Cooperation with other firms are, in fact, aimed to make external resources, like knowledge, available and usable. Through cooperation, complementary assets can be pooled together thus generating synergies and cross-fertilization effects (Becker and Dietz, 2004). Cooperation between firms vary from highly formalized Joint Ventures to informal agreements, and the exchange of knowledge intensive strategic assets is normally at the centre of these cooperative activities (Porter, 1990). Oxley and Sampson (2004) highlighted the many opportunities of collaborations in R&D, among which hints about partner strategies and directions of technological search, competitive benchmarking data, identification of key personnel, absorption of codified and tacit knowledge. Both formal and informal R&D cooperations allow firms to exploit these opportunities.

Informal cooperations are often referred, by economists, as information trading (Von Hippel, 1987). "Information trading refers to the informal exchange of information between employees working for different sometimes directly competing firms. Employees provide collegues working at other firms with technical advices in the expectation that their favours will be returned in the future" (Schrader, 1991, pp. 154).

Formal R&D cooperation is generally defined as firms' explicit arrangements committing parties in an active participation in joint R&D and other innovation projects[4].

Nevertheless, inside each strategic alliance, both informal and formal mechanisms of knowledge sharing could take place. Kale and Singh (2007, pp.986), in their fieldwork, observed that companies use several practices of alliance knowledge sharing: "(...) from using informal mechanisms, such as casual conversations and discussions between alliance managers, to having formal mechanisms such as alliance committees and task forces that meet periodically to review and exchange alliance management experiences and best

[3]Some of these interacting modes are: R&D consortia, Joint Ventures, implicit coordination, mutual exchange or informal know-how trading (Veugelers, 1997, pp. 303)

[4]This definition is given in the Community Innovation survey's questionnaires

practices."However, it is worth to highlight that there is a scarcity of empirical literature on the determinants of informal and formal R&D cooperation in an integrated framework in particular referring to formal and informal cooperation with competitors (Bonte and Keilbach, 2005). Probably because, as Allen *et al.* (2007) argue, managers rarely seek to understand and manage informal network and often focus formal and informal networks together.
On the contrary, I can observe an increasing number of papers exploring determinants and effects of formal R&D cooperations. Three main reasons have probably driven this scholar's choice:

1 - Lack of data on informal R&D cooperation. The study of informal R&D cooperation needs a case study approach and a laborious collection of primary data through *ad hoc* questionnaires and interviews. In Table 1 I provide a list of papers about informal R&D knowledge linkages/cooperations, although I am not mainly exploring this aspect.

2 - The policy relevance of formal R&D cooperations. Most EU and National public funding for R&D is, in fact, directed at stimulating innovation and cooperation between firms, and between firms and public institutions (Acosta and Modrego, 2001; Abramovsky *et al.*, 2004 and Czarnitzki *et al.*, 2007 for a discussion on the European policies for innovation) in order to improve information flows between economic agents and foster innovation.

3 - The increasing availability of data on formal R&D cooperation dues to the development of periodical European harmonized Community Innovation Surveys (CIS) since 1992, where firms are asked information about their cooperative and innovative behavior.

To the best of my knowledge, up to now, empirical papers dealing with formal R&D cooperations and using CISs databases are those in Table 2. In Table 2 I make a distinction between studies focused only on the R&D cooperation issue, without distinguishing

Table 1: **The studies on Informal R&D cooperation and informal knowledge transfer**

References	Research questions	Methods and data	Integration with analysis of formal cooperation
Von Hippel (1987)	Analysis of Informal Know-how trading	Case study on 45 US firms with a minimill plant	NO
Sharader (1991)	Analysis of Informal technology trasfer between firms	Factor and Probit analysis on data from a survey on 294 managers of companies from US steel industry	NO
Appleyard (1996)	Determinants of knowledge sharing	Logit analysis on a sample of 134 employees of Japanese and US semiconductor equipment companies	NO
Sattler *et al.* (2003)	Analysis of informal horizontal cooperations Does it lead to advantages?	Probit analysis using data from a survey of employees in companies of the US and German steel industry	NO
Giuliani and Bell (2005)	Impact of absorptive capacity on the probabilty to establish interfirms knowledge linkages	Social Network analysis on a sample of 32 Chilean wine producers	NO
Bonte and Keilbach (2005)	Determinants of firms' choices between different modes (formal and informal) of vertical cooperation	Multinomial logit analysis on a sample of 730 firms from the MIP data-set	YES
D'Este and Patel (2007)	Factors influencing researcher's engagement in a variety of interactions	Ordered logit on a sample of 1526 researchers of UK universities	YES
Okamuro (2007)	Determinants of successful R&D cooperation in Japanese small business	Probit analysis using data from a survey on 1577 Japanese SMEs	YES
Allen *et al.* (2007)	Compare and contrast formal versus informal knowledge networks	case study on 130 senior R&D personnel of ICI PLC group	YES
Giuliani (2007)	Analysis of structural characteristics of knowledge networks in clusters	Social Network analysis on a sample of 105 wine producers in Italy and Chile	NO
Todtling *et al.* (2009)	Analysis of the Relationship between innovation and external knowledge linkages	Logit analysis using data from a survey on 400 Austrian firms	YES
Weterings and Boschma (2009)	Do spatial proximity facilitates face-to-face interactions? And this increase firm's innovative performance?	Probit analysis on a sample of 265 software SME in Netherlands	NO
Giuliani and Arza (2009)	What drives the formation of 'valuable' university-industry linkages?	Two-stage hekman model on a sample of 73 wine producers located in Italy and Chile	NO

for the selected partners, and studies which do it, trying to explore which factors affect three cooperations types: horizontal cooperations with competing firms, vertical cooperations with suppliers and customers and science cooperations with universities or other research institutions. Finally, Table 2 highlights two points: (i) a

great part of these papers are one country focused (ii) none of these papers explores R&D cooperation for the Italian case.

Table 2: **The analysis of formal R&D cooperation using CIS data**

References:	Distinction among: Horizontal coop (H) Vertical coop (V) Science coop(S)	Countries analysed							
		ES	BE	FR	DE	UK	NL	AT	FI
Bayona *et al.* (2001)	No Distinction	X							
Cassiman and Veugelers (2002)	No Distinction		X						
Tether (2002)	V; H and S					X			
Mohnen and Hoareau (2003)	S			X	X				
Miotti and Sachwald (2003)	V, H and S			X					
Laursen and Salter (2004)	S					X			
Belderbos *et al.* (2004)	V; H and S						X		
Dachs *et al.* (2004)	V; H and S							X	X
Abramovsky *et al.* (2005)	V; H and S	X		X	X	X			
Vencatachellum and Versaevel (2006)	H			X					
Belderbos *et al.* (2006)	V; H and S						X		
Czarnitzki *et al.* (2007)	No Distinction				X				X
Van Beers *et al.* (2008)	S						X		X
Tether and Tajar (2008)	S					X			
Busom and Fernandez-Ribas (2008)	V and S	X							
Lopez (2008)	V; H and S	X							
Arranz and De Arroyabe (2008)	V; H and S	X							
Segarra-Blasco and Arauzo-Carod (2008)	V; H and S	X							
Lhuillery and Pfister (2009)	V; H and S			X					

Notes: References are ordered by year. "Horizontal coop" stands for Horizontal R&D cooperation; "Vertical coop" for vertical R&D cooperation; "Science coop" for R&D cooperation with universities or other research institutions.

The remainder of the paper is organized as follows: Section II explores the main determinants of R&D cooperation distinguishing among firm-level factors, industry-level factors, regional/country-level factors and dyadic-level factors; Section III explores the firm's choice among different R&D cooperation partners i.e. Suppliers and Customers (Vertical cooperation), Competitors (Horizontal cooperation) and Universities and Research Institutions (Science cooperation); Section IV reports some concluding remarks.

II. Determinants of R&D cooperation

Hereafter, I try to review the most important determinants of the firms' decision to engage in formal R&D cooperation agreements that the literature, up to now, has dealt with. These R&D cooperation's driving factors are summarized in Table 3, allowing for a distinction among (A) factors referring to the single firm features and behaviours; (B) factors referring to the industry in which the firm operates; (C) factors referring to the firm's country of origin's

characteristics and policies, and (D) factors referring to the dyadic attributes between interacting actors (dyadic-level). This section will follow this structure explaining the meaning and relevance of each factor analyzed. Finally, Table 3 will connect us to the last section of this paper about firms' R&D cooperation partners selection, summarizing the impact of explored determinants on the firms' propensity to engage in different types of cooperation agreements, namely, vertical cooperation with suppliers and clients, horizontal cooperations with competitors, and science cooperation with universities and public or private research institutes.

II.A. Firm-level factors

The firm-level inflows and outflows of knowledge spillovers

Firms generally absorb and transfer valuable flows of knowledge from/to other firms. These technology transfers can take place because of voluntary exchanges of information between firms jointly working to the same R&D project, firms' imitative behaviours or absorption of knowledge intensive information which other firms are not able to fully appropriate. In the latter case, this knowledge flows are often referred to as *spillovers*.
In Table 3 the knowledge spillovers variable is decomposed in two factors: *appropriability* (See Table 3, factor A-1); and *incoming spillovers* (See Table 3, factor A-2). The reason of this distinction is due to the need to identify, for each firm, the outgoing flows of knowledge, namely, the amount of information the firms are not able to appropriate; from the ingoing flows of knowledge the firm benefits drawing on public pool of knowledge[5].
To the extent that the aim of each firm is to maximize the incoming

[5]Kenneth Arrow (1962) in his seminal paper "*Economic Welfare and the allocation of resources for invention*" drew the attention of the economists to the consequences of positive externalities associated with private investment in Industrial Research and Development (R&D). He observed that the firm's incentive to invest in R&D is attenuated when the knowledge generated by the investment is involuntary transmitted to competitors and asserted that "no amount of legal protection can make a thoroughly appropriable commodity of something so intangible as information" (pp.615).

spillovers and minimize the outgoing knowledge flows, R&D cooperation is a way to manage these incoming and outgoing flows of knowledge since, by arranging a formal R&D arrangement, firms are able to minimize involuntary leakages.
From a theoretical point of view, the industrial organization literature, emphasizes the role of knowledge spillovers in the context of formal collaborative research (Spence, 1984; D'Aspremont and Jacquemin,1988; Kamien *et al.*, 1992). Such studies relate to the fact that economies characterized by bad appropriability conditions lead firms not to perform the desired R&D projects because of the impossibility to fully exploit their results easily threatened by rival firms. Therefore, in such economies, R&D cooperation is a useful way to internalize knowledge spillovers.

From an empirical point of view, the seminal paper of Cassiman and Veugelers (2002) studied the relationship between knowledge spillovers and formal R&D cooperation distinguishing between these two measures of knowledge flows: (i) incoming knowledge spillovers and (ii) appropriability as an inverse measure of outgoing knowledge flows. They measured firms' incoming spillovers by the importance of publicly available information for their innovation processes; and measured firms' outgoing spillovers by their level of appropriability, namely, the degree of strategic protection they adopted on their innovations (the more the appropriability the less the outgoing spillovers).
They found a positive impact of both incoming information flows and appropriability on the firm's decision to cooperate in R&D against the expectations about a higher probability of cooperation in case of bad appropriability conditions.
Following this line, and using the same definitions of spillovers, Lopez (2008) found an important positive effect of both incoming and appropriability on R&D cooperation. Bonte and Keilbach(2005) inserted appropriability as an explanatory variable of cooperation in R&D and found that it is an important determinant of vertical formal cooperation agreements. Vencatachellum

and Versaevel(2006), instead, analyzing the determinants of horizontal cooperation in France, provided evidence that the higher the incoming knowledge flows from competitors[6] the higher the probability to cooperate with them, but only over a certain threshold of spillovers. However, they did not control for the firms outflows of knowledge through the appropriability variable. An outstanding result, more in line with theoretical industrial organization predictions, is reported by the work of Hernan *et al.* (2003) which, using a large data-set on Reasearch Joint Ventures[7], found that patents' effectiveness, and therefore the level of appropriability, reduce R&D cooperations. Finally, Belderbos *et al.* (2004), found that industry level of appropriability do not affect firms' R&D cooperation propensity as well as the public incoming spillovers variable, but did not take into consideration the effect of the firm specific level of appropriability as Cassiman and Veugelers (2002) did.
Basically, the literature exploring the relationship between knowledge spillovers and R&D cooperation lets margins for contributions in order to achieve a higher consistency in the results.

Size of firms

Size turns out to be another important determinant of R&D cooperation (See Table 3, Factor A-3) . Cassiman and Veugelers (2006) highlighted how, since Schumpeter's (1943) work, the size of the firms is a control variable traditionally used by literature in firm-level analysis. Generally empirical literature found firms' size to positively affect their propensity to cooperate in R&D[8], however, "the relationship between firm size and R&D cooperation is ambiguous. On the one hand , given a potential R&D project, cooperation may be more beneficial for SMEs, as it allows them to

[6]In the CIS questionnaire the firms are asked to rate the importance for their innovating activities of information gathered from different sources among which competitors. Vencatachellum and Versaevel(2006), therefore, use a definition of spillovers quite different from that described above.

[7]The STEP to RJV database.

[8]See: Veugelers, 1997, Fritsch and Lukas, 2001; Bayona *et al.*, 2001; Angel, 2002; Cassiman and Veugelers, 2002; Hernan *et al.*, 2003; Becker and Dietz, 2004; Belderbos et al., 2004

share fixed research costs. On the other hand, the management resources and commitment required for partnerships may be high for them. Large firms may also find cooperation beneficial when potential R&D projects are very risky or costly."(Busom and Fernandez-Ribas, 2008, pp. 248).
Concerning to this point, Link and Rees (1991), comparing university-based research relationships between small and large firms observed diseconomies of scale in large firms owing to the fact that bureaucratization in the innovation decision-making process slows innovativeness, while small firms result more efficient. Dodgson (1993, pp.147) observed that SMEs should be inclined to be engaged in external collaboration because:"(i) it provides a means to complement and supplement their own in-house efforts; (ii) it provides the possibility of an income stream enabling the extension of in-house R&D; (iii) it provides a means to commercialize innovations; (iv) the access to complementary assets of marketing and distribution;(v) to achieve the ability of larger firms to deal with legal and regulatory issues". Moreover, R&D cooperation with well-known large firms improve SMEs' credibility with customers, bankers and staff. Rothwell and Dodgson (1994) observed that the contribution of small firms to innovation varies considerably between sectors of industry and it is considerably higher in sectors where capital and/or R&D requirements and other entry costs are not high.
Concluding, firms' size is generally positive correlated with their propensity to cooperate in R&D, but it would be useful to analyze separately SMEs and large firms, in order to disentangle the likely presence of different dynamics.

R&D intensity

Among determinants of R&D cooperation dealing with firms' innovative behavior, R&D expenditures of firms are considered as one of the most important (See Table 3, Factor A-4). It increases firms'absorptive capacity (Cohen and Levintal, 1989), reduces inefficiencies associated with external knowledge acquisition and in-

creases firms' bargaining power in negotiating with external partners (Veugelers, 1997). Lapan and Bardhan (1973) argued that firms need a certain absorptive capacity before they can benefit from new technologies discovered by other firms. Girma (2003) found that there is a minimum absorptive capacity threshold below which the magnitudes of productivity spillovers are non-existent or even negative[9]. Lee *et al.* (2001, pp. 623) stressed the fact that "internal capabilities help firms better use the complementary external resources that can be obtained on the basis of their social capital[10]. (...) Additionally, a higher level of internal capabilities and thus higher level of absorptive capacity helps firms learn more value from the opportunities provided by their networks."

To proxy for firms' absorptive capacity scholars often use the intensity of R&D[11], instead of R&D expenditures (Hagedoorn, 1993; Fritsch and Lukas, 2001; Tether, 2002; Hernan *et al.*, 2003; Belderbos *et al.*, 2004; Okamuro, 2007), or the permanent R&D variable which indicates whether the R&D activities of firm have a permanent character (Veugelers and Cassiman, 2002; Tether and Tajar, 2008), or a variable to indicate the presence of a R&D department (see: Kleinknecht and Reijnen, 1992). The literature usually converge in asserting a positive impact of this variable on the firms' propensity to cooperate and, while most studies explore only a linear relationship between R&D intensity and the firms' propensity to cooperate in R&D, Belderbos *et al.* (2004) and Fritsch and Franke (2004) showed a non-linear concave effect of R&D intensity on firms' propensity to engage in R&D cooperation, justifying this result with the decreasing returns of absorptive capacity. In other words, R&D intensive firms cooperate more in R&D than firms which invest less in R&D, but with decreasing returns to scale.

[9]This is consistent with studies on inter-organizational informal knowledge transfer such as Giuliani and Bell (2005, pp.57) which claim that "even at lower level of absorptive capacity, firms might be linked to the local knowledge system, provided that a minimum absorptive capacity threshold is reached."

[10]Social capital captures the beneficial effect of social networks on organizational performance (see: Pennings *et al.*, 1998).

[11]R&D intensity is usually defined as the ratio between R&D expenditures and size of firms (often measured by sales).

Innovativeness of firms

Less developed, and relatively recent, strands of literature deals with the innovativeness of firms (See Table 3, Factor A-5) and their propensity to cooperate. Stuart (1998) and Ahuja (2000) argued that firms with an higher number of patents, as a proxy of innovativeness, form alliances at a highest rate, even this could be related to appropriability issues. Tether (2001, 2002) observed that true innovators cooperate more than those which introduce only imitative innovations. Li *et al.* (2009) showed that when innovation radicality is high, R&D alliances are more likely to be formed between friends than strangers.

Foreign Multinational Companies (MNCs)

"Foreign owned firms tend to be amongst the most dynamic in the economy and, with the globalisation of markets, these firms may seek to collaborate, especially with domestic customers, in order to adapt their global products to local markets (Dussauge *et al.*, 1992). They also tend to be particularly prestigious firms with which various types of innovation partner are eager to work"(Tether, 2002, pp. 956). Tether (2002), in fact, empirically showed that foreign groups are more likely to have at least one R&D cooperative agreement especially with customers and consultants, nevertheless the results achieved by the literature are ambiguous. Veugelers (1997) showed that foreign ownership have not significant additional effect on the probability of cooperation. Cassiman and Veugelers (2004) showed that, although foreign subsidiaries are more likely to source know-how international, they are less likely to transfer technology locally and be locally networked. In line with this result, Belderbos *et al.* (2004) found that belonging to a foreign group decreases the probability of cooperation with competitors but does not affect the probability of cooperation with suppliers, customers and uni-

versities. Concluding, the analysis of the cooperative behaviour of foreign MNCs is still an open field of research and leaves margins for contributions.

Barriers to innovation

Other determinants of R&D cooperation are the so called barriers to innovation such as high costs (See Table 3, Factor A-7) or risks of innovation (See Table 3, Factor A-8)[12]. Empirical literature generally found a positive impact of these factors on the propensity of firms to cooperate (Becker and Dietz, 2004, Abramovsky *et al.*, 2005). R&D cooperations, in fact, allow firms to share costs or to reduce risks of innovation. In this regard, in the next section about partner selection, I point out how cooperation with customers could reduce the risk to introduce a radical innovation in the market or how cooperation between competing firms are often pushed by cost-sharing motives. However, some scholars like Miotti and Sachwald (2003) found that costs and risks of innovation do not influences the propensity to cooperate; and Cassiman and Veugelers (2002) found only marginal evidence that costs of innovation influence positively R&D cooperation and an unexpected significant negative impact of innovation risks on firms' propensity to cooperate.

II.B. Industry-level factors

Variables often inserted in empirical models aimed at explaining the probability of cooperation are: sectors dummies with the distinction between high and low tech (See Table 3, Factor B-1); and variables proxying market concentration (See Table 3, Factor B-2).

[12]Risk sharing agreements generally provide for the management of the operation by one of the partners, while the others contribute capital and absorb part of the risk of failure (Mariti and Smiley, 1983)

High-tech sectors

"The resource-based perspective suggests that firms conducting expensive, risky or complex research projects will seek R&D cooperation. In turn, these firms tend to be concentrated in high-tech sectors"(Miotti and Sachwald, 2003, pp.1483). Hagedoorn (1993), in line with this expectation, highlighted a positive relationship between the research orientation of alliances and the research intensity of the sectors affected. While for non high-tech industries[13] he found a stronger market-oriented motivation of partnering. Kleinknecht and Reijnen (1992, pp.354), on the contrary, underlined that "R&D cooperation does not seem to be a typically high-tech phenomenon"since R&D cooperation does not seem concentrated in sectors which cover high-tech activities (like chemicals), it seems to exist in an equally high percentage in typically medium-low tech sectors. Anyway, the R&D intensity of the sector the firm belongs to is an important control variable in explaining the variability of the firms' R&D cooperative behaviour.
Levy *et al.* (2009) provided evidence that companies in high-tech sectors are likely to activate open (multi-parner) and multiform collaboration with universities. Veugelers (1997) showed that the typically high-tech sectors are less likely to be engaged in cooperation, after correcting for the positive effect of their internal R&D expenditures; and Busom and Fernandez-Ribas (2008) highlighted that firms in high-tech sectors have not a significantly higher propensity to cooperate in R&D than firms belonging to other sectors.

Market concentration

The degree of industry concentration of firms may affect their motivation of combining resources with other firms. The Resource dependence theory (See: Pfeffer and Salancik, 1978) asserts that firms in industries with intermediate levels of concentration are more

[13]Generally, the identification of industries with a high, medium or low technological intensity follows the OECD classification.

likely to engage in resource combination efforts (through an alliance or an acquisition) because the environment is more uncertain. However, the impact of market concentration on the firms' propensity to engage in R&D cooperation is a theme empirically less explored (See Table 3, Factor B-2). A recent empirical contribution on this theme is the Hernan *et al.*'s (2003). They showed a positive impact of market concentration on the propensity of firms to cooperate in R&D, since a more concentrated industry offers a greater scope for internalization of spillovers. Wang and Zajac (2007), instead, did not achieve clear-cut conclusions since they found different results for different model specifications.

II.C. Regional/Country-level factors

A relative recent strand of literature deals with the impact of country-specific characteristics on the propensity of firms to cooperate in R&D. In this regard, Dasch *et al.*(2004) asserted that the drivers of cooperation are not firm specific but intrinsic to the underlying national system of innovation, therefore traditional literature which focus on motives of cooperation looking only at firm characteristics failed.

Country size

Hernan *et al.* (2003) focused on the size of the firms' country of origin (See Table 3, Factor C-1) and asserted that firms from larger countries are less likely to partecipate to cross-border Research Joint Ventures. This result could be due to the fact that firms originating in the larger EU countries find it easier to find Research Joint Ventures partners within their own borders. However, the impact of firms' country size on their propensity toward R&D cooperation remains a largely unexplored topic.

IPR regime

Lhuillery and Pfister (2009) focused on the country's intellectual property rights (IPR) regime (See Table 3, Factor C-2) and assert that cooperation is more likely to fail when the country IPR regime are insufficiently effective to prevent spillovers; this effect, however, could be also captured by the appropriability variable previously reviewed.

Public policies

Local, regional, national and European innovation policy instruments are generally important driving factors in increasing inter-firms R&D cooperations (See Table 3, Factor C-3).
Miotti and Saschwald (2003) showed a positive impact of public founding on the propensity of firms to engage in R&D cooperative agreements, in particular, this effect is statistically significant for cooperations with public institutions and horizontal cooperation. On the contrary, Belderbos *et al.* (2004) found an impact of public subsidy on the probability of R&D cooperation not significantly different from zero. Colombo *et al.*(2006) made a distinction between exploitative commercial alliances and explorative technological alliances[14] and found a not significant impact of public subsidies on both.

However, the importance of country-specific factors in driving inter-firms R&D cooperations is not a topic largely analyzed by literature although its evident policy implications. Up to now, as shown in Table 2, there is even a relative low number of studies on R&D cooperation which use a cross-country approach.

[14]These alliances include joint development agreements, Research Joint Ventures, technology transfer and technology sharing agreements.

II.D. Dyadic-level factors

This section explores determinants of R&D cooperation dealing with dyadic attributes between interacting actors. In particular, I focused on: (i) partners similarities or complementarities (See Table 3, Factors D-1 and D-2), and (ii) the sharing of past alliance experiences (See Table 3, Factor D-3).
Strategic management literature pointed out that similar firms are more likely to work together. "As a general rule, organizations are better able to evaluate and internalize the know-how of technology similar firms"(Stuart, 1998, pp.672). Also studies on informal knowledge collaborations often use this approach. In this regard, Schrader (1991) highlighted the main factors determining informal cooperations: confidence between firms which have exchanged knowledge in the past; which operate in similar market segments; which sell in the same region; or which have similar technological expertise.

Technology overlap

The resource-based view defined co-operation as a mechanism to maximize firm's value through effectively combining the resources of the partners through exploiting complementarities (Kogut, 1988; Hagedoorn, 1993; and Sakakibara, 2001). Firms' technology overlap (technology similarities) increases complementarities (See Table 3, Factor D-1). Complementarities are defined as "(. . .)knowledge stocks that, in combination, yield new and improved R&D results." (Sakakibara, 2001, pp.183). Lane and Lubatkin, (1998) studying formal alliances in the pharmaceutical industry, observed that overlap between student and teacher firm's technological resources (they defined this overlap also as "Relative absorptive capacity") positively affect interorganizational learning (the more partners are similar in basic knowledge, the more the student firms learn); Stuart (1998), studying strategic alliances in a high-technology indus-

try, showed that between-firms technological overlap[15] increases the probability of technology alliance formation. Mowery *et al.* (1998) found an inverted U-shape relationship between technological overlap and the probability of an alliance. Finally, Oxley and Sampson (2004) showed that technology overlap increase the probability of broad alliances involving more than pure R&D.

Size similarity

The relationship between firms' size similarities (See Table 3, Factor D-2) and the propensity to cooperate is also an interesting topic. Although *relative size* has been found to be a significant factor influencing alliance formation (Wang and Zajac, 2007), literature has not yet achieved clear-cut conclusions on this topic. Mowery *et al.* (1998) observed that, even if partners in Joint Ventures have significantly higher levels of technological overlap than non partners, differences in firm size increase alliance formation (large firms tend to ally with small firms). A reason could be that small firms which make a technological breakthrough, face three alternatives to bringing the new product to the market: (i) the costly alternative to develop a distribution network by itself; (ii) sell the patent(or the entire firm) to a larger firm which already possesses a distribution network; (iii) reach a cooperative agreement with a distribution network endowed larger firm (Mariti and Smiley, 1983).
Against these arguments, the work of Röller *et al.* (1998) theoretically showed that large firms have less incentives to cooperate with smaller firms in order to increase market power, this leads the industry to become increasingly asymmetric. In other words, they empirically showed that a factor that pushes firms to cooperate together is the similarity in size.

[15]Stuart (1998) defined between firms technological overlap as an average of the citation overlap of patents in their portafolios

Prior partners

Firms generally select their cooperation partners among those with which they have already cooperated in the past (See Table 3, Factor D-3) because of trust motives (Gulati, 1995). Wang and Zajac (2007,pp.1313) showed that "partner-specific knowledge of two firms in alliances developed from prior dyadic alliance experience increases the likelihood on both an alliance and an acquisition between these firms". Therefore, firms with a higher number of cooperative relationships are also the most inclined to further cooperations (Stuart, 1998; Ahuja, 2000) and prior direct ties of a dyad increase the probability of successive alliance formation (Rothaermel and Boeker, 2008). However, since R&D cooperation arrangements need a managerial effort and have positive coordination costs (Pyka and Saviotti, 2002; Belderbos *et al.*, 2006), there is a constrain in the number of cooperation agreements (Kogut *et al.*, 1992). Finally, MNCs are more inclined to select prior partners in case of higher degree of technological commitment (Li and Ferreira, 2008).

III. The R&D cooperation partners: who cooperates with whom.

It is likely that the importance of different factors in driving R&D cooperations varies with the types of cooperation partners.
Mowery *et al.* (1998, pp. 510) observed that "motives for establishing inter-firms alliances differ among firms, and these different motives may affect both the choice of partner(s) and the effect of partner choice on the capabilities of participating firms". The choice of different partners of cooperation can be affected by a large number of reasons such as the nature and the aims of the R&D projects. Busom and Fernandez-Ribas (2008) conjectured that, on the one hand, if a firm's aim in a cooperative agreement is to find complementary assets or skills, it will tend to form asymmetric partnership with highly heterogeneous partners, on the other hand, if the motivation for cooperation is based on internalizing outgoing spillovers

or increasing market power, symmetric partnership are more likely. If the aim is to introduce a new product or process in a brief time span the firm is more likely to cooperate with other firms, instead of public research organizations.

In this section I analyze the determinants of three types of R&D cooperations with different partners: (i) suppliers and customers (vertical R&D cooperation); (ii) competitors (horizontal R&D cooperation); (iii) universities and research institutions (science R&D cooperation). The literature on determinants of R&D cooperation, with the different types of partners mentioned above, is listed in the last three columns of Table 3. This literature do not explore the conditions under which a particular type is preferred to the others, but the condition under which a firm chooses between cooperating or does not cooperating with a particular partner. Anyway, since simultaneously managing R&D partnerships with multiple partners is associated to an increase in complexity and coordination costs (Pyka and Saviotti, 2002; Belderbos *et al.*, 2006), partner selection is one of the critical decisions a firm makes when forming an alliance. A first step in the study of this topic is done by Kaiser (2002) which performed a nested logit regression[16] in order to disentangle factors which drive firms, first, to do joint research, second, to choose among vertical cooperation, horizontal cooperation or a mixed combination of these. Miotti and Sachwald (2003) noticed that the interactions between motivation for cooperation and the profile of partners have been less explored and tried to partially fill this gap. Using a logit estimation method they found that horizontal cooperation is preferred in high-tech sectors and when the costs of innovation are high, while permanent R&D pushes firms to choose science cooperation among other types. In this direction, Levy *et al.* (2009) ask if firms prefer specific collaborative channels of cooperation with universities and find that companies in high-tech sectors or located in foreign

[16] A nested logit regression analysis allows the study, in a integrated framework, of each stage of firms' decision-making process to reach in its research cooperation: (1) the firm's decision whether or not to conduct research cooperatively; (2) if it decide to cooperate, the cooperation partner decision. See Eymann (1995) and Ophem and Schram (1997)

countries are likely to activate open (multi-partner) and multiform collaboration with the university, while domestic and regional companies have higher propensity to activate exclusive (dyadic) collaboration. However, these approaches remain quite isolated and the literature on partner selection among competitors, suppliers, clients or public research institutions is very limited.

In the remainder of the paper I briefly describe features and main determinants of three types of formal R&D cooperation: vertical R&D cooperation (Section III-A); horizontal R&D cooperation (Section III-B); science R&D cooperation (Section III-C). Finally, I report some concluding remarks (Section IV).

III.A. Vertical R&D cooperation

Vertical cooperation is here defined as cooperation with suppliers or customers.
On the one hand, cooperations with customers are generally aimed to access to complementary knowledge, including the users' technical know-how or to reduce the risk associated with bringing an innovation to the market. Co-operation arrangements for innovation with customers rise, in fact, the likelihood that other customers accept such innovation[17]. On the other hand, Fritsch and Lukas (2001) found that firms which introduce cost reduction innovation were more likely to co-operate with suppliers, while firms which introduce product innovations are more likely to cooperate with customers (See Table 3, Factor A-5) (however, empirical literature, does not find strong evidence of a positive impact of risk of innovation on the probability of vertical R&D cooperation (See Table 3, Factor A-8)). Foreign multinational recently established into the market could be inclined to cooperate with suppliers and customers in order to learn about the host market. Tether (2002) and Busom and Fernandez-Ribas (2008) provide empirical evidence on the propensity of foreign multinational firms toward vertical R&D coop-

[17]See, among other, Von Hippel (1976); Rothwell (1977); Shaw(1994).

eration (See Table 3, Factor A-6)), as well as firms whose activities are beginning to cross industry boundaries and have to learn from organizations in other industries.
Busom and Fernandez-Ribas (2008,pp. 253) observed that vertical cooperations are more likely among firms that sell mostly in the domestic market and have applied for international patents; while firm size does not play a significant role in contrast with Veugeler and Cassiman's (2002) and Belderbos *et al.*'s (2004) findings (See Table 3, Factor A-3).
Finally, Miotti and Sachwald (2003) showed that vertical cooperation is more likely in low-tech sectors (See Table 3, Factor B-1), and as regard to the spillovers variables (See Table 3, Factors A-1 and A-2), literature converges in asserting that high levels of appropriability increase firms' propensity to engage in formal vertical cooperations, while do not find highly significant impacts of incoming spillovers.

Concluding, firms arrange vertical co-operations in order to improve its involvement in the foreign economy, to improve its knowledge on intermediate goods technologies of production, users'needs and markets.

III.B. Horizontal R&D cooperations

Horizontal cooperation is defined as cooperation with competitors which sell on similar markets. Horizontal R&D cooperations are not frequent empirically (Czarnitzki *et. al.*, 2007, pp. 1352), since cooperations among firms competing in the end-product market are quite complex because they can lead to potential anti-competitive behavior. The aim of each partner is, in fact, to internalize the other's knowledge, minimizing the access on its own proprietary skills. In this regard, Miotti and Sachwald (2003, pp. 1484) argued that "co-operation between competitors is particularly risky and should be limited to two types of cases: first, when a particularly strong common interest has been identified and, second, when the

co-operation concerns far-from-market research leading to generic results".

Horizontal R&D cooperations could be very useful for R&D cost-sharing in the case of products easily copied but costly to develop[18] (Miotti and Sachwald, 2003 provided evidence on this point (See Table 3, Factor A-7)) and to generate scale economies. This strategy is generally used by newer and smaller firms to challenge a dominant incumbent, even if Sinha and Cusumano(1991) suggested that companies with large market shares and low-cost positions are more likely to cooperate then small firms because the relative costs of a joint venture should be lower for bigger firms. Moreover, larger firms have an edge in exploiting any benefits due to their great market positions. Finally, if firms have highly complementary skills and resources, they prefer to cooperate in areas where technology is highly appropriable as in applied research. Rokuhara(1985) and Samuels(1987) provide evidence which support this point, pointing out that cooperative research among rival firms in Japan has been applied rather than basic.

Referring to the relationship between knowledge spillovers and Horizontal R&D cooperations, Dachs *et al.* (2004) showed that horizontal cooperation is not influenced by appropriability both in Finland and Austria (See Table 3, Factor A-1), while Lopez (2008), analyzing Spanish innovative firms, found evidence on this.

Dachs *et al.* (2004) found also a a positive effect of R&D intensity on horizontal cooperation in both Finland and Austria (See Table 3, Factor A-4). However, the most part of literature has not provided evidence of a significant impact of R&D intensity/permanent R&D on the firms' propensity to engage in horizontal R&D cooperations (See Table 3, Factor A-4)).

Finally, it has not been achieved clear-cut conclusions on the behaviour of foreign MNCs toward this cooperation type (See Table 3, Factor A-6). On the one hand, Tether (2002) observed a not significant impact of the foreign MNC variable on the probability

[18]This is a common problem in the service sector.

of horizontal cooperation and a positive impact on the probability of vertical cooperation, on the other hand, Belderbos *et al.*(2004) found a negative impact of the foreign MNC variable on the probability of horizontal cooperation and an impact not significantly different from zero for the vertical cooperation. However, only few studies on this topic include in the model specification the foreign MNC variable.

III.C. Science cooperations

Industry-university, more or less formal, linkages have been largely analyzed by the literature. Industry-university R&D cooperations are aimed to have a rapid and privileged access to new knowledge and to increase the firms' understanding of scientific developments (Belderbos *et al.*, 2004). University researchers interact with industry using a variety of channels: consultancy, contract research, training, joint research, conferences (Schartinger *et al.*, 2002; Cohen *et al.*, 2002; D'Este and Patel, 2007) but in this context I am going to discuss only the determinants and the features of university- industry joint research through formal cooperation agreements.
The recent rise of university-industry partnerships has stimulated public-policy debate on how these relationships affect innovative research (Mansfield, 1991; Beise and Stahl, 1999; Cohen *et al.*, 2002; Segarra-Blasco and Arauzo-Carod, 2008) and on the impact of public funding on the formation of collaborative agreements between industry and universities. Since the 1980s, many countries have implemented policies to promote university-industry partnerships and numerous policymakers have encouraged universities and government labs to embrace the cause of technology commercialization and to make their science and engineering more relevant to industry needs (Cohen *et al.*, 2002). Miotti and Sachwald (2003), in this regard, found that public subsidy for innovation increases R&D cooperation, in particular with research institutions (See Table 3, Factor C-3).
Among the other variables influencing the propensity of firms to

cooperate with Public Research Organizations (PROs), the role of firm size "is one of the basic tenets of the literature on university-industry relationships"(Fontana *et al.*, 2006, pp.311).
Empirical literature on formal R&D cooperation generally converges in asserting a positive effect of firms' size on their propensity to cooperate with universities and research institutions (See Table 3, Factor A-3). It is also likely that there is a link between innovativeness of firms and their propensity to cooperate with PROs (See Table 3, Factor A-5). Concerning to this point, Mohnen and Hoareau (2003) found that radical innovators tend to source knowledge from universities and governments labs but not to cooperate with them directly. Fritsch and Lukas (2001) found that firms oriented toward product innovation have an higher propensity to be engaged in R&D cooperation with research institutions, while firms oriented toward process/cost-reduction innovations are not significantly inclined to cooperate.
Finally, the propensity of firms in engaging in R&D cooperations with universities or other research institutions are, usually, expected to be positively correlated with the costs and risk of innovation (See Table 3, Factors A-7 and A-8). However, the empirical literature has provided only contrasting results on this theme. On the one hand, Miotti and Sachswald (2003) found that high innovation costs reduce the probability of cooperations with universities or other research institutions, on the other hand, Cassiman and Veugelers (2002) found the same negative result for innovation's risks.

IV. Concluding remarks

This paper reviews the empirical literature in industrial organization and strategic management that deals with R&D cooperation's motives, focusing on the selection of cooperation partners. The main contribution of this paper is to highlight points in which literature has not still achieved clear-cut conclusions as regard to the effect of particular factors on the firms' propensity to engage in R&D co-

operations, with other firms or science institutions, suggesting open fields of research.
Factors influencing the propensity of firms to engage in formal R&D cooperation is largely analyzed by literature, however, I found inconclusive results on the effect of appropriability, size similarities, and foreigness of companies on their propensity toward R&D cooperation even distinguishing among different types of partners.
Only recently, in fact, scholars have driven their attention to the determinants of the firms' decision to cooperate with particular types of partners like competitors (horizontal cooperation), suppliers, clients (vertical cooperation), or research institutes (science cooperation). Partner selection is, in fact, one of the critical decisions a firm makes when forming an alliance, however, there is a lack of analysis on firms strategies on partner choice among competitors, suppliers and customers and private and public research institutions. Which are the firms preferring to cooperate only with competitors? And which are those preferring a combined cooperation with different types of partners? These are intriguing questions left open for further research.

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References

Abramovsky, L., Harison, R., and Simpson, H. (2004). Increasing innovative activity in the UK? Where now for government support for innovation and technology transfer. *IFS Briefing note No. 53*.

Abramovsky, L., Kremp, E., Lopez, A., Schmidt, T., and Simpson, H. (2005). Understanding co-operative R&D activity: Evidence from four european countries. *The institute for fiscal study Working paper 05/23*.

Acosta, J. and Modrego, A. (2001). Public financing of cooperative R&D project in spain: The concerted projects under the national R&D plan. *Research Policy*, 30:625–641.

Ahuja, G. (2000). The duality of collaboration: Induscements and opportunities in the formation of interfirm linkages. *Strategic management Journal*, 21(3):317–343.

Allen, J., James, A., and Gamlen, P. (2007). Formal versus informal knowledge network in R&D: a case study using social network analysis. *R&D Management*, 37(3):179–196.

Angel, D. (2002). Inter-firm collaboration and technology development partnership within us manufacturing industries. *Regional studies*, 36(4):333–344.

Appleyard, M. (1996). How does knowledge flow? Interfirm patterns in the semiconductor industry. *Strategic Management Journal*, 17(Special Issue: Knowledge and the firm):137–154.

Arranz, N. and De Arroyabe, J. (2008). The choice of partners in R&D cooperation: an empirical analysis of Spanish firms. *Tachnovation*, 28:88–100.

Arrow, K. (1962). *Economic Welfare and the Allocation of Resources for Invention* in R.R. Nelson (eds), The Rate and Direction of Inventive activity.

Bayona, C., Garcia-Marco, T., and Huerta, E. (2001). Firms' motivations for cooperative R&D: an empirical analysis of Spanish firms. *Research Policy*, 30:1289–1307.

Becker, W. and Dietz, J. (2004). R&D cooperation and innovation activities of firms-evidence for the German manufacturing industry. *Research Policy*, 33:209–223.

Becker, W. and Peters, J. (2000). Technological opportunities, absorptive capacities, and innovation. *Universitaet Augsburg, discussion paper series n.195*.

Beise, M. and Stahl, H. (1999). Public research and industrial innovation in Germany. *Research Policy*, 28:397–422.

Belderbos, R., Carree, M., and Lokshin, B. (2006). Complementarities in R&D cooperation strategies. *Review of industrial organization*, 28:401–426.

Belderbos, R., Carree, M. A., Diederen, B., Lokshin, B., and Veugelers, R. (2004). Heterogeneity in R&D co-operation strategies. *International Journal of Industrial Organization*, 22:1137–1263.

Bonte, W. and Keilbach, M. (2005). Concubinage or marriage? Informal and formal cooperation in innovation. *International Journal of industrial organization*, 23:279–302.

Busom, I. and Fernandez-Ribas, A. (2008). The impact of firm participation in R&D programmes on R&D partnership. *Research Policy*, 37:240–257.

Caloghirou, Y., Ioannides, S., and Vonortas, N. (2003). Research joint ventures. *Journal of Economic Surveys*, 17(4):541–570.

Cassiman, B. and Veugelers, R. (2002). R&D cooperation and spillovers: some empirical evidence from Belgium. *American Economic Review*, 44(3):1169–1184.

Cassiman, B. and Veugelers, R. (2004). Foreign subsidiaries as a channel of international technology diffusion. some direct firm level evidence from Belgium. *European Economic Review*, 48(2):455–476.

Cassiman, B. and Veugelers, R. (2006). In search of complementarity in innovation strategy: Internal R&D and exernal knowledge acquisition. *Management science*, 52(1):68–82.

Cohen, W. and Levinthal, D. (1989). Innovation and learning: The two faces of R&D. *Economic Journal*, 99:569–596.

Cohen, W., Nelson, R., and Walsh, J. (2002). Links and impacts: The influence of public research on industrial R&D. *Management Science*, 48(1):1–23.

Colombo, M., Grilli, L., and Piva, E. (2006). In search of complementary assets: the determinants of alliance formation of high-tech start-ups. *Research Policy*, 35:1166–1199.

Czarnitzki, D., Ebersberger, B., and Fier, A. (2007). The relationship between R&D collaboration, subsidies and R&D performance: empirical evidence from Finland and Germany. *Journal of applied econometrics*, 22:1347–1366.

Dachs, B., Ebersberger, B., and Pyka, A. (2004). Why do firm cooperate for innovation? A comparison of Austrian and Finnish CIS3 results. *Working Paper of Austrian Research Centre*.

D'Aspremont, C. and Jacquemin, A. (1988). Cooperative and noncooperative R&D in duopoly with spillovers. *American Economic Review*, 78(5):1133–1137.

D'Este, P. and Patel, P. (2007). University-indutsry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy*, 36:1295–1313.

Dodgson, M. (1993). *Technological collaboration in industry-Strategy, policy and internationalization in innovation*. London, UK.

Dussage, P., Hart, S., and Ramanantsoa, B. (1992). *Strategic Technology Management*. Wiley, Chichester, UK.

Eymann, A. (1995). *Consumer spatial choice behaviour*. Heidelberg.

Fontana, R., Geuna, A., and Matt, M. (2006). Factors affecting university-industry R&D projects: The importance of searching, screening and signalling. *Research Policy*, 35:309–323.

Freeman, C. (1991). Networks of innovators: a synthesis of research issues. *Research Policy*, 20:499–514.

Fritsch, M. and Franke, G. (2004). Innovation, regional knowledge spillovers and R&D cooperation. *Research Policy*, 33:245–255.

Fritsch, M. and Lukas, R. (2001). Who co-operates in R&D? *Research Policy*, 30:297–312.

Girma, S. (2003). Absorptive capacity and productivity spillovers fro FDI: a threshold regression analysis. *European Economy Group No. 25/2003*.

Giuliani, E. (2007). The selective nature of knowledge networks in clusters: evidence from the wine industry. *Journal of Economic Geography*, 7:139–168.

Giuliani, E. and Arza, V. (2009). What drives the formation of 'valuable' university-industry linkages? insights from the wine industry. *Research Policy*, In press.

Giuliani, E. and Bell, M. (2005). The micro-determinants of meso-level learning and innovation: evidence from a chilean wine cluster. *Research Policy*, 34(1):47–78.

Gulati, R. (1995). Does familiarity breed trust? The implications of repeated ties for contractual choice in alliances. *Academy of Management Journal*, 38:85–112.

Hagedoorn, J. (1993). Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences. *Strategic management journal*, 14(5):371–385.

Hagedoorn, J. (2002). Inter-firm R&D partnerships: an overview of major trends and patterns since 1960. *Research Policy*, 31:477–492.

Hernan, R., Marin, P., and Siotis, G. (2003). An empirical evaluation of the determinants of research joint ventures formation. *The Journal of industrial economics*, 51(1):75–89.

Kaiser, U. (2002). An empirical test of models explaining research expenditures and research co-operating: evidence from the german service sector. *International Journal of Industrial Organization*, 20:747–774.

Kale, P. and Singh, H. (2007). Building firm capabilities through learning: the role of the alliance learning process in alliance capability and firm-level alliance success. *Strategic Management Journal*, 28:981–1000.

Kamien, M., Muller, E., and Zang, I. (1992). Research JointVentures and R&D cartels. *American Economic Review*, 82:1293–1306.

Kleinknecht, A. and Reijnen, J. (1992). Why do firms cooperate on R&D? An empirical study. *Research Policy*, 21:347–360.

Kogut, B. (1988). Joint Ventures: Theoretical and empirical perspectives. *Strategic Management Journal*, 9:319–332.

Kogut, B., Shan, W., and Walker, G. (1992). The make or cooperate decision in the context of an industry network. *In N. Nohria and R Eccles (Eds.)"Network and Organizations."Harvard Business School Press, Boston MA*.

Lane, P. and Lubatkin, M. (1998). Relative absorptive capacity and interorganizational learning. *Strategic Managment Journal*, 19:461–477.

Lapan, H. and Bardhan, P. (1973). Localised technical progress and the transfer of technology and economic development. *Journal of Economic Theory*, 6:585–95.

Laursen, K. and Salter, A. (2004). Searching high and low. What types of firms use universities as a source of innovation. *Reseach Policy*, 33:1201–1215.

Lee, C., Lee, K., and Pennings, J. (2001). Internal capabilities, external networks and performance: a study on technology-based ventures. *Strategic management Journal*, 22(6/7):615–640.

Levy, R., Roux, P., and Wolff, S. (2009). An analysis of science-industry collaborative patterns in a large european university. *Journal of Technology Transfer*, 34:1–23.

Lhuillery, S. and Pfister, E. (2009). R&D cooperation and failures in innovation projects: empirical evidence from French CIS data. *Research Policy*, 38:45–57.

Li, D., Eden, L., Hitt, M., and Ireland, R. (2008). Friends, acquaintances, or strangers? Partner selection in R&D alliances. *Academy of management Journal*, 51(2):315–334.

Li, D. and Ferreira, M. (2008). Partner selection for international strategic alliances in emerging economies. *Scandinavian Journal of management*, 24:308–319.

Link, A. and Rees, J. (1991). Firm size, university-based research and the returns to R&D. in *Innovation and Technological Change- An international comparison.* z.j. acs and d.b. audtretsch (Eds). pages 60–70.

Lopez, A. (2008). Determinants of R&D cooperation: evidence from spanish manufacturing firms. *International Journal of Industrial Organization*, 26(1):113–136.

Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy*, 26:1–12.

Mariti, P. and Smiley, R. (1983). Co-operative agreements and the organization of industry. *The Journal of Industrial Economics*, 31(4):437–451.

Miotti, L. and Sachwald, F. (2003). Co-operative R&D: Why and with whom? an integrated framework of analysis. *Research Policy*, 32:1481–1499.

Mohnen, P. and Hoareau, C. (2003). What types of enterprise forges close links with universities and govenment labs? Evidence from CIS2. *Managerial and decision economics*, 24:133–145.

Mowery, D., Oxley, J., and Silverman, B. (1996). Strategic alliances and inter-firm knowledge transfer. *Strategic Management Journal*, 17(Winter Special Issue):77–91.

Mowery, D., Oxley, J., and Silverman, B. (1998). Technological overlap and inter-firm cooperation: implication for the resource-based view of the firm. *Research Policy*, 27:507–523.

Okamuro, H. (2007). Determinants of successful R&D cooperation in Japanese small businesses: The impact of organizational and contractual characteristics. *Research Policy*, 36:1529–1544.

Ophem, H. and Van Schram, A. (1997). Sequential and multinomial logit: A nested model. *Empirical economics*, 22:131–152.

Oxley, J. and Sampson, R. (2004). The scope and governance of international R&D alliances. *Strategic management Journal*, 25:723–749.

Pennings, J., K.Lee, and Witteloostuijn, A. (1998). Human capital, social capital, and firm dissolution. *Accademy of management Journal*, 41:425–440.

Pfeffer, J. and Salancik, G. (1978). *The external control of organizations: A Resource dependence perspective*. New York.

Porter, M. (1990). *The competitive advantage of nations*. New York.

Pyka, A. and Saviotti, P. (2002). *Innovation networks in the Biotechnology- based industries. In A. Pyka and G. Küppers (eds)*. Innovation network- Theory and Practice. Cheltenham.

Rokhuhara, A. (1985). *R&D and anti-monopoly policy*. Tokyo.

Röller, L., Tombak, M., and Siebert, R. (1998). The incentives to form Research JointVentures: Theory and evidence. *WZB Discussion Paper FS IV*.

Rothaermel, F. and Boeker, W. (2008). Old technology meets new technology: complementarities, similarities, and alliance formation. *Strategic Management Journal*, 29:47–77.

Rothwell, R. (1977). The charachteristics of innovators and technocally progressive firms. *R&D management*, 7(3):191–206.

Rothwell, R. and Dodgson, M. (1994). *Innovation and Size of the firm. in* The handbook of industrial innovation. Cheltenham, UK.

Sakakibara, M. (2001). The diversity of R&D consortia and firm behavior: evidence from japanese data. *Journal of industrial economics*, 48(2):181–196.

Samuels, R. P. (1987). Research collaboration in japan. *M.I.T Japan Science and technology program working paper No. 2 M.I.T. Cambridge (MA)*.

Sattler, H., Shrader, S., and Lüthje, C. (2003). Informal cooperation in the US and Germany: cooperative managerial capitalism vs. competitive managerial capitalism in interfirm information trading. *International Business Review*, 12:273–295.

Schartinger, D., Rammer, C., Fischer, M., and Frhlich, J. (2002). Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants. *Research Policy*, 31:303–328.

Schmiedeberg, C. (2008). Complementarities of innovation activities: an empirical analysis of the German manufacturing sector. *Research Policy*, 37:1492–1503.

Schrader, S. (1991). Informal technology transfer between firms: cooperation through informal trading. *Research Policy*, 10:153–171.

Schumpeter, J. (1943). *Capitalism, Socialism, and democracy*. London, UK.

Segarra-Blasco, A. and Arauzo-Carod, J. (2008). Sources of innovation and industry-university interaction: Evidence from spanish firms. *Research policy*, 37:1283–1295.

Shaw, B. (1994). *User-Suppliers links and Innovation*. In: Dodgson and Rothwell (Eds), The handbook of industrial innovation. Cheltenham, UK.

Sinha, K. D. and Cusumano, M. A. (1991). Complementary resources and cooperative R&D: A model for research joint ventures R&D among competitors. *Management Science*, 37(9):1091–1106.

Spence, M. (1984). Cost reduction, competition and industry performance. *Econometrica*, 52:101–121.

Stuart, T. (1998). Network positions and propensities to collaborate: an investigation of strategic alliance formation in a high-technology industry. *Administrative science quarterly*, 43:668–698.

Tether, B. (2001). Identifying innovation, innovators and innovative behaviours: A critical assessment of the community innovation survey (CIS). *CRICDiscussion paper No. 48*.

Tether, B. (2002). Who cooperates for innovation, and why. an empirical analysis. *Research Policy*, 31:947–967.

Tether, B. and Tajar, A. (2008). Beyond industry-university links: sourcing knowledge for innovation from consultants, private research organizations and the public science-base. *Research Policy*, 37:1079–1095.

Todtling, F., Lehner, P., and Kaufmann, A. (2009). Do different types of innovation rely on specific kinds of interactions? *Technovation*, 29(1):59–71.

Van Beers, C., Berghall, E., and Poot, T. (2008). R&D internationalization, R&D collaboration and pulic knowledge institutions in small economies: evidence from Finland and Netherlands. *Research Policy*, 37:294–308.

Vencatachellum, D. and Versaevel, B. (2006). Horizontal R&D cooperation and spillovers: Evidence from France. *CNRS Working paper 06/12*.

Veugelers, R. (1997). Internal R&D expenditures and external technology sourcing. *Research Policy*, 26:303–315.

Von Hippel, E. (1976). The dominant role of the user in scientific instruments innovation process. *Research Policy*, 5(3):212–239.

Von Hippel, E. (1987). Cooperation between rivals: informal know how trading. *Research Policy*, 16(6):291–302.

Wang, L. and Zajac, E. (2007). Alliance or acquisition? A dyadic perspective on interfirm resource combinations. *Strategic Management Journal*, 28:1291–1317.

Weterings, A. and Boschma, R. (2009). Does spatial proximity to customers matter for innovative performance? Evidence from the Dutch software sector. *Research Policy*, 38(5):746–755.

Table 3: **Factors driving formal R&D cooperation with different types of partners**

	Factors	References	Cooperation types analyzed:			
			Pooled	Horizontal	Vertical	Science
(A) Firm level	**1) Appropriability**	Cassiman and Veugelers (2002)	+		+	0
		Hernan *et al.* (2003)	-			
		Dachs *et al.* (2004)	+/0	0	+/0	+/0
		Bonte and Keilbach (2005)			+	
		Lopez (2008)	+	+	+	+
	2) Incoming spillovers	Cassiman and Veugelers (2002)	+		0	+
		Belderbos *et al.* (2004)		0	0	0
		Lopez (2008)	+	0	0	+
	3) Size	Cassiman and Veugelers (2002)	+		+	+
		Hernan *et al.* (2003)	+			
		Belderbos *et al.* (2004)		+	+	+
		Lopez (2008)	+	+	+	+
		Busom and Fernandez-Ribas (2008)	+		0	+
		Miotti and Sachwald (2003)	+	+	+	+
	4) R&D intensity	Cassiman and Veugelers (2002)	+/0		0	0
		Hernan *et al.* (2003)	+			
		Belderbos *et al.* (2004)		0	+	+
		Dachs *et al.* (2004)	+/0	+	+/0	0
		Lopez (2008)	0/+	0	+	0
		Busom and Fernandez-Ribas (2008)	0/-		0	+
		Miotti and Sachwald (2003)	+	0	0	+
	5) Innovativeness	Stuart (1998)		+		
		Ahuja (2000)	+			
		Fritsch and Lukas (2001)			+	+/0
		Mohnen and Hoareau (2003)				0
	6) Foreign MNC	Veugelers (1997)	0			
		Tether (2002)	+	0	+	0
		Cassiman and Veugelers (2004)	-			
		Belderbos *et al.* (2004)		-	0	0
		Busom and Fernandez-Ribas (2008)	+		+	0
	7) Costs	Cassiman and Veugelers (2002)	+		+	+
		Belderbos *et al.* (2004)		0	0	0
		Miotti and Sachwald (2003)	0	+	0	-
	8) Risks	Cassiman and Veugelers (2002)	-/0		0	-
		Belderbos *et al.* (2004)		+	0	0
(B) Industry level	**1) high-tech sector**	Kleinknecht and Reijnen (1992)	0			
		Hagedoorn (1993)	+			
		Veugelers (1997)	-			
		Bayona *et al.* (2001)	+			
		Miotti and Sachwald (2003)	+	+	0	-
		Busom and Fernandez-Ribas (2008)	0		0	0
	2) Concentration	Hernan *et al.* (2003)	+			
		Wang and Zajac (2007)	+/-			
(C) Regional/Country level	**1) Country size**	Hernan *et al.* (2003)	-			
	2) IPR regime	Lhuillery and Pfister (2009)	+*			
	3) Public funding	Veugelers (1997)	+			
		Miotti and Sachwald (2003)	+	+	0	+
		Belderbos *et al.* (2004)		0	0	0
		Colombo *et al.* (2006)	0			
		Busom and Fernandez-Ribas (2008)	+		+	+
(D) Dyadic level	**1) Tech. overlap/ Complementarities**	Stuart (1998)		+		
		Mowery *et al.* (1998)	+			
		Lane and Lubatkin (1998)	+*			
		Oxley and Sampson (2004)	+			
	2) Size similarity	Roller *et al.* (1998)	+			
		Mowery *et al.* (1998)	-			
	3) Prior partners	Gulati (1995)	+			
		Wang and Zajac (2007)	+			
		Rothaermel and Boeker (2008)	+			
		Li and Ferreira (2008)	+			

Notes: 0 stands for not significant coefficients. x/x stands for different results for different econometric specifications.
Pooled cooperation stands for cooperation without distinction among cooperation partners.
Appropriability is intended in a broad meaning including for example also patent effectiveness. Incoming spillovers include only public incoming flows of knowledge the firm benefits (á la Cassiman and Veugelers, 2002).
* The sign refers to a form of alliance's probability of success.