UNIVERSITAT
ROVIRA I VIRGILI
DEPARTAMENT D'ECONOMIA

CENTRE DE RECERCA EN ECONOMIA INDUSTRIAL I ECONOMIA PÚBLICA

WORKING PAPERS

Col·lecció "DOCUMENTS DE TREBALL DEL DEPARTAMENT D'ECONOMIA - CREIP"

The determinants of partner choice for cooperative innovation: The effect of competition

Guiomar Ibáñez Zarate

Document de treball n.19- 2015

DEPARTAMENT D'ECONOMIA – CREIP
Facultat d'Economia i Empresa

UNIVERSITAT
ROVIRA I VIRGILI
DEPARTAMENT D'ECONOMIA

Edita:

Departament d'Economia
www.fcee.urv.es/departaments/economia/public_html/index.html
Universitat Rovira i Virgili
Facultat d'Economia i Empresa
Avgda. de la Universitat, 1
43204 Reus
Tel.: +34 977 759 811
Fax: +34 977 300 661
Email: sde@urv.cat

CREIP
www.urv.cat/creip
Universitat Rovira i Virgili
Departament d'Economia
Avgda. de la Universitat, 1
43204 Reus
Tel.: +34 977 558 936
Email: creip@urv.cat

Adreçar comentaris al Departament d'Economia / CREIP

Dipòsit Legal: T - 857 - 2015

ISSN edició en paper: 1576 - 3382
ISSN edició electrònica: 1988 - 0820

DEPARTAMENT D'ECONOMIA – CREIP
Facultat d'Economia i Empresa

THE DETERMINANTS OF PARTNER CHOICE FOR COOPERATIVE INNOVATION: THE EFFECT OF COMPETITION*

GUIOMAR IBÁÑEZ-ZÁRATE†

May 2015

Abstract

This study analyses the effect of competition intensity as a determinant of cooperative partner choice. To the best of our knowledge, this is the first attempt to study the relationship between research and development (R&D) cooperation and direct measures of competition intensity. Competition intensity is measured by the number of competitors in the firm's core market and the price elasticity reported by firms. Using information from German firms for 2011, our results show that competition intensity is a determinant for different types of collaborative innovation (e.g., with customers, suppliers, competitors, universities, or firms of the same group). Overall, the effect of competition is negative for cooperation with universities, customers and firms of the same group, and positive for cooperation with suppliers and competitors (and ambiguous for cooperation with consultants). Competition negatively affects partnerships with customers and universities, which look for radical innovation and involve high risks of disclosure. By contrast, competition positively influences partnerships with suppliers and competitors, which pursue incremental innovation and which involve a symmetric risk of information disclosure.
Keywords: innovation; R&D cooperation; competition intensity; appropriability conditions.
JEL Classification Numbers: L10; O32; O33; L60.

*The financial support from the Spanish Ministry of Science and Innovation (ECO2013-42884-P), the Generalitat de Catalunya (2009SGR900), and the Agència de Gestió d'Ajuts Universitaris i de Recerca (2013FI_B1 00228) is gratefully acknowledged.
†Departament d'Economia and CREIP, Universitat Rovira i Virgili, Avinguda de la Universitat 1, 43204 Reus, Spain. Tel.: +34977759884; fax: +34977759810; email: guiomar.ibanez@urv.cat.

1 Introduction

Firms consider cooperation to be a key innovation strategy for widening their technological base in a competitive environment where innovation is growing in complexity, risk, and cost. Research partnerships facilitate the access to complementary resources, the deployment of new skills and capabilities, and the sharing of the costs and risks related to innovation (Staropoli, 1998; Grant and Bade-Fuller, 2004; Lavie, 2006). This allows for economies of scale and fosters the development of competitive advantages, all of which leads to an improvement of firms' strategic position (Teece, 1986; Lavie, 2006).

The industrial organization literature has shown that R&D cooperation is determined by competition in the product market, spillovers, and R&D investments. Collaborative agreements make it possible for firms to protect knowledge spillovers (López, 2008), improving firms' competitive position. Therefore, market structure can be affected by research partnerships (Hagedoorn et al., 2000).

The promotion of cooperative R&D has been a central policy tool to enhance the firms' competitiveness, mainly in the high-tech sectors. However, R&D collaborations may also harm competition in the product market since they can be used as a subterfuge to sustain tacit collusion agreements, especially in the case of collaboration among rival firms (Duso et al., 2014; Flores-Fillol et al., 2014).

Despite its importance to explain the firms' decision to cooperate in R&D, the empirical literature has not considered competition intensity as a determinant of R&D cooperation. This is probably due to the lack of information regarding firms' competitive environment. This study is the first to address this question by using new data to assess the effect of competition intensity on the decision to cooperate in R&D with different types of partners.

While the relationship between R&D cooperation and competition has not been addressed, the relationship between competition and innovation has captured the interest of many authors. Aghion et al. (2005) find evidence of an inverted-U relationship between competition and innovation. We connect the literature on R&D cooperation and the findings provided by Aghion et al. (2005) to elucidate, empirically, how competition affects firms' decision to cooperate in R&D with a certain type of partner.[1] We make use of two different measures to capture competition intensity: the number of competitors in the core market and the price elasticity reported by firms.

Following the existing literature, we control for firms' characteristics, innovation obstacles, and appropriability conditions to explain the determinants of firms' partner choice. Our analysis uses the Mannheim innovation panel (MIP), which provides information from firms located in Germany. The survey focuses on firms' innovative activities and provides useful information on cooperative agreements. We select the 2011 survey wave because it provides valuable information on firms' market structure. Our study focuses on a subsample of innovative manufacturing firms. Six different types of collaborative partners are considered as dependent variables: 1) *customers*, 2) *suppliers*, 3) *competitors*, 4) *universities*, 5) *firms of the same group*, and 6) *consultants*.[2] The considered explanatory variables are: competition intensity (number of competitors in the core market and price elasticity), firm's characteristics, importance of appropriability measures, obstacles to innovation, and

[1] In some studies competition has been approximated by general or indirect measures, such as exports as a proxy for firms' participation in more competitive markets, and the Herfindahl index used by Becker and Dietz (2004) to estimate the impact of competition on the firm's propensity to cooperate.

[2] 3) also includes firms from the same industry. 4) also includes public research centres. 6) also includes commercial laboratories, and private R&D institutions.

dummy variables for industries. A set of logit specifications is used to estimate the probability of the firm to conduct cooperative agreements in general, and with a certain type of partner in particular.

The main findings can be summarised as follows. Competition intensity does not affect German firm's propensity to cooperate in general. Nevertheless, it is an important determinant in firms' decision to cooperate in R&D with a certain type of partner in particular. More precisely, the effect of competition is negative in the case of cooperation with universities, customers, and firms of the same group; and it is positive in the case of cooperation with suppliers and competitors. The negative effect of competition intensity on partnerships with customers and universities is explained by the search of radical innovations and the high risks of disclosure. In contrast, the positive effect of competition intensity on partnerships with suppliers and competitors is explained by the search of incremental innovations and a symmetric risk of information disclosure. These findings lead to the conclusion that market competition and appropriability measures are the main determinants of the German firms' decisions to cooperate with particular types of partner.

The rest of the paper is organised as follows. Section 2 reviews the literature. Section 3 presents some stylised facts, the data, describes the variables and the empirical model. The results and their discussion are presented in Section 4 and Section 5, respectively. Finally, a brief concluding section closes the paper.

2 Literature Review

It is well known that innovation is a crucial factor for competitiveness in an environment with an accelerated pace of technological progress, which leads firms to broaden their innovative capabilities (Miotti and Sachwald, 2003). According with Cassiman and Veugelers (2002), successful innovation depends on the development and integration of new knowledge in the innovation process. In this context, innovative cooperation allows firms to develop new knowledge and to incorporate external knowledge into the innovation process (Colombo, 1998). Many authors point out that firms engage in cooperative agreements with the purpose of combining their own specific assets and core competencies with other firms that have complementary assets and competencies which cannot be acquired independently (Sakakibara, 2001; López, 2008). Other authors argue that collaboration is a means of shaping competition by improving a firm's competitive position (Hagedoorn et al., 2000). Such collaborative behaviour protects and reinforces firms' existing competitive advantages and creates new ones.

There is a vast volume of literature that analyses why firms enter into collaborative innovation and what the results of such collaborative agreements are. Firms' cooperative behaviour can largely be explained from two main literature approaches.[3] First, the theoretical approach, in which most of the analyses have been addressed from an industrial organisation perspective, particularly using game-theory tools to study the relative efficiencies of competition and cooperation in R&D in raising final output and enhancing social welfare (Hagedoorn et al., 2000).[4] Second, the empirical approach from a resource-based perspective (Lowe and Taylor, 1998; Fritsch and Lukas, 2001; Tether, 2002; Miotti and Sachwald, 2003), which explains that innovation partnerships can

[3]Many authors explain R&D cooperation considering the transaction cost approach, which analyses the conditions under collaborative agreements are the most efficient form of organization. This approach rests on the idea of cost minimization, but does not capture many of the strategic advantages of cooperation such as knowledge sharing, or advantages of cooperation depending on the partner choice (Williamson, 2002; Arranz and Fdez. de Arroyabe, 2008).

[4]Into this theoretical approach, a separate mention is given to the economics networks, which analyses collaborative incentives to reduce production costs in an environment of market competition, although this approach does not address particularly R&D collaboration.

facilitate firms' access to external complementary resources. These complementarities could yield competitive advantages that would ultimately improve the strategic position of firms in competitive markets (Teece, 1986; Lavie, 2006).

In the theoretical literature, cooperation among firms is used, mainly, as a means of internalizing technological externalities (Colombo, 1998; Hanaki et al., 2007). Most of the authors make use of game-theory models to examine the effects of R&D cooperation on R&D investment, on equilibrium prices and output, and on social welfare, considering oligopoly competition. The seminal works of Brander and Spencer (1984), Spence (1984), Katz (1986), and d'Aspremont and Jacquemin (1988) show that cooperation in R&D can be welfare-enhancing due the increment on R&D investments when the spillovers are large enough and when there is competition in the product market. D'Aspremont and Jacquemin (1988) present a duopoly model, which is extended by Suzumura (1992) to oligopoly competition in quantities, and by Kamien et al. (1992), who analyse R&D cartelisation and joint research ventures. This branch of the literature provides a framework for the analysis of the effect of cooperation that depends on the nature of market competition and the market structure in which firms are embedded.

In the literature of economic networks, R&D cooperation has been studied with interesting results in a seminal paper by Goyal and Joshi (2003). The authors analyse networks of collaboration in an oligopoly context, and show how the firms' incentives to collaborate are influenced by the nature of market competition and the costs of forming links. They conclude that firms collaborate to generate competitive advantages and demonstrate that, when the costs of forming links are small, the empty network is the unique stable result under price competition. This suggests that, in a general setting with fierce price competition, collaborative links are not established. Billand and Bravard (2004) extend Goyal and Joshi's (2003) model, finding that collaboration arises as an equilibrium result under Bertrand competition.[5]

The empirical literature from a resource-based perspective of cooperation considers that strategic cooperation arises when firms in vulnerable strategic positions need the resources that cooperation brings (Arranz and Fdez. de Arroyabe, 2008). Cooperation improves the strategic position of firms in competitive markets by providing resources from other firms that enable them to share costs and risks (Staropoli, 1998; Grant and Bade-Fuller, 2004; Lavie, 2006). This perspective emphasises the strategic factors, the characteristics of the firms, and the idea of needs and opportunities. The literature derived from this approach focuses, on the one hand, on the identification of cooperation determinants, which can be grouped into (*i*) a firm's characteristics, (*ii*) appropriability conditions, and (*iii*) obstacles to innovation; and, on the other hand, it also focuses on the analysis of the impact of R&D collaboration on the innovation output, which is strongly related to the chosen cooperative partner. The main findings on the determinants of cooperation and on the effects that the cooperation with certain partners have on innovation are explained below.

[5] Although Goyal and Joshi (2003) do not focus particularly on R&D collaboration, they point out that their results can explain the cooperative incentives that motivate the behavior of a set of firms who are competing to apply for a patent for a cost-reducing technological process, where the patent race is won by a group of collaborative firms.

2.1 Determinants of cooperation

2.1.1 Firm characteristics

Firm characteristics that have an effect on the cooperation decision are firm size, R&D intensity, participation in a group of firms, export intensity, proportion of employees with a university degree, and technological level.

Firm size. Most of the authors find that size has a positive and significant effect on the propensity to cooperate in R&D. Size is measured as the number of employees or sales (Link and Bauer, 1987; Kleinknecht and Reijnen, 1992; Vonortas, 1997: Fritsch and Lukas, 2001; Cassiman and Veugelers, 2002; Becker and Dietz, 2004; Veugelers and Cassiman, 2005; Cassiman et al., 2007; Arranz and Fdez. de Arroyabe, 2008; López, 2008; de Faria et al., 2010). However, Kleinknecht and Reijnen (1992) find that size and R&D intensity only matters for private firms which cooperate with public research institutions, but not in their relationships with other private firms. Belderbos et al. (2006) find no significance of firm size on the probability of cooperation, although the authors include other independent variables that are positively and significantly related to size, such as investment intensity and being part of a foreign group.

R&D intensity. Size and R&D intensity are found to be associated, as generally larger firms also have a higher investment in R&D, which is often considered as the basic input of innovation. Cohen and Levinthal (1989) point out that external knowledge is more effective for firms' innovation processes when the firms undertake their own R&D. It has been shown that the higher the R&D intensity, the greater the propensity for R&D cooperation (Becker and Dietz, 2004; Negassi, 2004; Sampson, 2007). According with Link and Bauer (1987), R&D capital determines firms' absorptive capacity, their ability to identify new technological opportunities, and their capacity to establish collaborative agreements. However, König et al. (1994) and Vonortas (1997) do not find a significant relationship between R&D intensity and cooperation. Finally, Fritsch and Lukas (2001) find that R&D intensity has a positive effect on the probability to cooperate with suppliers and research institutes, but that it negatively influences the propensity to cooperate with customers and competitors.

Group. Being part of a group can influence a firm's likelihood to cooperate (Dachs et al., 2008), given that the integration of the firm into a group may indicate access to a substantial pool of resources (Lowe and Taylor, 1998; Miotti and Sachwald, 2003). According to de Faria et al. (2010), firms that belong to a formal group are more likely to search for knowledge outside their boundaries and to engage in cooperation activities.

Export intensity. Export intensity (share of exports in turnover) is generally included in the analyses to capture the intensity of the competition that a firm faces (Abramovsky et al., 2009; de Faria et al., 2010). Frequently, it is also considered as a proxy of firms' competitiveness since firms that participate in more competitive environments usually are more export intensive (Cassiman and Veugelers, 2002). According to Dachs et al. (2008), firms that sell large parts of their production abroad are also more likely to cooperate in R&D. Export intensity and being part of a group are characteristics that can be associated with size, and many authors assume that they also measure firm's competitiveness.

Personnel education. The degree of personnel education is commonly associated with a firm's capacity to capture externalities (de Faria et al., 2010). It has been found that firms with a greater proportion of personnel with a university degree are more likely to engage in R&D cooperation agreements, and give more importance to the management of knowledge spillovers.

Technological level. According with many authors, a firm's technological level is a determinant of collaborative behaviour. In this regard, firms that seek R&D cooperation tend to be concentrated in the high-tech and medium-high-tech sectors, since these firms conduct more expensive, risky, or complex innovation projects (Miotti and Sachwald, 2003; Becker and Dietz, 2004; Arranz and Fdez. de Arroyabe, 2008). Some authors indicate that cooperative relationships are more common between firms that belong to high-tech industries (Kotabe and Swan, 1995; Yasuda, 2005; Vuola and Hameri, 2006).

2.1.2 Appropriability conditions

Appropriability is intrinsically associated with cooperation, since it affects the firm's ability to protect the returns from cooperative innovation (Cassiman and Veugelers, 2002). Appropriability conditions have been deeply analysed, particularly in the theoretical literature. D'Aspremont and Jacquemin (1988) and Kamien et al. (1992) show that when spillovers are high enough, cooperative firms increase their R&D investment and are more profitable in comparison to firms acting non-cooperatively. However, high levels of spillovers also lead to a free-rider effect and disencourage cooperation. Sakakibara (2001) finds evidence that cooperative projects among Japanese industries are formed in industries with strong appropriability conditions. Cassiman and Veugelers (2002) show that better appropriability conditions increase the likelihood of cooperation with customers and suppliers. Veugelers and Cassiman (2005) find that appropriability conditions do not affect firms' decisions to cooperate with universities, and López (2008) shows that a high level of legal protection is a disincentive to R&D cooperation among Spanish firms.

Appropriability conditions are considered in most empirical analyses. Generally, these conditions are classified as legal or strategic. Examples of legal appropriability measures of intellectual property protection include patents, utility patents, industrial designs, trademarks, and copyrights. Examples of strategic measures to protect cooperation output include commonly used secrecy, lead time advantage, and complex design. Cassiman and Veugelers (2002) find that higher appropriability through strategic protection has a positive effect on the probability of cooperation.

2.1.3 Obstacles to innovation

Firms tend to use R&D cooperation as a means of complementing innovation inputs and to overcome obstacles to innovation. The obstacles that are considered in the literature can be grouped into high costs of innovation, high risks of innovation, lack of technological information, and lack of market information. Cassiman and Veugelers (2002) and Veugelers and Cassiman (2005) consider as obstacles to innovation: the lack of suitable available financing, high costs of innovation, payback periods being too long, innovation costs being hard to control, and the high risks of innovation. Sakakibara (2001), Cassiman and Veugelers (2002), Miotti and Sachwald (2003), Arranz and Fdez. de Arroyabe (2008), and Okamuro (2007) include in their analyses at least one of the following variables to explain the effect of the obstacles to innovation on the propensity to cooperate: high cost of innovation, high risk of innovation, lack of technological information, and lack of market information. According to Miotti and Sachwald (2003), firms' cooperative behaviour may be positively related to the number of obstacles to innovation, although their results show that these obstacles do not influence the propensity to cooperate. Similarly, Veugelers and Cassiman (2005) show that risk of innovation is not an important obstacle that needs to be considered by firms when they decide to cooperate with universities. In contrast, Tether (2002) finds a positive and significant effect of sharing costs and risks on the propensity to cooperate. Miotti and Sachwald (2003) and Belderbos et al. (2004) qualify these results, finding that cooperation with rivals, which is quite rare, seems to mostly be used to share R&D costs, particularly in high-tech sectors. López (2008) finds that cost-risk sharing is the most important determinant for cooperation with suppliers and customers and cooperation with research institutions.

2.2 Impact of R&D collaboration and the importance of the cooperative partner

The impact that the choice of cooperative partner has on innovation has not been studied to the same extent that the determinants of cooperation have. The choice of coopertive partner is generally associated with the impact of R&D collaboration on the firm's innovation output. Most of the works have included in their analysis the determinants of cooperation with customers, suppliers, and universities and/or public research centres. Competitors are considered less because there is no available information on this category or the surveys observations are not large enough. Fritsch and Lukas (2001) and Cassiman and Veugelers (2002) find, respectively, that vertical cooperation is focused on incremental innovation and development activities. Miotti and Sachwald (2003) show that vertical cooperation has a positive effect on product innovation, but that is not frequent in high-tech industries, rather, firms that conduct expensive, risky, or complex research projects tend to be concentrated in high-tech sectors. Belderbos et al. (2004) find that competitors' cooperation focus on incremental innovations, while cooperation with customers and universities are important knowledge sources for firms pursuing radical innovations. Veugelers and Cassiman (2005) find that firms in high-technology sectors are more likely to be involved in cooperative agreements with universities and research centres, and demonstrate that cooperation with universities is complementary to other innovation activities.[6]. Vertical cooperation is more common in medium-low technology industries where competition discourages innovation (Aghion et al., 2005). Moreover, Becker and Dietz (2004) find that market power enables firms to shift R&D expenditures to suppliers through cooperation agreements. Moreover, de Faria et al. (2010) show that cooperation with customers is focused on product innovation, while suppliers' cooperation is focused on process innovation. From the above-mentioned perspective, some studies have deepened on the determinants of this choice. Miotti and Sachwald (2003) conclude that the choice of R&D cooperative partners is determined by the complementarity of resources for innovation for accessing knowledge and building innovative networks. Arranz and Fdez. de Arroyabe (2008) analyse the choice of partners in R&D cooperation among Spanish firms, finding that vertical cooperation is used as a means of overcoming market and technological risks, while cooperation with public partners is used to obtain financing. De Faria et al. (2010) study the importance of cooperative partners, showing that the firms which give greater value to cooperation with suppliers and firms from the same group are firms that belong to high-tech industries, with high levels of innovation intensity and absorptive capacity.

Competition has not been considered as a determinant of R&D cooperation or of the choice of collaborative partner. Only Becker and Dietz (2004) have considered in their analysis the effect of competitive conditions including a variable that measures the degree of market concentration, finding no significant effect on the propensity to cooperate, and negative and low significance in the number of partners chosen. Sakakibara (2001) analyses three decades of Japanese government-sponsored R&D consortia, finding that firms in oligopolistic industries are motivated to cooperate on R&D projects with industries that have higher growth. Elsewhere, the effect of oligopolistic competition on a firm's incentive to cooperate has been studied theoretically by

[6] The link between scientific knowledge and innovating firms is especially important in fast developing technologies sectors, such as biotechnology, IT, and new materials (Mowery, 1998; Zucker et al., 1998; Cockburn and Henderson, 2000).

d'Aspremont and Jacquemin (1988), Katz (1986), De Bondt and Veugelers (1991), Kamien et al. (1992), and Suzumura (1992), among others, who all stress the role of spillovers on the cooperation decision. In this regard, Hanaki et al. (2007) point out that R&D collaboration is a strategy for controlling knowledge spillovers, and find it reasonable that innovative firms may want to form R&D collaboration strategically to control knowledge externalities. Sakakibara (2001) points out that firms in more concentrated industries have fewer appropriability problems and less need to share innovation costs. From a strategic perspective, competition becomes a relevant condition as a determinant of cooperative innovation behaviour, especially considering the evidence that demonstrates the relationship between competition and innovation. In this regard, Aghion et al. (2005) find an inverted-U relationship between competition and innovation. Competition discourages laggard firms from innovating but encourages innovation among neck-and-neck firms which operate at a similar technological level. Innovation incentives depend upon the difference between post-innovation and pre-innovation rents of incumbent firms. More competition may encourage innovation and growth, because it may reduce a firm's pre-innovation rents by more than it reduces its post-innovation rents. Competition may increase the incremental profits from innovating, and thereby foster R&D investments aimed at escaping competition among neck-and-neck firms. In the neck-and-neck sectors, pre-innovation rents should be especially reduced by product market competition. In sectors where innovations are made by laggard firms with already low initial profits, product market competition will mainly affect post-innovation rents, and therefore the Schumpeterian effect of competition should dominate. Aghion et al. (2005) point out that neck-and-neck industries show a higher level of innovation activity for any level of product market competition, which only occurs in industries considered high-tech.[7]

3 Empirical study

3.1 Stylised facts

Most of the literature has focused on cooperation as a way to complement capabilities and resources to overcome innovation obstacles. The present empirical analysis contributes to the literature by including market structure as a determinant of cooperation. The market structure is approximated by two different variables: the number of competitors in the relevant market, and a measure of price elasticity. In addition, different types of cooperative partners are considered: 1) customers, 2) suppliers, 3) competitors, 4) universities, 5) firms of the same group, and 6) consultants.

From the previous literature, the following stylised facts allow the effect of market structure on cooperation with a certain partner type to be deduced. First, R&D cooperation, which allows firms to develop new knowledge and to incorporate external knowledge into the innovation process, is a crucial aspect for successful innovation. Second, as there is an inverted-U relationship between competition intensity and innovation, and as R&D cooperation is a fundamental input for innovation, the relationship between competition intensity and R&D cooperation should also be (typically) inverted-U shaped. Third, appropriability conditions are an important factor for R&D cooperation. Fourth, R&D cooperation with customers and universities has a positive effect on radical product innovation, which is more common in high-tech industries. Fifth, R&D cooperation

[7] Industries such as aerospace, pharmaceuticals, machinery, IT-telecommunications, and scientific instruments face neck-and-neck competition, where there is an innovations race to sustain a comparative and competitive advantage in the market.

with suppliers and competitors has a positive effect on incremental process innovation (mainly focused on input cost reduction and quality improvement).

Following these stylised facts, the empirical analysis studies the effect of competition intensity on R&D cooperation. In particular, we identity the determinants of R&D cooperation with a certain partner type. In the following section, we describe the data and the variables, and the considered empirical model.

3.2 Data and variables

The MIP is a micro dataset based on annual data that captures the innovation behaviour of German firms. The innovation survey covers firms with at least five employees and from various industries, and which are representative for Germany, allowing projections about the population of German firms. This survey is conducted by the Centre for European Economic Research (ZEW) on behalf of the Federal Ministry of Education and Research, in cooperation with the Institute of Applied Social Science and the Institute for Systems and Innovation Research. The MIP is the German contribution to the European Commission's Community Innovation Surveys (CIS).

For this analysis, the 2011 wave of the MIP is used, which provides valuable information on firms' competition environment. Particularly, the survey includes information regarding the number of competitors in the firm's relevant market, and a proxy for price elasticity. Each firm responds directly about the number of competitors that participate in their core market. Regarding price elasticity, firms indicate to what extent the characteristic "*price increases lead to immediate loss of clients*" describes their competitive situation. The respondents can indicate whether the described characteristic *applies fully*, *applies somewhat*, *applies very little*, *or does not apply*. With this information a categorical variable is built with three categories: (1) *does not apply at all or very little*, which indicates low price elasticity, (2) *applies somewhat*, which indicates intermediate price elasticity, and (3) *applies fully*, which indicates high price elasticity. The price elasticity variable allows the intensity of price competition to be approximated. As the two questions regarding number of competitors and price elasticity are not part of the regular questionnaire, it is not possible to construct a panel dataset. The 2011 wave also contains general information on firms, e.g. the number of employees, the number of employees with a university degree, and exports as a percentage of turnover, among others. More importantly for the purpose of this study, the survey contains data on innovation and R&D activities, for example on whether firms have undertaken continuous R&D activities in the last three years, R&D expenditures as a percentage of turnover, use of legal and strategic measures to protect intellectual property, obstacles to innovation such as high costs and risk of innovation, lack of technological information, and lack of market information.

This study concentrates on manufacturing firms, given that collaboration in R&D is more frequent in these industries. The sample includes $3,606$ firms. 55.5% $(2,000)$ of these firms report innovation in products or processes in the last three years $(2008-2010)$.[8] However, only 19.1% (688 firms) report cooperative agreements on innovation activities in this time. Table 1 displays the descriptive statistics (mean) of the innovative manufacturing firms of the sample. The descriptive statistics show the differences between the firms' characteristics depending on their collaborative partners. The statistics demonstrate that firms which cooperate with partners of the same group are the those with the largest number of employees, those that show the greatest proportion of exporters, and those that give the most importance to legal measures of intellectual

[8] We focus attention on innovative firms, as it is only firms that respond affirmatively to innovation questions that are able to respond to cooperative questions of the survey.

property protection. Firms that collaborate with customers show the highest R&D intensity, while firms that cooperate with competitors have the greatest proportion of employees with a university degree, and are the firms that give the most importance to the three obstacles of innovation considered, i.e., high cost and high financial risk, lack of technological information, and lack of market information. These firms also report the greater importance of strategic measures for their innovation output. Regarding the competition variables, it is shown that the sample mean of the number of competitors is higher than the average number of competitors of cooperative firms, i.e. cooperative firms face a lower number of competitors.[9] Focusing on cooperative firms, the ones that cooperate with competitors report that they face the highest number of competitors in their core market. Observing the variable that measures price elasticity, it is shown that firms which cooperate with rivals have the highest price elasticity reported by cooperative firms.[10]

Analysing the proportion of firms that cooperate with certain types of partner by industry, we observe that: cooperation with firms of the same group is preferred in the food-tobacco, chemical, and glass-ceramic industries; cooperation with customers is the most common among firms from the metal industry; firms from wood, plastic, and furniture industries cooperate the most with suppliers; cooperation with competitors is the most frequent among firms from the mining, transportation, and telecommunications industries; cooperation with universities is preferred by electric-equipment manufacturers; and cooperation with consultants is the

[9] Undertaking a t-test we find evidence that the difference between the sample mean of the number of competitors and the mean of cooperative firms is significant at 5%.

[10] The null hypothesis of equal means is rejected under the t-test.

most common among firms from the textile and machinery industries.

Table 1

Descriptive statistics for innovative and cooperative firms (mean).

Variable	Sample	Innovative	Non-Cooperative	Cooperative	Cooperative Partner					
					Customers	Suppliers	Competitors	Universities	Group	Consultants
Firm's characteristics										
Size	3.6023	3.9649	3.6864	4.5816	4.6510	4.7630	4.9833	4.7987	5.4223	5.0026
Exports	0.5897	0.7182	0.6741	0.8564	0.8920	0.8431	0.7979	0.8912	0.9086	0.8737
Univ	0.3271	0.3998	0.3399	0.5294	0.5410	0.5187	0.6263	0.5893	0.5644	0.5512
Rdicat	1.6197	2.1176	1.7550	2.8395	2.9386	2.8739	2.8375	2.8903	2.9209	2.8216
Competition										
Competitors	2.7292	2.7019	2.7146	2.6404	2.5861	2.6436	2.6700	2.5978	2.5238	2.7087
Pricecat	1.7085	1.6766	1.6696	1.6547	1.6014	1.6953	1.7692	1.6381	1.6343	1.6493
Appropriability										
Legal	0.1541	0.2325	0.1727	0.3518	0.3572	0.3907	0.3847	0.3899	0.4643	0.3956
Strategic	0.2852	0.4243	0.3521	0.5811	0.6224	0.6008	0.6519	0.6208	0.6185	0.6008
Obstacles to innovation										
Cost_risk	0.4974	0.5942	0.5780	0.6367	0.6683	0.7282	0.7391	0.6312	0.6776	0.6623
Lack-teck	0.1235	0.1478	0.1431	0.1551	0.1733	0.2030	0.2055	0.1693	0.1419	0.1667
Lack_mkt	0.1463	0.1767	0.1545	0.2114	0.2453	0.2282	0.2949	0.2371	0.2360	0.1892
Industries										
Mining	0.0696	0.0435	0.0472	0.0334	0.0277	0.0279	0.0648	0.0412	0.0493	0.0415
Foodt	0.0899	0.0805	0.0954	0.0363	0.0173	0.0314	0.0093	0.0351	0.0359	0.0184
Textil	0.0585	0.0540	0.0530	0.0480	0.0484	0.0557	0.0370	0.0495	0.0493	0.0645
Woodp	0.0549	0.0490	0.0588	0.0232	0.0173	0.0348	0.0093	0.0144	0.0179	0.0276
Chemical	0.0527	0.0720	0.0597	0.1076	0.1384	0.1115	0.1111	0.1155	0.1390	0.1106
Plastic	0.0538	0.0540	0.0539	0.0610	0.0588	0.0662	0.0278	0.0515	0.0628	0.0507
Glassc	0.0374	0.0355	0.0337	0.0407	0.0415	0.0418	0.0370	0.0392	0.0628	0.0369
Metal	0.1078	0.0975	0.1050	0.1003	0.1176	0.0906	0.0741	0.1052	0.0942	0.1106
Electric	0.0990	0.1375	0.1127	0.1962	0.1903	0.1533	0.1759	0.1979	0.1749	0.1567
Machinery	0.0765	0.1095	0.0963	0.1497	0.1661	0.1533	0.0926	0.1670	0.1435	0.1843
Furniture	0.0987	0.0980	0.1012	0.0770	0.0623	0.1045	0.0741	0.0701	0.0807	0.0737
Transport	0.1328	0.0800	0.0877	0.0378	0.0277	0.0488	0.1111	0.0268	0.0269	0.0691
Telecom	0.0682	0.0890	0.0954	0.0887	0.0865	0.0801	0.1759	0.0866	0.0628	0.0553
Observations	*3606*	*2000*	*1038*	*688*	*289*	*287*	*108*	*485*	*223*	*217*

See Table A1 for the description of the variables.

Table 1. Descriptive statistics for innovative and cooperative firms.

As mentioned above, six different types of partners are considered: 1) customers, 2) suppliers, 3) competitors, 4) universities, 5) firms of the same group, and 6) consultants. Table 2 describes the number and percentage of firms by partners. There are in total 745 cooperative firms. 33.7% (251 firms) cooperate only with one partner, universities being the most frequent (16.8%), followed by suppliers (6%), consultants (4%), customers (3.6%), other firms of the same group (2.3%), and competitors (0.9%). 29.3% of the cooperative firms are engaged in cooperation with two different types of partners, universities being one of these two partners in 69% of cases. Less common is cooperation with three or more different type of partners. In decreasing order, 18.8% cooperate with three different types of partners, 10.7% cooperate with four different types of partners, 6% cooperate with five different type of partners, and 1.5% cooperates with all the types of partners considered.

The considered dependent variables are a general measure of R&D cooperation (*coop*) and a specific measure of cooperation with each partner (*coop_ cust*, *coop_ supp*, *coop_ comp*, *coop_ unires*, *coop_ gr*, *coop_ cons*).[11],[12]

[11] See Table $A1$ in the Appendix, for a description of the variables.

[12] Fritsch and Lukas (2001) include in their analysis the relationship with customers, suppliers, other firms, and public research

To explain the choice of cooperative partner, independent variables grouped into five categories are considered: firm characteristics, market characteristics, appropriability measures, obstacles to innovation, and industries. According to the literature, the following firm characteristic variables are included: *size*, *exports*, personnel with a university degree above the sample mean (*univ*), and R&D intensity (*#rdicat*). Two variables are included to measure appropriability: the use and importance of (*i*) *legal* and (*ii*) *strategic* measures as a means of protecting intellectual property.[13] In the legal category are considered: applications for patents, the registration of trademarks, and the use of copyrights. In the strategic measures are included: secrecy, complex design, and lead time advantage over competitors. Three dichotomic variables are includes as bostacles to innovation: high innovation costs and risks (*cost_ risk*),[14] lack of technological information (*lack_ tech*), and lack of market information (*lack_ mkt*). These obstacles can lead to the extension, the end or the discontinuity of innovation projects, and even the decision not to start any innovation project at all.[15] A full description of variables is shown in Table *A*1 in the Appendix.

The correlation matrix is presented in Table *A*3 (see Appendix). Generally, correlation coefficients are either low or moderate and never exceed 0.6. Therefore, there is a low risk of facing collinearity issues or redundancies with this set of variables.

The main novelty of this study is the inclusion of market characteristics as determinants for cooperation with certain types of partners. As was mentioned above, two dimensions of competition are considered: the number of competitors in the firm's core market (*competitors*), and a proxy for price elasticity (*pricecat*). The variable that measures price elasticity captures the intensity of price competition, and can be determined by the degree of product differentiation. Three categories of price elasticity are considered: low, intermediate (*2.pricecat*), and high (*3.pricecat*), which correspond to independent products, partial substitutes, and close substitutes, respectively.

institutions. Cassiman and Veugelers (2002) consider cooperation with suppliers and customers, and cooperation with research institutions. Miotti and Sachwald (2003) include cooperation within interrelated groups of firms, clients, suppliers, competitors, and universities. Belderbos et al. (2004) and Belderbos et al. (2006) consider cooperation with competitors, suppliers, customers, and universities. López (2008) analyse cooperation with competitors, with suppliers and customers, and with research institutions. Arranz and Fdez. de Arroyabe (2008) group partners into three categories: vertical, horizontal, and public institutions. Into these categories are suppliers and clients, competitors, consultancy enterprises, and enterprises within firm's group, and government research institutes and universities, respectively. De Faria et al. (2010) study cooperation with other firms within the firm group, suppliers, clients or customers, competitors, consultants, commercial labs or R&D firms, universities, and government research institutions.

[13] Sakakibara (2001), Cassiman and Veugelers (2002), Veugelers and Cassiman (2005), and López (2008) include in their studies appropriability conditions to explain the propensity to cooperate.

[14] We build a unique variable that measures both aspects -high innovation costs and high financial risks- given the high correlation between both if we consider them separately.

[15] Sakakibara, (2001), Cassiman and Veugelers (2002), Miotti and Sachwald (2003), Veugelers and Cassiman (2005), Okamuro (2007), and Arranz and Fdez de Arroyabe (2008) include in their works variables regarding obstacles to innovation to explain the propensity to cooperate in R&D.

Table 2
Number and percentage of cooperative firms by partners.

Manufacturing firms	**3606**
Cooperative firms	745 (20.66%)[a]
Firms that cooperate only with one partner	251 (33.69%)[b]
Firms that cooperate only with firms of the same enterprise group	17 (2.28%)[b]
Firms that cooperate only with customers	27 (3.62%)[b]
Firms that cooperate only with suppliers	45 (6.04%)[b]
Firms that cooperate only with competitors	7 (0.94%)[b]
Firms that cooperate only with universities	125 (16.78%)[b]
Firms that cooperate only with consultants	30 (4.03%)[b]
Firms that cooperate with two partners	218 (29.26%)[b]
Firms that cooperate with two partners, being one of them a university	150 (20.13%)[b]
Firms that cooperate with two partners, and one of them is not a university	68 (9.13%)[b]
Firms that cooperate with three partners	140 (18.79%)[b]
Firms that cooperate with four partners	80 (10.74%)[b]
Firms that cooperate with five partners	45 (6.04%)[b]
Firms that cooperate with all the partners	11 (1.48%)[b]

a: percentage with respect to manufacturing firms.
b: percentage with respect to cooperative firms (745 firms).

Table 2. Cooperative firms by partner.

3.3 Empirical model

This section describes the empirical strategy. Taking into account that the dependent variables are dichotomic (1 when a firm undertakes R&D cooperation or when it chooses a certain type of partner), a logit regression model is used.[16] The key question is whether the competition environment affects the decision to cooperate, and what its specific effect on the partner choice for cooperative R&D is. The regression coefficients estimate the impact of the independent variables on the probability that the firm will conduct cooperative agreements in general, and with a certain type of partner in particular. I restrict attention to innovative firms to estimate the likelihood of cooperation. To estimate the probability of choosing a particular partner, I restrict attention to innovative and cooperative firms.

The logit model estimates $p = Pr(y = 1|x)$, that is, either the probability of cooperation in general, or the probability of choosing a particular partner to cooperate with, given a set of explanatory variables $\mathbf{x}$. Therefore, the following equations are estimated:

$$\begin{aligned} y &= \alpha + \beta_1 competitors + \beta_2 pricecat + \beta_3 size + \beta_4 exports + \beta_5 univ + \beta_6 rdicat + \\ &+ \beta_7 legal + \beta_8 strategic + \beta_9 cst\_risk + \beta_{10} lack\_tech + \beta_{11} lack\_mkt + \\ &+ \gamma_i industry\_dummies, \quad (i = 1, ..., 13) \end{aligned}$$

[16]Many authors analyse the choice of cooperative partner using a logit model to estimate de probability of cooperation with a particular partner. See Fritsch and Lukas (2001), Miotti and Sachwald (2003), and Arranz and Fdez. de Arroyabe (2008).

where y represents the different dependent variables that are estimated: *coop*, *coop_ gr*, *coop_ cust*, *coop_ supp*, *coop_ comp*, *coop_ unires*, and *coop_ cons*, $\beta_1, ..., \beta_{11}$ are the coefficients to be estimated, and γ_i are a set of coefficients for industry dummies. The thirteen industries considered in the sample are included. The estimations cluster the standard errors on the industries to obtain a better adjustment.

The same set of independent variables is used to successively estimate first the likelihood of cooperation, and second the likelihood of cooperating with a certain type of partner. The difference between the two estimations is that in the first only the sub-sample of innovative firms is considered, while in the second the sub-sample of innovative and cooperative firms is considered. This set of logit specifications allows a clear interpretation of the results, which are presented in the next section.

4 Results

This section is organised as follows. First, the determinants for R&D cooperation are analysed. Second, the estimation results for partner choice for R&D cooperation are discussed by grouping the explanatory variables in the following way: firms' characteristics, competition intensity, appropriability measures, obstacles to innovation, and industry-specific effects.

4.1 Determinants for R&D cooperation

Table 3 provides the estimates (coefficients and robust standard errors) of the cooperation variable. The robust standard errors have been clustered by industry. As expected and in accordance with the literature, *size* and R&D intensity (*rdicat*) positively and significantly affect the propensity to engage in cooperative agreements. Firms that have a proportion of employees with a degree above the sample mean (*univ*) are more likely to collaborate in innovation. As R&D intensity (*rdicat*) and employees' qualifications (*univ*) approximate the firm's absorptive capacity, the results confirm that German firms with higher absorptive capacity are more likely to cooperate in innovation activities. Being an export firm (*exports*) does not appear to influence the likelihood to cooperate, in contrast to the majority of the results in the literature.

Regarding competition intensity, it is found that it does not have an influence on the firms' decision to cooperate. Neither the number of competitors (*competitors*) nor price elasticity (*pricecat*) are significant for firms' propensity to cooperate. These results coincide with Becker and Dietz (2004), who find that competition intensity (measured by the Herfindahl index for industrial sectors) is not significant for the decision to cooperte.

The results confirm the importance that German firms give to appropriation measures when they evaluate whether to collaborate in innovative projects. The coefficients of *legal* and *strategic* appropriation are positive and significant, with legal measures being more significant than the strategic ones. Obstacles to innovation do not significantly affect the likelihood of engaging in cooperation. The coefficient estimates of *cost_ risk* and *lack_ tech* are positive, while that of *lack_ mkt* is negative, although none of the three cases are significant.

Belonging to a particular industry appears to be relevant the explanation of why firms collaborate on innovation. In comparison with firms from the chemical (*chemical*) sector, mining firms are more likely to cooperate. Firms from the food-tobacco (*foodt*), wood-paper (*woodp*), metal (*metal*), electric equipment (*electric*), machinery (*machinery*), furniture-toys (*furniture*), and telecommunications (*telecom*) industries cooperate less on innovation than their counterparts from the chemical sector. Firms from the textile (*textil*), plastic (*plastic*), glass-ceramic (*glassc*), or transportation (*transport*) industries do not show significant differences with respect to firms in the chemical industry regarding the likelihood to engage in collaborative R&D agreements.[17]

Table 3
Logit regressions on cooperation decision

Variable	COOP		Variable	COOP	
size	0.234***	(0.068)	*Industry*		
exports	0.266	(0.291)			
univ	0.374*	(0.222)	mining	0.263*	(0.142)
2.rdicat	1.650***	(0.226)	foodt	-0.492***	(0.106)
3.rdicat	1.844***	(0.268)	textil	0.249	(0.155)
4.rdicat	2.419***	(0.295)	woodp	-0.957***	(0.129)
2.competitors	0.315	(0.788)	plastic	-0.020	(0.101)
3.competitors	0.550	(0.710)	glassc	-0.080	(0.082)
4.competitors	0.454	(0.752)	metal	-0.240**	(0.118)
2.pricecat	0.118	(0.108)	electric	-0.282***	(0.043)
3.pricecat	-0.001	(0.178)	machinery	-0.379***	(0.080)
legal	0.501**	(0.235)	furniture	-0.511***	(0.084)
strategic	0.518*	(0.271)	transport	0.139	(0.102)
cost_risk	0.134	(0.163)	telecom	-0.644***	(0.165)
lack_tech	0.071	(0.198)			
lack_mkt	-0.154	(0.140)	Constant	-3.822***	(0.704)
Observations	936				

Notes:
(1) The variables categories 1.competitors, i.e., no competitors, and 1.pricecat, i.e., low price elasticity, are the references.
(2) The industry of reference is chemicals.
*** Significant at 1%, ** Significant at 5%, *Significant at 10%.

Table 3. Logit regression on cooperation decision.

4.2 Partner choice for R&D cooperation

In this section, the determinants of cooperation with certain types of partners are shown. Table 4 presents the estimation results showing that the propensity to cooperate with each partner is driven by different factors.

4.2.1 A firm's characteristics

A firm's size is found to have positive and highly significant effect on the likelihood to cooperate with competitors, firms of the same group, and consultants. By contrast, size is not a determinant either for vertical cooperation or for cooperation with universities. These results may be explained by the fact that 80% of the German firms included in the sample have less than 140 employees, that is, most of the firms are small and medium size. Otherwise, firms that cooperate with competitors, consultants, and firms of the same group are larger than firms that cooperate with customers, suppliers or universities, according to the descriptive statistics shown in Table 1. The *exports* variable does not have a significant effect on the choice of cooperative partner,

[17] We do not group industries by technology level, as the original allocation of sector is mixed regarding the technological level of the firms, e.g. the industry called 'furniture' includes furniture, toy, medical technology, and maintenance firms, making it difficult to classify them in only one category of technological level.

coinciding with the results obtained in Table 3. The proportion of employees with a university degree positively and significantly affects the propensity to cooperate with universities and consultants, confirming the literature results, which shows that firms with more qualified human resources have a greater propensity to cooperate with scientific institutions. In contrast, personnel qualification shows a negative and low significant effect on the likelihood to cooperate with customers. Finally, the results show that the R&D intensity has a positive and significant effect on the propensity to cooperate with customers and suppliers. In contrast with the findings in the literature, German firms with high investment in R&D show a tendency to cooperate vertically. Despite the fact that R&D intensity explains firms' decision to cooperate, it does not show a significant effect on the probability to cooperate with competitors, universities, firms of the same group or consultants.

4.2.2 Competition intensity

The results show that competition intensity is a relevant determinant for firms' cooperation with customers, suppliers, competitors, universities, and firms of the same group, while it has no significant impact on firms' cooperation with consultants. Competition intensity, measured by the number of competitors in the firm's core market, has a negative and significant effect on the likelihood to cooperate with customers and firms of the same group. Nevertheless, the causality of these results does not seem to be the same.

Cooperation with customers is generally associated with product innovation and/or radical innovation, which involves greater risks.[18] Two circumstances could explain this result. First, higher competition intensity may discourage radical product innovations, given the intrinsic risk and uncertainty associated with this type of innovation. Second, higher competition intensity may discourage collaboration with customers given the risks of appropriation or disclosure of a firm's valuable knowledge. Indeed, the positive effect of the *strategic* variable indicates that risk of appropriation is an important issue for cooperation with customers.

Regarding cooperation with firms of the same group, the results also show that the number of competitors negatively and significantly affects the propensity to cooperate. Firms that belong to a group have access to a substantial pool of resources for innovation (Lowe and Taylor, 1998). However, as the competition intensity increases, these firms may seek outside cooperation to complement their innovative skills. This could explain why an increase in competition negatively affects a firm's propensity to cooperate with partners of the same group.

The number of competitors does not show a significant effect on the likelihood of cooperating with suppliers, competitors, universities, or consultants.

Price elasticity (measured by *2.pricecat* and *3.pricecat*) affects the propensity to cooperate with suppliers, competitors, and universities differently. The likelihood to cooperate with suppliers is positively affected by a high price elasticity. High price elasticity (*3.pricecat*) indicates that firms compete with other firms producing close-substitute products. These firms are more likely to look for cost reductions or quality improvements to enhance their competitiveness. Cooperation with suppliers is commonly associated either with incremental or with process innovation (Fritsch and Lukas, 2001; de Faria et al., 2010).

Moreover, an intermediate level of competition (*2.pricecat*, which indicates a moderate degree of product differentiation) is found to have a positive and significant effect on the propensity to cooperate with competi-

[18] Fritsch and Lukas (2001); Miotti and Sachwald (2003); Belderbos et al. (2004); and De Faria et al. (2010) show that cooperation with customers is mainly oriented towards product innovation and/or radical innovation.

tors,[19] while this effect vanishes for a higher level of competition (*3.pricecat*). Therefore, competition intensity and cooperation with competitors are related to an inverted U-shape manner (Aghion et al., 2005). The reason for this is that the inherent risk associated with collaboration with competitors diminishes as the degree of substitutability across firms decreases.

In contrast, price elasticity (*2.pricecat* and *3.pricecat*) discourages cooperation with universities. This means that firms in more competitive environments are less likely to cooperate with universities. Similarly to the case of collaboration with customers, high competition intensity may discourage collaboration given the risk of disclosure of a firm's valuable knowledge. Again, the positive effect of the *legal* variable indicates that legal protection of intellectual property is a relevant factor for collaboration with universities. Furthermore, cooperation with universities is characterised by a low degree of short-run applicability, which is important in highly competitive markets.

4.2.3 Appropriability measures

The appropriability measures positively affect the propensity to cooperate in general, and the propensity to cooperate with a certain type of partner in particular.[20] Legal protection (*legal*) positively affects the likelihood of cooperating with suppliers and universities, while strategic measures (such as secrecy, design complexity, and lead time advantage) foster cooperation with customers, competitors, firms of the same group, and consultants.

The results suggest that the higher the risk of technological information disclosure is (which is the case for cooperation with suppliers, universities, and consultants), the more important legal protection becomes. On the other hand, the use of strategic appropriability measures has a positive effect on the propensity to cooperate with customers and competitors. The reason for this is that these kinds of collaborative agreements involve sharing valuable information from a commercial point of view, which explains the importance of secrecy, design complexity, and lead time advantage over competitors as a means of protecting cooperative output.

4.2.4 Obstacles to innovation

Concerning the obstacles to innovation, the results show that firms that face high innovation costs and risks (*cost_risk*) are more likely to cooperate with customers and suppliers.[21] Lack of market information (*lack_mkt*) positively affects the propensity to cooperate with customers. This result is easily explained, as one of the main sources of a firm's market information is clients and customers. These results confirm findings from the previous literature, which suggests that many innovative projects arise as a result of the continued interaction between members of the same supply chain. Collaboration becomes a means of overcoming mutual obstacles to innovation and an instrument for improving the overall competitiveness of the supply chain (Ireland and Webb, 2007). In contrast, the lack of technological information (*lack_tech*) is found not to have a significant effect on the probability to cooperate with certain types of partners, because sharing technological information involves a higher risk of disclosure.

[19] Cooperation with rivals allows firms to look for complementary R&D resources (Cassiman and Veugelers, 2002), although this kind of collaboration is more hazardous than vertical cooperation (Atallah, 2002).

[20] Firms better prepared to protect their knowledge are more likely to cooperate in innovation (Cassiman and Veugelers, 2002; Abramovsky et al., 2009).

[21] This result coincides with the findings of López (2008), who finds that cost-risk sharing is an important determinant for vertical cooperation.

Table 4
Logit regressions on the partner choice

Variable	(1) COOP_CUST	(2) COOP_SUPP	(3) COOP_COMP	(4) COOP_UNIRES	(5) COOP_GR	(6) COOP_CONS
size	-0.037 (0.083)	0.164 (0.119)	0.317*** (0.065)	0.217 (0.176)	0.526*** (0.105)	0.261***(0.080)
exports	-0.427 (0.434)	-0.221 (0.443)	-0.269 (0.544)	0.337 (0.457)	0.497 (0.481)	-0.099 (0.507)
univ	-0.425* (0.258)	-0.236 (0.399)	0.413 (0.354)	0.631*** (0.203)	0.385 (0.278)	0.489** (0.235)
2.rdicat	0.976 (0.727)	0.640 (0.466)	0.539 (0.751)	-0.353 (0.593)	0.134 (0.530)	0.294 (0.467)
3.rdicat	1.325* (0.739)	0.873** (0.407)	-0.197 (0.877)	-0.082 (0.544)	0.306 (0.544)	0.463 (0.726)
4.rdicat	1.330 (0.812)	0.938** (0.409)	0.712 (0.705)	-0.233 (0.500)	0.253 (0.541)	0.444 (0.780)
2.competitors	-1.595* (0.912)	0.875 (1.323)	-0.735 (0.857)	-0.478 (1.313)	-1.310*** (0.357)	-0.425 (0.982)
3.competitors	-2.105** (0.962)	1.017 (1.167)	-0.380 (1.093)	-0.812 (1.321)	-1.263*** (0.342)	0.318 (1.056)
4.competitors	-2.038** (0.985)	0.435 (1.360)	-0.518 (1.071)	-0.349 (1.201)	-1.222*** (0.462)	0.208 (0.791)
2.pricecat	0.271 (0.253)	0.533 (0.353)	0.932** (0.414)	-0.330** (0.166)	-0.124 (0.300)	-0.074 (0.264)
3.pricecat	-0.105 (0.762)	0.869* (0.516)	0.404 (0.512)	-0.947** (0.473)	0.336 (0.570)	0.087 (0.640)
legal	0.053 (0.306)	1.195** (0.525)	0.319 (0.711)	1.024* (0.603)	1.842*** (0.441)	0.901** (0.359)
strategic	1.480*** (0.488)	0.131 (0.345)	1.220*** (0.323)	0.702 (0.590)	-0.071 (0.402)	0.120 (0.483)
cost_risk	0.521** (0.224)	1.003*** (0.196)	0.221 (0.345)	0.109 (0.253)	0.271 (0.311)	0.141 (0.181)
lack_tech	0.084 (0.338)	0.721 (0.503)	-0.603 (0.395)	0.127 (0.448)	-0.105 (0.413)	0.279 (0.301)
lack_mkt	0.498** (0.219)	-0.577 (0.382)	0.118 (0.391)	0.222 (0.213)	0.357 (0.352)	-0.235 (0.372)
Constant	0.122 (1.019)	-3.839*** (1.358)	-4.801*** (1.177)	-0.430 (1.501)	-3.479*** (0.724)	-3.088*** (1.179)
Observations	323	319	281	366	315	316

Notes:
(1) The categorical variables have as references: 1.rdicat, i.e., no investment in R&D; 1.competitors, i.e., no competitors; and 1.pricecat, i.e., low price elasticity.
(2) *** Significant at 1%, ** Significant at 5%, *Significant at 10%.

Table 4. Logit regressions on the partner choice.

4.2.5 Industry

Table 4 presents the estimates for the industry dummies. Taking firms from the chemical sector as a reference, the results show that firms from the electric industry (*electric*) cooperate more with customers. Firms from the textile (*textil*), wood-paper (*woodp*), plastic (*plastic*), glass-ceramic (*glassc*), machinery (*machinery*) and transportation (*transport*) sectors are more likely to cooperate with suppliers. Cooperation with competitors is relevant for firms from the mining (*mining*), textile, glass-ceramic, electric, machinery and transportation industries. Firms from the mining, textile, electric and machinery are more likely to cooperate with universities. Cooperation with firms of the same group is important for firms from the mining, textile, plastic, glass-ceramic, and transportation industries. Finally, the propensity to cooperate with consultants is relevant for firms from the mining, textile, wood-paper, glass-ceramic, metal (*metal*), electric, machinery and furniture (*furniture*) industries.

The results do not show a consistent pattern which can explain the propensity to cooperate with a particular type of partner depending on the technological level of the industry. Thus, the results from the industry variables do not provide evidence on the propensity to cooperate with a certain type of partner. In conclusion, the firms' partner choice is mainly driven by competition intensity and appropriability measures.

Table 4 (continued)

Logit regressions

Variable	(1) COOP_CUST	(2) COOP_SUPP	(3) COOP_COMP	(4) COOP_UNIRES	(5) COOP_GR	(6) COOP_CONS
Industry sectors						
mining	0.838 (0.550)	0.132 (0.301)	1.790** (0.697)	1.957*** (0.534)	0.695* (0.362)	0.945** (0.429)
foodt	-1.324*** (0.347)	-0.408** (0.207)	-	0.141 (0.451)	0.217 (0.216)	-0.039 (0.374)
textil	-0.642** (0.265)	1.020*** (0.217)	1.320*** (0.356)	1.036*** (0.208)	0.368*** (0.117)	1.270*** (0.141)
woodp	-0.246 (0.267)	1.918*** (0.194)	-	-1.780*** (0.207)	0.085 (0.184)	1.168*** (0.298)
plastic	0.085 (0.205)	0.634*** (0.208)	-0.059 (0.303)	0.297 (0.199)	0.681*** (0.113)	0.130 (0.135)
glassc	-0.641*** (0.220)	0.310** (0.135)	1.076*** (0.175)	0.394 (0.253)	0.542*** (0.200)	0.782*** (0.109)
metal	0.360 (0.233)	0.307 (0.223)	0.423 (0.271)	0.302 (0.268)	-0.475** (0.216)	0.683*** (0.229)
electric	0.217*** (0.079)	0.194 (0.121)	0.948*** (0.087)	0.247*** (0.066)	0.001 (0.068)	0.299* (0.154)
machinery	-0.449*** (0.115)	0.242** (0.111)	0.364** (0.142)	0.532*** (0.139)	-0.764*** (0.171)	0.457*** (0.102)
furniture	-0.662*** (0.209)	0.006 (0.242)	-0.142 (0.214)	0.168 (0.140)	-0.571*** (0.108)	0.319** (0.136)
transport	-0.953*** (0.345)	1.173*** (0.440)	2.507*** (0.564)	-1.102** (0.542)	1.007*** (0.375)	0.517 (0.464)
telecom	-	-	-	-	-	-
Observations	323	319	281	366	315	316

Notes:

(1) The industry of reference is chemicals.

(2) *** Significant at 1%, ** Significant at 5%, *Significant at 10%.

5 Discussion

In previous works, competition has either been ignored as a determinant of the partner choice for cooperative innovation, or it has been approximated by general or indirect measures.[22] To the best of our knowledge this is the first study that includes competition intensity as a determinant of cooperative partner choice. More precisely, two competition intensity variables are included: the number of competitors in the core market (*competitors*), and the price elasticity (*pricecat*) reported by the firms. Our results show that competition intensity is a determinant for different types of collaborative innovation (e.g., with customers, suppliers, competitors, universities, or firms of the same group). Overall, the effect of competition is negative for cooperation with universities, customers and firms of the same group, and positive for cooperation with suppliers and competitors (and ambiguous for cooperation with consultants).

In order to explain these results, the different types of collaborative partnerships are classified in Figure 3.1 according to two dimensions: the intensity of innovation and the risk of disclosure. While collaboration with universities and customers aims at obtaining radical innovations, collaboration with suppliers and competitors typically produces incremental innovation (*citations*). Regarding the risk of disclosure, it is lower in collaborations with closely-related partners (suppliers) and in collaboration with competitors, as the incentives to disclose information are aligned, and the adoption of legal protection mechanisms is a pre-requisite for the existence of these partnerships (*citations*). Differently, the risk of disclosure is higher in partnerships with universities and customers (*citations*).

Therefore, when both the intensity of innovation and the risk of disclosure are high (north-east region in Figure 3.1) the effect of competition on the propensity to cooperate is negative. On the other hand, this effect

[22] Many authors consider exports as a proxy for firms' participation in more competitive markets. Becker and Dietz (2004) use the Herfindahl index to estimate the impact of competition on the firm's propensity to cooperate.

is positive when both the intensity of innovation and the risk of disclosure are low (south-west region in Figure 3.1).

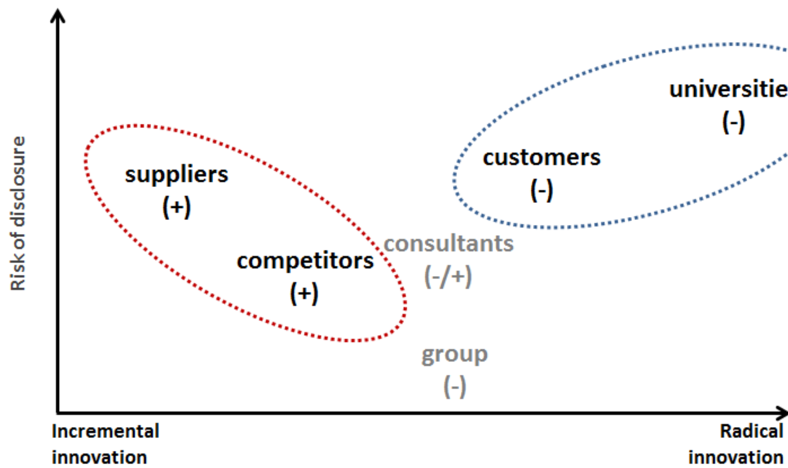

Fig. 1. Partnerships classification.

6 Concluding remarks

This study is the first to analyse the effect of competition intensity as a determinant of cooperative partner choice. Competition intensity is measured by the number of competitors in the core market and the price elasticity reported by firms.

Using information from German firms for 2011, the results show that competition intensity is a determinant for different types of collaborative innovation (e.g., with customers, suppliers, competitors, universities, or firms of the same group). Overall, the effect of competition is negative for cooperation with universities, customers, and firms of the same group, and positive for cooperation with suppliers and competitors (and ambiguous for cooperation with consultants). Competition negatively affects partnerships with customers and universities, which look for radical innovation and involve high risks of disclosure. In contrast, competition positively influences partnerships with suppliers and competitors, which pursue incremental innovation and which involve a more egalitarian risk of information disclosure. These findings suggest that our results could be extended by considering the intrinsic risk of disclosure in collaborative agreements (which is exogenous in our analysis) and the innovation intensity of such agreements (incremental or radical innovation).

Several limitations of the present analysis call for further research on this topic. This study adopts a static perspective due to data availability. The use of panel data would allow firm-specific unobserved heterogeneity to be accounted for. Furthermore, a deeper analysis within industries would allow industry-specific appropriability and competition conditions to be included.

References

[1] Abramovsky, L., Kremp, E., López, A., Schmidt, T., Simpson, H., 2009, 'Understanding co-operative innovative activity: evidence from four European countries,' Economics of Innovation and New Technology, 18, 243 – 265.

[2] Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitt, P., 2005, 'Competition and innovation: an inverted-U relationship,' The Quarterly Journal of Economics, May, 701 – 728.

[3] Arranz, N., Fdez. de Arroyabe, J.C., 2008, 'The choice of partners in R&D cooperation: an empirical analysis of Spanish firms,' Technovation, 28, 88-100.

[4] d'Aspremont, C., Jacquemin, A., 1988, 'Cooperative and noncooperative R&D in duopoly with spillovers,' American Economic Review, 78, 1133-1137.

[5] Becker, W., Dietz, J., 2004, 'R&D cooperation and innovation activities of firms – evidence for the German manufacturing industry,' Research Policy, 33, 209-223.

[6] Belderbos, R., Carree, M., Lokshin, B., 2004, 'Cooperative R&D and firm performance,' Research Policy, 33, 1477-1492.

[7] Belderbos, R., Carree, M., Lokshin, B., 2006, 'Complementarity in R&D cooperation strategies,' Review of Industrial Organization, 28, 401-426.

[8] Billand, P., Bravard, C., 2004 'Non-cooperative networks in oligopolies,' International Journal of Industrial Organization, 22, 593-609.

[9] Brander, J.A., Spencer, B.J., 1984, 'Strategic commitment with R&D: the symmetric case,' Bell Journal of Economics, 14, 225-235.

[10] Cassiman, B., Veugelers, R., 2002, 'R&D Cooperation and spillovers: some empirical evidence from Belgium,' The American Economic Review, 92, 1169-1184.

[11] Cassiman, B., Veugelers, R., Zuniga, P., 2007, 'Science linkages and innovation performance: an analysis on CIS-3 firms in Belgium,' IESE Business School Working Paper, 671.

[12] Cohen, W.M., Levinthal, D.A., 1989, 'Innovation and learning: the two faces of R&D,' The Economic Journal, 99, 569-596.

[13] Colombo, M.G., 1998. 'Some introductory reflections.' In: Colombo, M.G. (Ed.), The Changing Boundaries of the Firm. Explaining Evolving Inter-Firm Relations. Routledge, London, pp. 1-25.

[14] Dachs, G., Ebersberger, B., Pyka, A., 2008, 'Why do firms cooperate for innovation? A comparison of Austrian and Finnish CIS 3 results,' International Journal of Foresight and Innovation Policy, 4, 200-229.

[15] De Bondt, R., Veugelers, R., 1991, 'Strategic investment with spillovers,' European Journal of Political Economy, 7, 345-366.

[16] Duso, T., Röller, L.H., Seldeslachts, J., 2014, 'Collusion through joint R&D: an empirical assessment,' The Review of Economics and Statistics, 96 (2), 349-370.

[17] De Faria, P., Lima, F., Santos, R., 2010, ‘Cooperation in innovation activities: the importance of partners,’ Research Policy, 39, 1082-1092.

[18] Flores-Fillol, R., Ibañez-Zarate, G., Theilen, B., 2014, ‘Domestic and international research joint ventures: the effect of collusion,’ Economics Letters, 122, 79-83.

[19] Fritsch, M., Lukas, R., 2001, ‘Who cooperates on R&D?,’ Research Policy, 30, 297-312.

[20] Goyal, S, Joshi, S., 2003, ‘Networks of collaboration in oligopoly,’ Games and Economic Behaviour, 43, 57-85.

[21] Grant, R., Bade-Fuller, C.A., 2004, ‘A knowledge accessing theory of strategic alliances,’ Journal of Management Studies, 41, 61-84.

[22] Hagedoorn, J., Link, A.N., Vonortas, N.S., 2000, ‘Research partnership,’ Research Policy, 29, 567-586.

[23] Hanaki, N., Nakajima, R., Ogura, Y., 2007, ‘The dynamics of R&D collaboration in the IT industry,’ Social Science Research Network working paper, http://ssrn.com/abstract=1000103.

[24] Ireland, R.D., Webb, J.W., 2007, ‘A multi-theoretic perspective on trust and power in strategic supply chains,’ Journal of Operations Management, 25, 482-497.

[25] Kamien, M.I., Muller, E., Zang, I., 1992, ‘Research joint ventures and R&D cartels,’ American Economic Review, 82, 1293-1306.

[26] Katz, M., 1986, ‘An analysis of cooperative research and development,’ Rand Journal of Economics, 17, 527-543.

[27] Kleinknecht, A., Reijnen, J.O.N., 1992, ‘Why do firms cooperate on R&D? An empirical study,’ Research Policy, 21, 347-360.

[28] König, H., Licht, G., Staat, M., 1994, R&D co-operation and innovation activity, in Gahlen, B., Hesse, H., Ramser H.J. (Eds.), Europäische Integrationsprobleme aus wierschaft-swissenschaftlicher Sicht. Siebeck, Tübingen, 219-242.

[29] Kotabe, M., Swan, K.S., 1995, ‘The role of strategic alliances in high-technology new product development,’ Strategic Management Journal, 16, 621-636.

[30] Lavie, D., 2006, ‘The competitive advantage of interconnected firms: an extension of the resource-based view,’ Academy of Management Review, 31, 638-658.

[31] Link, A.N., Bauer, L.L., 1987, ‘An economic analysis of cooperative research,’ Technovation, 6, 247-260.

[32] López, A., 2008, ‘Determinants of R&D cooperation: evidence from Spanish manufacturing firms,’ International Journal of Industrial Organization, 26, 113-136.

[33] Lowe, J., Taylor, P., 1998, ‘R&D and technology purchase trough licence agreements: complementary strategies and complementary assets,’ R&D Management, 28, 263-278.

[34] Miotti, L., Sachwald, F., 2003, ‘Co-operative R&D: why and with whom? An integrated framework of analysis,’ Research Policy, 32, 1481-1499.

[35] Mowery, D., Oxley, J., Silverman, B, 1998, ‘Technological overlap and interfirm cooperation: implications for the resource-based view of the firm,’ Research Policy, 27, 507-523.

[36] Negassi, S., 2004, ‘R&D co-operation and innovation a microeconometric study on French firms,’ Research Policy, 33, 365-384.

[37] Okamuro, H., 2007, ‘Determinants of successful R&D cooperation in Japanese small business: the impact of organizational and contractual characteristics,’ Research Policy, 36, 1529-1544.

[38] Sakakibara, M., 2001, ‘Cooperative research and development: who participates and in which industries do projects take place?,’ Research Policy, 30, 993-1018.

[39] Sampson, R., 2007, ‘R&D Alliances and firm performance: the impact of technological diversity and alliance organization on innovation,’ Academy of Management Journal, 50, 364-386.

[40] Spence, M., 1984, ‘Cost reduction, competition and industry performance,’ Econometrica, 52, 101-121.

[41] Staropoli, C., 1998, ‘Cooperation in R&D in the pharmaceutical industry-the network as an organizational innovation governing technological innovation,’ Technovation, 18, 13-23.

[42] Suzumura, K., 1992, ‘Cooperative and noncooperative R&D in an oligopoly with spillovers,’ American Economic Review, 82, 1307-1320.

[43] Teece, D.J., 1986, ‘Profiting from technological innovation: implications for integration, collaboration, licensing and public policy,’ Research Policy, 15, 285-305.

[44] Tether, B.S., 2002, ‘Who co-operates for innovation, and why: an empirical analysis,’ Research Policy, 31, 947-967.

[45] Veugelers, R., Cassiman, B., 2005, ‘R&D cooperation between firms and universities. Some empirical evidence from Belgian manufacturing,’ International Journal of Industrial Organization, 23, 355-379.

[46] Vonortas, N.S., 1997, ‘Cooperation in Research and Development,’ Kluwer Academic Publisher, Boston.

[47] Vuola, O., Hameri, A., 2006, ‘Mutually benefiting joint innovation process between industry and big-science,’ Technovation, 26, 3-12.

[48] Yasuda, H., 2005, ‘Formation of strategic alliances in high-technology industries: comparative study of the resources-based theory and the transaction-cost theory,’ Technovation, 25, 763-770.

[49] Zucker, L.G., Darby, M.R., Brewer, M.B., 1998, ‘Intellectual human capital and the birth of U.S. biotechnology enterprises,’ American Economic Review, 88, 290-306.

A Appendix

Table A1

Description of variables

Variable	Definition
	Dependent variables
coop	Dummy variable =1 if the firm cooperates on innovation activities during the last three years (2008-2010).
coop_gr	=1 if the firm cooperates with firms within the same enterprise group.
coop_cust	=1 if the firm cooperates with customers or clients.
coop_supp	=1 if the firm cooperates with suppliers of equipment, materials, components, of software.
coop_comp	=1 if the firm cooperates with competitors or other enterprises of the same sector.
coop_unires	=1 if firm cooperates with universities, other higher education institutions, or governmental research institutes.
coop_cons	=1 if firm cooperates with consultants, commercial labs or private R&D institutes
	Independent variables
Firm characteristics	
size	Log of the average number of employees in the last three years.
exports	=1 if the firm reports positive exports in the last three years.
univ	=1 if the firm reports a percentage of employees with university degree above the average of the sample.
rdicat#	Categorical variable of the total R&D expenditure as a share of turnover. 1: no investment in R&D, 2: 0%<x=1%, 3: 1%<x=3%, 4: x>3%.
Market characteristics	
competitors#	Categorical variable of the number of the main competitors: 1: none, 2: 1 to 5, 3: 6 to 15, 4: more than 15.
pricecat#	Categorical variable of the level of applicability of the condition “price increase lead to immediate loss of clients”: 1: applies not at all or very little, 2: applies somewhat, 3: applies fully.
Appropriability	
legal	Legal measures that the firm used to protect its IP during the last three years, and its importance: patents, trademarks, and copyright. x=0 if the firm has not used any of the measures, and 0<x=1 depending on the average importance of used measures.
strategic	Strategic measures that the firm used to protect its IP during the last three years, and its importance: secrecy, complex design, and lead time advantage. x=0 if the firm has not used any of the measures, and 0<x=1 depending on the average importance of used measures.
Obstacles to innovation	
cost_risk	Dummy variable =1 if the firm recognizes that high innovation cost and/or high financial risk provokes the ended/discontinued, not started, or extended duration of innovation projects.
lack_tech	Dummy variable =1 if the firm recognizes that lack of technological information provokes the ended/discontinued, not started, or extended duration of innovation projects.
lack_mkt	Dummy variable =1 if the firm recognizes that lack of market information provokes the ended/discontinued, not started, or extended duration of innovation projects
Industries	
See Table A2 for Industries description and the equivalence with the NACE Rev.2.	

Table A2

Description of industries and equivalence with NACE Rev.2 classification.

MIP Sector	Description	NACE Rev. 2
1	Mining	5-9, 19, 35
2	Food/Tobacco	10-12
3	Textiles	13-15
4	Wood/Paper	16-17
5	Chemicals	20-21
6	Plastics	22
7	Glass/Ceramics	23
8	Metals	24-25
9	Electrical equipment	26-27
10	Machinery	28
12	Furniture/Toys/Medical technology/Maintenance	31-33
15	Transport equipment/postal services	49-53, 79
17	IT/Telecommunications	61-63

Table A3
Correlation matrix

	coop	size	exports	univ	rdicat	competitors	pricecat	legal	strategic	cost_risk	lack_tech	lack_mkt
coop	1.00											
size	0.30*	1.00										
exports	0.24*	0.31*	1.00									
univ	0.19*	-0.02	0.11*	1.00								
rdicat	0.51*	0.28*	0.38*	0.30*	1.00							
competit	-0.06*	-0.06*	-0.01	-0.05*	-0.07*	1.00						
pricecat	-0.03	-0.03	-0.07*	-0.05*	-0.05	0.20*	1.00					
legal	0.34*	0.38*	0.34*	0.22*	0.47*	-0.09*	-0.04	1.00				
strategic	0.38*	0.31*	0.35*	0.25*	0.55*	-0.03	-0.08*	0.57*	1.00			
cost_risk	0.12*	0.07*	0.12*	0.12*	0.20*	0.04	0.06*	0.15*	0.19*	1.00		
lack_tech	0.07*	0.05	0.07*	0.00	0.13*	0.03	0.05*	0.07*	0.08*	0.25*	1.00	
lack_mkt	0.08*	0.07*	0.09*	-0.00	0.14*	0.01	0.06*	0.12*	0.10*	0.29*	0.55*	1.00
mining	-0.05	0.04	-0.21*	0.02	-0.11*	0.03	0.05*	-0.07*	-0.13*	-0.05*	-0.04	-0.04
foodt	-0.09*	-0.03	-0.18*	-0.15*	-0.12*	0.06*	0.06*	-0.05*	-0.09*	-0.04	0.00	0.01
textil	-0.02	-0.09*	0.11	-0.06*	-0.04	0.02	0.04	-0.00	-0.04	-0.02	0.04	0.03
woodp	-0.09*	-0.02	0.04	-0.11*	-0.09*	0.02	0.03	-0.05*	-0.07*	-0.01	0.00	0.01
chemical	0.10*	0.05*	0.14	0.14*	0.20*	-0.01	-0.03	0.16	0.15*	0.06*	0.03	0.03
plastic	0.01	0.00	0.12	-0.08*	-0.00	0.03	-0.02	-0.01	0.03	0.1	-0.01	-0.02
glassc	0.02	0.01	0.00	-0.04	0.02	-0.04	0.01	0.02	0.01	-0.00	0.02	-0.00
metal	-0.02	0.06*	0.09*	-0.11*	-0.02	0.03	0.00	-0.04	0.00	-0.01	-0.03	-0.01
electric	0.13*	0.06*	0.20*	0.18*	0.33*	-0.02	-0.04	0.15*	0.19*	0.06*	0.06*	0.04
mach.	0.10*	0.16*	0.17*	0.07*	0.21*	-0.06*	-0.04	0.16*	0.16*	0.07*	0.01	0.03
furniture	-0.04	-0.07*	-0.03	-0.05*	-0.04	-0.01	-0.06*	-0.04	-0.04	0.02	-0.01	0.00
transport	-0.12*	-0.06*	-0.30*	-0.12*	-0.20*	-0.05*	0.06*	-0.18*	-0.21*	-0.07*	-0.05	-0.05*
telecom	0.01	-0.09*	-0.08*	0.32*	-0.12*	-0.00	-0.06**	0.01	0.08*	0.01	-0.02	-0.04

*Level of significance at 0.01
See Table A1 for the description of the variables

Table A3 (continued)
Correlation matrix

	mining	foodt	textil	woodp	chemical	plastic	glassc	metal	electric	machinery	furniture	transport	telecom
mining	1.00												
foodt	-0.09*	1.00											
textil	-0.07*	-0.08*	1.00										
woodp	-0.07*	-0.08*	-0.06*	1.00									
chemical	-0.06*	-0.07*	-0.06*	-0.06*	1.00								
plastic	-0.07*	-0.07*	-0.06*	-0.06*	-0.06*	1.00							
glassc	-0.05*	-0.06*	-0.05*	-0.05*	-0.05*	-0.05*	1.00						
metal	-0.10*	-0.11*	-0.09*	-0.08*	-0.08*	-0.08*	-0.07*	1.00					
electric	-0.09*	-0.10*	-0.08*	-0.08*	-0.08*	-0.08*	-0.07*	-0.12*	1.00				
mach.	-0.08*	-0.09*	-0.07*	-0.07*	-0.07*	-0.07*	-0.06*	-0.10*	-0.10*	1.00			
furniture	-0.09*	-0.10*	-0.08*	-0.08*	-0.08*	-0.08*	-0.07*	-0.12*	-0.11*	-0.10*	1.00		
transport	-0.11*	-0.12*	-0.10*	-0.09*	-0.09*	-0.09*	-0.08*	-0.14*	-0.13*	-0.11*	-0.13*	1.00	
telecom	-0.07*	-0.09*	-0.07*	-0.07*	-0.06*	-0.06*	-0.05*	-0.09*	-0.09*	-0.08*	-0.09*	-0.11*	1.0

*Level of significance at 0.01
See Table A1 for the description of the variables