Cooperation for innovation and its impact on technological and non-technological innovations: empirical evidence for European manufacturing SMEs

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ABSTRACT

We advance the notion that cooperation for innovation can demonstrate beneficial effects on firms' innovation performance. Whilst most empirical studies to date have focused on the impact of cooperation on technological product and process innovations, this study adopts a broader definition of innovation that encompasses both technological innovations and non-technological organizational and marketing innovations taking into account their complementary and interrelated nature. Drawing on a unique sample of traditional manufacturing small and medium-sized enterprises (SMEs) in seven EU regions, the study shows that cooperation for innovation increases firms' innovativeness. This conclusion is based on the positive association across the breadth of cooperation, i.e. the number of cooperative ties, with each measure of innovation outcomes, without exhibiting diminishing returns. In addition, empirical evidence suggests heterogeneous effects of individual cooperative ties on innovation performance. Overall, the results indicate that a portfolio approach to cooperation for innovation enhances innovation performance in traditional manufacturing SMEs. Finally, the findings confirm the complementary nature of technological and non-technological innovations.

Keywords:

Innovation Cooperation (technological and non-technological), performance impact effects, European Community data, traditional manufacturing SMEs, cooperation portfolio management.

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This study investigates how cooperation for innovation with various partners affects innovation output in traditional manufacturing SMEs.[1] Since the mid-1990s, not only multinational companies but also small and medium-sized enterprises have tended to engage more extensively in cooperation activities (De Faria, Lima, and Santos, 2010). Nowadays firms cooperate with a diverse network of parties, which enables them to access external knowledge and resources and, in that way, complement their internal innovation activities. Empirical work on the performance effects of R&D cooperation and, more broadly, cooperation for innovation, have mostly focused on technological product and process innovations (Pippel, 2014; Sánchez–Gonzáles, 2014). However, since the Community Innovation Survey (CIS) was introduced in the early 1990s, the concept of innovation has been extended to take into account non-technological aspects of innovation. This trend resulted in the broad definition of innovation proposed in the *Oslo Manual* (2005), incorporating non-technological organizational and marketing innovations. Likewise, in the stream of innovation research focused on cooperation, most recent studies have examined how cooperation is associated with non-technological organizational and marketing innovations (see for example: Pippel, 2014; Sánchez–Gonzáles, 2014). Similarly, Pittaway *et al*. (2004) argue that, on the one hand, more research is necessary on the relationship between technological process and non-technological organizational innovations, and, actual cooperation for innovation, on the other hand. In line with these developing concerns in extant literature, this study investigates whether the impact of cooperation is heterogeneous and conditional on actual types of innovation.

[1] Cooperation and networking are found to be used interchangeably in the literature. For instance, Pittaway *et al*. (2004) adopted the definition by Perez and Sanchez (2002, p. 261), whereby networks are defined as "a firm's set of relationships with other organizations".

A second feature of this study is a focus on SMEs in traditional manufacturing industries. Previously in the literature, even those studies that include SMEs in their samples do not report results specific to SMEs or different types of industries. In contrast, this study utilizes a unique sample of SMEs from six traditional manufacturing industries in seven EU regions to investigate performance effects of cooperation not only on technological innovations but also on non-technological innovations.[2]

Our methodological approach takes into account the interconnection and 'complementarity' of technological and non-technological innovations, which previously, to our knowledge, has not been a subject of empirical investigation. This study is one of only a few to investigate the impact of cooperation on non-technological innovations (particularly in the context of SMEs) and is the first of its kind in this stream of research to take into account that technological and non-technological innovations may be associated.

A further novelty of this study is that we explore, besides the performance effects of individual cooperative partners, how the number of different cooperative partners affects not only technological and non-technological innovations but also the subsequent commercialization of technological innovations. Katila and Ahuja (2002) were among the first to examine the effects of the scope and depth of search strategy (i.e. the use of external knowledge sources) on firms' innovation performance. Following this line of investigation, Laursen and Salter (2006) introduced the concept of the breadth and depth of external search strategies and found a curvilinear relationship with innovation performance.[3] Some authors use these concepts to investigate how the breadth and depth of other factors besides the use of external knowledge sources affect innovation performance, such as: cooperation for

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[2] In these regions these six industries (both detailed below) account for upwards of 40 percent of all manufacturing jobs. More generally, in around half of EU regions the share of these traditional industries in manufacturing employment increased over the period 1995 to 2009. For the definition of and extensive documentation on the continued importance of traditional manufacturing industry in most EU regions, see Wintjes *et al*. (2014).

[3] Prior to their 2006 study, Laursen and Salter (2004) develop a measure of openness to the external knowledge sources by counting the number of sources (up to 15) that the UK firms utilize in their innovation process.

innovation (see Grimpe and Kaiser, 2010; Chen, Chen, and Vanhaverbeke, 2011; Ebersberger *et al*., 2012); innovation objectives (see Leiponen and Helfat, 2010); and types of innovation (see Gronum, Verreynne, and Kastelle, 2012). We follow the former line of investigation and explore how breadth of cooperation influences SME innovation performance.[4]

The aim of this study is twofold. First, we seek to understand how cooperation for innovation affects innovation performance in traditional manufacturing SMEs. To this end, cooperation relationships explored in the study include firms within an enterprise group, suppliers, customers, competitors, other private sector firms (consultants, commercial labs and private R&D institutes), HEIs, and public-sector agencies. Innovation performance is measured by the introduction of both technological (product and process) and non-technological (organizational and marketing) innovations. Moreover, we utilize innovative sales as a measure of the commercial success of product and process innovations (see for example: Aschhoff and Schmidt, 2008). Our modeling strategy takes into account the complementary nature of all four types of innovation. The second aim of this study is to contribute to the extant theory on cooperation for innovation by identifying the performance impact of breadth of cooperation.

This study is organized as follows: the next section discusses the importance of cooperation for innovation and its impact on firms' innovation performance, particularly in the context of SMEs. The third section on methodology reviews the database used in the study and specifies the model. The fourth section presents and discusses the empirical results. Finally, we present conclusions as well as implications for policy makers and managers.

[4] The same construct is used by Chen *et al*. (2011), but they refer to it as the scope of openness. Grimpe and Kaiser (2010) and Ebersberger *et al*. (2012), on the other hand, use the same construct and terminology as in our study, that of cooperation breadth. We cannot investigate the effect of the depth of cooperation due to a lack of information on the intensity of cooperative ties.

IMPORTANCE OF COOPERATION FOR INNOVATION

The proposed benefits of cooperation on firms' innovation activities are extensive: risk pooling and cost sharing; shortening of the innovation process; fast commercialization of products; obtaining access to complementary and/or similar resources; and access to external knowledge (Hagedoorn, 1993; Belderbos, Carree, and Lokshin, 2004b; Pittaway *et al*., 2004)**.** Theoretical insights into the motivation for establishing and maintaining cooperative relationships are provided by transaction cost economics (Williamson, 1985) and the resource-based view of the firm (Barney, 1991). The former suggests that the motivation is associated with gaining access to *similar* resources, whereby internal and external knowledge are treated as substitutes (Santamaria, Nieto, and Barge–Gil, 2009; Vega–Juardo, Gracia–Guitierrez, and Fernandez–De–Lucio, 2009). That is, the firm is seen as a substitute for the market, whereby the choice between external procurement and internal production (i.e. the “make or buy” decision) is influenced by minimizing transaction costs. By exploiting similar resources, firms can achieve economies of scale, experience and risk diversification (Hagedoorn, 1993; Arranz and de Arroyabe, 2008). With respect to the actual type of cooperative partners that are conducive to the combining of similar resources, Miotti and Sachwald (2003) report that cooperation with firms' competitors is prominent in this case.

In contrast, the resource-based view of the firm proposes that the motivation behind cooperating for innovation is to gain access to complementary resources (Miotti and Sachwald, 2003; Arranz and de Arroyabe, 2008; De Faria *et al*., 2010). In relation to cooperative partners, the literature suggests that vertical cooperation (with customers and suppliers) is aimed at utilizing complementary resources. As a result of this, vertical cooperation is also termed symbiotic or differentiated cooperation (Arranz and de Arroyabe, 2008). Besides vertical cooperation, Miotti and Sachwald (2003) found that cooperation with universities is targeted at pooling complementary resources.

Consistent with the resource-based emphasis on firms' capabilities, the concept of absorptive capacity likewise advances the complementarity of internal and external innovation sources (Cohen and Levinthal, 1990). Considered to be necessary for exploring and exploiting external knowledge, firms' internal innovation capacity (i.e. absorptive capacity) is usually proxied by the presence within firms with established R&D departments and qualified R&D personnel (Miotti and Sachwald, 2003; De Faria *et al*., 2010). However, because SME innovation is not captured by R&D measures (Santarelli and Sterlacchini, 1990; Ortega–Argilés, Vivarelli, and Voigt, 2009; Raymond and St–Pierre, 2010) - indeed, SMEs more often conduct informal R&D activities (Kleinknecht, Monfort, and Brouwer, 2002) - and because this applies in particular to SMEs in traditional manufacturing industry (GPrix, 2011), in this study we construct a more direct indicator of firms' absorptive capacity (see below, "model specification").

Cooperation for innovation is prominent in the literature on open innovation, a concept introduced by Chesbrough (2003). Namely, the literature on open innovation recognizes two distinct forms of open innovation practices: 1) inbound practices associated with the acquisition of external knowledge; and 2) outbound practices pertinent to the commercialization phase of the innovation process, such as venturing and selling out of Intellectual Property (IP) rights. Based on this dyadic categorization, cooperation for innovation is regarded as an inbound open innovation practice. Similar to the resource-based view of the firm, the open innovation literature proposes that external and internal innovation sources are complementary, with both synergistically contributing to firms' innovation performance (De Faria *et al*., 2010). Next, we review the benefits of cooperation with a variety of cooperative partners.

Research interest in cooperation with suppliers can be traced back to the 1980s with Japanese car and electronics manufacturers' successes and was closely associated with the relationships between these firms and their suppliers (Sako, 1994; Liker *et al*., 1996; Bidault, Despres, and Butler, 1998). Amongst rationales for such cooperation, firms may manage to reduce their risks and mistakes in the design of technological products and processes as well as in non-technological marketing and organizational innovations (Fujimoto, Iansiti, and Clark, 1996; Nishiguchi and Ikeda, 1996; Robertson and Swan, 1996). Pippel (2014) suggests that the main incentives for firms to cooperate on technological innovations apply also to non-technological organizational and marketing innovations. While cooperation with customers can be of primary relevance for marketing innovations, cooperation with suppliers could be more focused on organizational innovations.

As well as collaboration with suppliers, similarly positive outcomes may arise from close cooperation between firms and their customers (Fitjar and Rodriguez–Pose, 2013). Accessing customer knowledge may be beneficial for firms' innovativeness. This cooperative tie is particularly valuable in the context of new technologies and products (Urban and Von Hippel, 1988; Neale and Corkindale, 1998; Lilien *et al*., 2002; Tether, 2002; Bogers, Afuah, and Bastian, 2010) and may be of help in improving existing designs (Shaw, 1994) and in inventing new products or applications. Conversely, the dependence on customer knowledge alone may force producer firms to search for new solutions along more established pathways instead of pursuing new or even radical innovations (Laursen, 2011). However, empirical findings confirm that vertical cooperation with customers and suppliers plays a distinct role in the innovation process, and particularly of SMEs (Zeng, Xie, and Tam, 2010). This joint development of a product between firms and customers is said to improve market share and product credibility (Tidd and Trewhella, 1997; Tether, 2002) and potentially reduce risks associated with the introduction of a new product to the marketplace (Gemünden, Heydebreck, and Herden, 1992; Ragatz, Handfield, and Scannell, 1997; Tether, 2002). Concerning non-technological innovations, cooperation with customers is particularly relevant for marketing innovations (Pippel, 2014; Sánchez–Gonzáles, 2014). Customers' needs and preferences may also significantly contribute to the introduction of organizational innovations, particularly those focusing on firms' external relations.

Horizontal cooperation with competitors is most frequently found in high technology sectors (Mariti and Smiley, 1983) and often sought as a cost and/or risk reduction strategy. By its very nature it is regarded as a potentially precarious alliance due to the possibility of anticompetitive behavior by the cooperating (sic) firms (Tether, 2002). However, such cooperative alliances may have common problems for which they seek solutions and thus avoid potential areas of market rivalry (Tether, 2002) and a firm's competitive positioning (Miotti and Sachwald, 2003). Regarding non-technological innovations, cooperation with competitors may allow firms to realize and adopt successful organizational structures of their rivals (Pippel, 2014). In addition, firms can develop and implement joint pricing and promotion strategies, or, if cooperating in designing new products, firms can engage in a common marketing strategy for a jointly developed new product (Pippel, 2014; Sánchez–Gonzáles, 2014). However, all potential pitfalls of cooperating with competitors on technological innovations, such as opportunistic behavior and restrictive knowledge sharing, can arise in cooperating on non-technological innovations (Pippel, 2014; Sánchez–Gonzáles, 2014). Pippel (2014) further recognizes that, when cooperating for organizational innovations, competing firms might experience mimetic isomorphism (Garcia–Pont and Nohria, 2002), i.e. developing similar characteristics as a consequence of imitation. Thus, the likelihood of mimetic isomorphism reduces the probability of sustained cooperation with competitors on organizational innovations, under the assumption that cooperative partnerships are more based on pooling diverse, rather than similar resources.

Firms who cooperate with private sector institutions, experts and consultants may not only seek to manage costs but also purse the possibility of shared experiences on innovation, helping the firm to pinpoint and specify its exact needs in innovation, contributing ideas for new needs and solutions (Bessant and Rush, 1995) and offering opportunities to bring outside perspectives into the company (Bruce and Morris, 1998). Furthermore, the role of consultants in undertaking organizational and marketing innovations is derived from their potentially broad knowledge base. Namely, consultants can provide an extensive and expert knowledge in many areas relevant for introducing non-technological innovations (Pippel, 2014; Sánchez–Gonzáles, 2014).

Seeking external cooperation with HEIs and other public-sector knowledge providers normally entails little to no commercial or market risk (Cassiman and Veuglers, 2002). It is aimed at knowledge development (Miotti and Sachwald, 2003) via access to academic expertise (Link and Scott, 2005; Azagra–Caro *et al*., 2006) to inform both technological and non-technological innovation (e.g. new marketing information; Cohen, Nelson, and Walsh, 2002) as well as at reducing costs (e.g. by securing funds for research; Fontana, Geuna, and Matt, 2006) and/or risks. Concerning non-technological innovations, cooperating with HEIs and public research institutes can foster the introduction of innovations that are radical, rather than incremental in nature (Pippel, 2014), given that their main focus is on conducting basic research and providing a heterogeneous knowledge base (Miotti and Sachwald, 2003). Moreover, universities can suggest improvements in firms' organizational structure and management and provide training and knowledge transfer to firms' employees (Sánchez–Gonzáles, 2014).

The main advantage of cooperating with firms within the same enterprise group is substantially reduced risk of opportunistic behavior. Firms can cooperate with other firms in the same group on organizational innovations as well on marketing innovations, such as those related to pricing and marketing strategies (Pippel, 2014).

Empirical evidence on the impact of cooperation on firm performance

Extending the division suggested by De Faria *et al*. (2010) and Un, Cuervo–Cazurra, and Asakawa (2010), we note that empirical studies in the R&D and innovation cooperation literature can be divided into several categories: i) determinants of R&D and innovation cooperation (e.g. Miotti and Sachwald, 2003; Belderbos *et al*., 2004a; Arranz and de Arroyabe, 2008; López, 2008); ii) the effect of knowledge spillovers on cooperation (e.g. Cassiman and Veugelers, 2002; Chun and Mun, 2012); iii) the impact of cooperation on innovation performance (e.g. Zeng *et al*., 2010; Lasagni, 2012; Tomlinson and Fai, 2013; Pippel, 2014; Sánchez–Gonzáles, 2014); iv) the impact of cooperation on firm performance (e.g. Belderbos *et al*., 2004b; Faems, van Looy, and Debackere, 2010; Lasagni, 2012; Zeng *et al*., 2010). The focus of this research is on the third and fourth research strands. Yet, the empirical findings on both the innovation and performance effects of cooperation are ambiguous (Belderbos *et al*., 2004b). Nonetheless, a generic conclusion can be derived from the literature; namely, that a portfolio approach to cooperation for innovation is adopted by many firms (Faems *et al*., 2010) and that different cooperative partners have a differential effect on firms' innovation performance.

Cooperation with customers is usually reported as the most frequent type of inter-firm cooperation. In the context of SMEs, several studies find that cooperating with customers and suppliers enhances product and process innovations (Kaminski, de Oliveira, and Lopes, 2008; Nieto and Santamaria, 2010). Indeed, Zeng *et al*. (2010) report that vertical cooperation with customers and suppliers has a larger positive impact on the innovation performance of Chinese SMEs than does horizontal cooperation with government agencies, universities and research institutes. Similar results are found in Nieto and Santamaria (2010) for Spanish

SMEs. However, some studies indicate an increasing importance of research organizations in firms' innovation activities. For instance, Lasagni (2012), analyzing the sample of SMEs in six European countries, reports equally significant impacts of vertical cooperation and cooperation with research organizations on the introduction of product innovation.

Few studies of SMEs focus on inter-firm cooperation (with customers, suppliers and competitors). Tomlinson and Fai (2013) found a highly significant impact of cooperation with suppliers on both product and process innovation in UK SMEs. Concerning other forms of inter-firm cooperation, cooperation with customers only marginally increases the probability of introducing product innovation, while cooperation with competitors is insignificant for both forms of technological innovation. Parida, Westerberg, and Frishammar (2012) analyze inter-firm cooperation in Swedish SMEs operating in the Information and Technology sector. Innovation performance is measured by the introduction of both radical and incremental product innovations. Performance effects of inter-firm cooperation are differentiated with respect to the degree of novelty. In particular, horizontal cooperation with competitors (and non-competitors) plays a more distinct role in the introduction of incremental innovation, whereas vertical cooperation with customers and suppliers is positively associated with radical product innovation.

Empirical studies on the impact of cooperation on non-technological innovations are even more scarce (Pippel, 2014; Sánchez–Gonzáles, 2014;). Moreover, to our knowledge, no study explores this issue for SMEs. While Sánchez–Gonzáles (2014) reports positive effects of the investigated cooperative ties (with suppliers, customers, competitors, experts and universities) on both organizational and marketing innovations, Pippel (2014) reports performance heterogeneity with respect to the various cooperative partners. In this respect, there are the common partners positively affecting innovation performance in relation to both organizational and marketing innovations (those are cooperative relations with suppliers, consultants, universities and other firms within an enterprise group). In addition, cooperation with customers increases the probability of introducing organizational innovation, without any effect on marketing innovation. Finally, cooperation with government research institutes and competitors does not affect non-technological innovation performance.

As yet, the empirical findings in this literature are still scarce and far from establishing a set of "stylized facts". Moreover, the coverage by type of firm and sector is still far from comprehensive. The contribution of this study is to investigate the innovation effects of cooperation for SMEs in traditional manufacturing sectors.

METHODOLOGY

Cooperation for innovation can influence innovation output, which our survey measures in two ways: first, by the introduction of product, process, organizational and marketing innovations; and, second, by the proportion of sales due to product and process innovations (innovative sales). To date, both theoretical and empirical research in the innovation literature has been almost exclusively focused on technological product and process innovations, although Schumpeter (1947) had earlier identified other non-technological forms of innovation (such as, organizational innovation and opening up of new markets) (Kaivo–oja, 2009, p. 206; Pippel, 2014). Moreover, Schumpeter suggested a positive correlation between product and process innovations, which has been confirmed in recent empirical studies (see for example: Miravete and Pernías, 2006; Martinez–Ros and Labeaga, 2009; Doran, 2012). In contrast, few studies explore whether, and how, technological and non-technological innovations are interrelated by common observed and unobserved determinants. To investigate this possibility, we use a multivariate probit model to allow both types of innovation to be closely related (Schmidt and Rammer, 2007; Pippel, 2014).

The underlying assumption of multivariate probit model is similar to that of the seemingly unrelated regression (SUR) approach; that is, the outcomes of each equation in the model (in our case, four equations), have common observed and unobserved determinants and are associated, in the context of the study, in such a way that firms may engage simultaneously in one or more – or all - types of innovation (Pippel, 2014). In a similar vein, when analyzing the impact of technological collaboration on product and process innovations, Nieto and Santamaría (2010) apply a bivariate probit model and find that product and process innovations are dependent on each other. Concerning non-technological innovations, Sánchez–Gonzáles (2014) also utilize a bivariate probit model to investigate the effects of cooperation on organizational and marketing innovations, and the results reveal that these types of innovation are also correlated. In our analysis, we combine arguments from these two streams of research and, following Schmidt and Rammer (2007), investigate the hypothesis that all four types of innovation are correlated. This approach most closely builds upon Doran (2012), who explored whether product, process and organizational innovations are substitutes or complements in a sample of Irish firms. His study reports either a complementary relationship between these three types of innovations or no relationship, and conversely finds no evidence of substitutability between different forms of innovation.

Data

This study employs a unique survey dataset gathered in 2010. The survey questionnaire covers the period 2005-2009.[5] The sample of 312 SMEs is dominated by innovating firms,[6] as almost all firms (94%) had engaged in innovative activities by introducing some type of technological (product and process) and/or non-technological (organizational and marketing)

[5] The dataset was obtained from the GPrix project commissioned by the European Commission, FP7-SME-2009-1; Grant Number: 245459 (http://www.gprix.eu/): Which support measures can help regions based on traditional industries to prosper in the knowledge economy?
[6] Our definition of SMEs is in accordance to the new EU (2008) guidelines, whereby small firms employ fewer than 50 employees, while medium-sized firms have between 50 and 250 employees.

innovations (for definitions, see the *Oslo Manual*, OECD, 2005). Moreover, the sample includes SMEs from seven EU regions and mainly (80%) belonging to one of six manufacturing industries strongly represented in these regions.[7]

Descriptive statistics are presented in the Appendix 1. The largest number of firms introduced process and product innovations (83 % and 81% respectively). In addition, more than half of firms engaged in non-technological innovations (68 % in organizational innovation and 61% in marketing innovation). The modal firm in the sample had 36 employees. Slightly more than one fifth (23 %) of firms had experienced “very strong” competitive pressure. On average, the surveyed SMEs exported 20 percent of their sales. Slightly more than a third (36%) of firms invested more resources in innovation in 2009 than in 2005. With respect to firms' innovation capabilities in 2005, the largest number of firms (26%) self-reported above average or leading capabilities in product innovation, whereas the smallest number (13%) reported above average or leading capabilities in organizational innovation. Regarding cooperation partners, the largest number of firms stated that they engaged in vertical cooperation (34% of firms cooperated with customers and 32% with suppliers), followed by cooperation with universities and HEIs (31%) and with private sector (consultants, commercial labs and private R&D institutes) (24%). Although the literature suggests that mostly large firms tend to cooperate with government labs and HEIs (Mohnen and Hoareau, 2003; Lasagni, 2012) while both SMEs and large firms focus their cooperative efforts on vertical cooperation along the supply chain (Laursen and Salter, 2004; Lasagni, 2012), SMEs in our sample tend to cooperate with HEIs to almost the same degree as with customers and suppliers (31%), and with public sector (government and public research

[7] The regions: West Midlands (United Kingdom), North Brabant (Netherlands), Saxony-Anhalt (Germany), Limousin (France), Norte-Centro (Porto/Aveiro, Portugal), Comunidad Valenciana (Spain) and Emilia-Romagna (Italy). The industries: leather and leather products; ceramics or other non-metallic mineral products; textiles and textile products; mechanical/metallurgy or basic metals and fabricated metal products; automotive or motor vehicles, trailers and semi-trailers; and food products and beverages. For detailed information about sampling and the survey, see http://www.gprix.eu/.

institutes), but to a lesser extent (21%). Conversely, only a small number of firms stated they engaged in horizontal cooperation with their competitors (9%). Although not a main concern of our study, we note that this feature of our sample firms is more consistent with the resource-based view of the firm, which predicts vertical cooperation with other firms, than with the transactions costs view, which predicts horizontal cooperation with other firms. As we have noted, the transactions cost prediction is supported mainly by evidence from high-tech sectors. Our survey evidence suggests that this prediction may not apply to firms in general. Finally, regarding the breadth of cooperation, on average, firms cooperate with two cooperative partners, while there are no firms that cooperate with all seven potential partners.

Model specification

The four dependent variables in the multivariate probit model are binary indicators measuring firms' engagement in technological and non-technological innovations: the dependent variable *Product innovation* is equal to 1 if the firm introduced any new or significantly improved goods and services in the period 2005-2009 (zero otherwise); *Process innovation* is equal to 1 if the firm implemented a new or significantly improved production process, distribution method, or support activity for its goods or services (zero otherwise); *Organizational innovation* is equal to 1 if the firm introduced new business practices for organizing procedures, new methods of organizing work responsibilities and decision making or new methods of organizing external relations with other firms or public institutions (zero otherwise); and *Marketing innovation* is equal to 1 if the firm introduced significant changes to the design or packaging of a good or service, new media or techniques for product promotion, new methods for sales channels or new methods of pricing goods or services (zero otherwise). In addition, we separately investigate the impact of cooperation for innovation on innovative sales measured as the share of total sales accounted for by sales arising from new products and/or processes introduced since 2005.[8] The variable *Innovative sales* is a categorical variable: = 1 when innovative sales is equal to 0 percent; =2 when innovative sales ranges from 1 percent to 5 percent; =3 from 6 percent to 10 percent; =4 from 11 percent to 15 percent; =5 from 16 percent to 25 percent; =6 from 26 percent to 50 percent; and =7 when innovative sales are more than 50 percent of total sales.

The main explanatory variables measure firms' cooperation activities as dichotomous variables equal to 1 if the firm cooperates with the following potential partners (and zero otherwise): within group (*Coop_within_group*); suppliers (*Coop_suppliers*); customers (*Coop_customers*); competitors (*Coop_competitors*); consultants, commercial labs, and private R&D institutes (*Coop_private sector*); HEIs (*Coop_HEIs*); and government institutions and public research centers (*Coop_public sector*) (see Appendix 1 for descriptive statistics). Moreover, to capture the breadth of cooperation and to explore its relationship with firms' innovation performance, we construct the variable *Breadth*, which is equal to the number of cooperative relationships. That is, the variable is equal to zero if the firm does not cooperate for innovation with any of the seven potential partners, and is equal to seven if the firm cooperates with all of the potential partners (Cronbach's alpha coefficient = 0.61). Looking at the Table A1, we can see that none of the surveyed firms cooperates with all seven cooperative partners (the maximum value of *Breadth* variable is six). Finally, the variable *Breadth* is squared (*Breadth_sq*), to enable us to test whether the relationship between the breadth of cooperation and innovative performance is curvilinear (taking an inverted U shape).

Control variables include a continuous variable (*Size*) to account for the heterogeneity of SMEs. We model exporting activities (*Export*) as a continuous variable measuring the

[8] Negassi (2004) suggests that innovative sales (as a turnover-based measure) could be more appropriate than the technological aspects of innovation (i.e. introduction of product and process innovation) in capturing the effect of non-R&D innovation inputs which, we can assume, are pertinent to SMEs in traditional manufacturing sectors.

share of total sales sold abroad in 2009. Exporting firms might be more innovative than their counterparts, as international competition creates more pressure on firms to innovate (Nieto and Santamaria, 2007; Belderbos *et al*., 2014). Moreover, exporting activities serve as a proxy for firms' foreign competitiveness (Herrera and Nieto, 2008). In addition, the model includes a variable measuring competitive pressure (*Competition*), which is equal to 1 if the firms responded 'Very strong' to the question: "How would you judge the competition in your main market(s)?", and zero otherwise. The theoretical industrial organization literature predicts that higher competitive pressure negatively affects innovation, because it reduces monopoly rent generated by innovating firms (Aghion *et al*., 2005).

Following Blundell, Griffith, and Van Reenan (1995), our models includes variables measuring firm-level "quasi fixed effects" (or initial conditions). These initial conditions control for firms' time invariant unobserved effects on innovation, i.e. firms' innovative capacity with respect to technological and non-technological innovations at the beginning of the period covered by the survey (see also Radicic *et al*., 2014). By controlling for past innovative capacity, we take into account firms' absorptive capacity (see for example: Miotti and Sachwald, 2003). These effects are modeled by the following variables:

- the dummy variable that measures the resources invested in innovation in 2005 relative to 2009 (*Resources*) (DV = 1 if the firm's response to the question "Five years ago did you devote?" was 'Fewer resources to innovation'; = 0 if 'About the same' or 'More');
- dummy variables measuring the firms' innovation capacities for introducing product/process/organizational/marketing innovations within the industry in 2005 (respectively *Capacity_product*, *Capacity_process*, *Capacity_org* and *Capacity_marketing*) (DV = 1 for 'Above average' and 'Leading'; = 0 for 'Average' and 'Lagging');

Finally, to control for industry heterogeneity, sectorial dummy variables were included for all six industries of interest: automotive; ceramics; leather; metallurgy; textile; and food processing. The base category is other manufacturing industries. In addition, the model includes six country dummy variables for Germany, Italy, France, Portugal, Spain and the Netherlands (with the United Kingdom being the base category).

EMPIRICAL RESULTS AND DISCUSSION

The correlation matrix showing the Pearson correlation coefficients among the independent variables is presented in the Appendix 2. The correlations are overall weak to moderate (Taylor, 1990). The estimation of the multivariate probit model with individual cooperative partners (Model 1) is presented in Table 1.[9]

Insert Table 1 about here

Concerning the impact of cooperative relationships on technological innovation, horizontal cooperation with competitors, cooperation with HEIs and with public sector institutions are each positively and significantly associated with the introduction of product innovation. Cooperation with competitors is beneficial in introducing product innovations, as it can lead to cost reduction (Belderbos *et al*., 2004b), while universities can facilitate firms' product innovation given their broader knowledge base compared to other partners (Un *et al*., 2010). Cooperating with the public sector is less risky due to low possibility of knowledge leakage (Cassiman and Veuglers, 2002), which might explain why this variable has the largest impact on product innovation. The insignificant impact of cooperation with competitors on process and non-technological innovations can be explained by the possibility

[9] Following Cappellari and Jenkins (2003), in the case of a small sample size, as in our study, when estimating a multivariate probit model using the GHK simulation method for maximum likelihood estimation (for another application, see, for instance, Ziegler and Nogareda, 2009), it is of critical importance to use the number of replications (i.e. random draws) which is equal to the square root of the sample size (thus, in Models 1 and 2, the number of draws is 16).

that competitors might try to restrict access to their knowledge to prevent other firms from gaining competitive advantages (Un *et al*., 2010). In contrast, only cooperation with the public sector appears to increase the likelihood of undertaking process innovation.

Our empirical results regarding the effects of vertical and horizontal cooperation on technological product and process innovations conflict with Tomlinson and Fai (2013), who report the largest and most significant impact of cooperation with suppliers among UK manufacturing SMEs with no effect of horizontal cooperation, but are in line with their reported insignificant impact of cooperation with customers on process innovation. This difference may reflect our particular focus on SMEs in traditional manufacturing industry rather than on manufacturing SMEs in general. Nonetheless, our findings are consistent with those of Nieto and Santamaria (2010), who observe that process innovations are less attractive for SMEs and, in line with this argument, found no significant impact of vertical cooperation and cooperation with research organizations on process innovation.

Reviewing non-technological innovations, cooperation with suppliers, private sector institutions (consultants, private commercial labs and R&D research centers) and with the public sector each increase the probability of introducing organizational innovation, while cooperation within an enterprise group is the only form of cooperation that affects marketing innovation (and only marginally, at the 10% level of significance). These findings are partly in line with Pippel (2014), who reports a positive impact of cooperation with suppliers, consultants, other firms within an enterprise group and universities on both organizational and marketing innovations, while cooperation with customers only affects organizational innovation.

Overall, these results suggest that cooperation with the public sector is the only cooperative tie to affect all three of product, process and organizational innovations (but not marketing). Although only 21 percent of SMEs in our sample cooperate with the public sector, which is in line with Mohnen and Hoareau (2003), who report that mostly large firms tend to cooperate with government labs and HEIs, we can see that this type of cooperation increases not only product and process innovations but also organizational innovations. Finally, cooperation with customers does not appear to significantly impact innovation, irrespective of its type.

Concerning the control variables, firm size has a positive effect on organizational innovation, i.e. medium-sized firms are more likely to introduce this type of innovation than are smaller firms. Exporting activities have negative effects on process innovation. In relation to our theoretical expectation this is anomalous (see above, “model specification”); however, in view of the weak statistical significance of this estimate, we do not attempt interpretation. Very strong competitive pressure reduces the probability of introducing technological product and process innovations, but has no effect on non-technological innovations. These two estimates are each statistically significant at the 1 percent level and consistent with the industrial organization prediction that high levels of competition adversely affect innovation. With respect to the quasi fixed effects, an increase in the total resources dedicated to innovation is beneficial to introducing process, organizational and marketing innovations, but, rather surprisingly, has no effect on product innovation. In contrast, the most significant impact (at the 1% level) on product innovation is found for established innovation capacity regarding this type of innovation. In other words, the probability of undertaking product innovation is associated with firms' innovative capacity (initial conditions) for product innovation. Established capacity for product innovation also has an impact on firms' current marketing innovation, consistent with the requirement for new products to be marketed.

These findings are consistent with the resource-based view of the firm and the importance of absorptive capacity for the firms in our sample. Yet our results also point to more subtle effects, whereby established capabilities may also exert negative effects on innovative outcomes: our results suggest that past innovation capacity in process innovation has an adverse effect on the current introduction of product innovation; and that established capacity for organizational innovation exerts a detrimental effect on the current introduction of process innovation. These negative influences from initial conditions or established innovation capacity in firms are consistent with "lock-in" effects (path dependency) (Teece, 1986), and suggest that SMEs in traditional manufacturing industries may experience considerable inertia in their processes and organization.

The results of the multivariate probit model with the breadth of cooperation as the variable of interest are shown in Model 2 (Table 1).[10] The impact and significance of the control variables is similar to those reported in Model 1 (Table 1). The results show that the breadth of cooperation (i.e. the number of cooperative relationships) is positively and significantly associated with the introduction of all, but one type of innovation. In addition, while our results hint at a curvilinear relationship between the breadth of cooperation and technological and non-technological innovations (positive linear effects are consistently matched by the hypothesized negative quadratic effects), only the linear effect is statistically significant.

This finding suggests that the hypothesized curvilinear relationship may not apply to SMEs generally. The manufacturing SMEs in our sample benefit from having broad and extensive cooperative ties with different partners, but we do not find evidence that the positive innovation effects diminish and eventually reverse as the number of partnerships reaches a certain level (i.e. there is no turning point).

In relation to the diagnostics of the multivariate probit models (Models 1 and 2), our attention is focused on the estimated correlation coefficients. Each correlation coefficient ρ represents the correlation between the error terms in two equations. If the coefficient is

[10] A separate model has to be estimated, because the breadth of cooperation is an exact linear combination of all seven cooperative partners.

statistically significant, that implies that the error terms are correlated and that the two equations should be estimated jointly (Greene, 2012, p. 747). In other words, a correlation coefficient measures the correlation between the outcomes after the observed heterogeneity (i.e. observed firm characteristics) is taken into account. The correlation coefficients between the error terms of four equations in Models 1 and 2 are presented in Table 2. Given that all combinations of correlation coefficients are highly statistically significant (at the 1% level), we can conclude that the multivariate probit model is an appropriate method for our analysis.

Insert Table 2 about here

The economic interpretation of these uniformly positive and highly significant correlations between each pair of error terms is two-fold:

1. all four types of innovation have significant common unobserved factors; such that
2. if a positive change in an unobserved influence increases one type of innovation then, via positive correlations, it will increase the other three types also.

This provides unambiguous evidence that all four types of innovation activities are complementary (Schmiedeberg, 2008). This notion 'complementarity' is a contemporaneous effect – the unobserved influences act on all four types of innovation at the same time. Of course, this does not exclude the possibility of "lock-in" effects on one or more types of current innovations, from capabilities established in the past.

Table 3 shows the results of the ordered logit models for the dependent variable *Innovative sales* (Model 3 with individual cooperative partners and Model 4 with the breadth of cooperation as the variables of interest). The results of Model 3 suggest that cooperation with customers, private sector institutions and HEIs positively and significantly increase innovative sales from product and process innovations, with cooperation with customers having a highly significant impact (at the 1% level). Therefore, while cooperation with customers was the only cooperative tie without any effect on technological and non-technological innovations (Table 1), it exerts the largest and a highly significant effect on innovative sales, which measures the commercial success of technological product and process innovations. Miotti and Sachwald (2003) found that vertical cooperation in a sample of French firms, unlike cooperation with competitors and public institutions, was the only form of cooperation that increases innovative sales, whilst Von Hippel (1988) identified cooperation with customers as relevant for mitigating the risk inherent to the market introduction of innovation (Belderbos *et al*., 2004b). Our findings on the impact of cooperation with customers on innovative sales are consistent with these previous contributions to the literature.

Insert Table 3 about here

A significant influence of cooperation with private sector and HEIs could be explained by both a low likelihood of knowledge leakage (that is, no commercial risk), coupled with a broad knowledge base that these cooperative partners can provide to firms. Finally, similar to our findings, Zeng *et al*. (2010), report no impact of cooperation with other public sector institutions on SME innovation performance.

Overall, the findings reported in Model 3 coincide with those of Harris, Coles, and Dickson (2000), who argue that cooperation for innovation is important in facilitating innovation activities, but does not necessarily result in innovation success. In other words, cooperative partners that influence the introduction of technological innovation do not significantly affect the commercial success of this form of innovation.

Finally, the results obtained in Model 4 imply that the breadth of cooperation has a highly positive effect on innovative sales (at the 1% level), without exhibiting a statistically significant non-linear relationship with this measure of innovation output. Therefore, looking at both Models 2 and 4, we conclude that SMEs benefit from diverse cooperative networks, which is reflected in higher innovation performance as well as in the commercial success of innovation. Given that most SMEs in our sample are innovative firms, this conclusion echoes that of Freel (2000), who argues that innovative small firms engage in diverse and extensive cooperation with a number of partners, although the impact of cooperation with each individual partner might not be necessarily beneficial to small firms.

Looking at the impact of other explanatory variables in Models 3 and 4, it can be noted that very strong competitive pressure is again negatively associated with innovative sales, while initial conditions with respect to total resources devoted to innovation activities and to firms' established innovation capacity for product innovation positively affect innovation performance measured by innovative sales.

Finally, Table 4 presents the marginal effects for Model 3. These reveal striking results for the influence of our variables of interest on firms' abilities to achieve commercial success through innovation: devoting more resources to innovation (*Resources*), above average or leading capacity for product innovation (*Capacity_product*), cooperation with customers (*Coop_customers*), and cooperation with private-sector institutions (*Coop_private sector*) all reduce the probabilities of firms being in the lower categories of innovative sales (0%, 1-5% and 6-10%) while increasing the probability of being in the higher categories (16-25%, 26-50% and >50%). In each case, these results are uniformly statistically significant, while in no case is there a statistically significant effect for the median category of 11-15 percent. In addition, the same pattern appears for above average or leading capacity for organizational innovation (*Capacity_org*) and for cooperation with HEIs (*Coop_HEIs*), although these estimates are not uniformly statistically significant. Finally, these estimates also contribute to understanding the effects of competition on the ability of firms to achieve commercial success through innovation: very high competitive pressures increase the probability of firms being in the lower categories while reducing the probability of being in the higher categories. Of course, marginal effects can be interpreted quantitatively. In each case, the estimated effects are neither too large to be implausible nor too small to economically irrelevant: statistically significant estimates range from the effect of cooperating with HEIs on the probability of a firm being in the lowest category of commercial success (a reduction of 1.8%) to the effect of cooperating with customers on the probability of being in the highest category of commercial success (an increase of 12.2%). These are economically substantial effects. In all respects, the marginal effects for model 4 are similar (see Appendix 3). The one addition is the effect of breadth of cooperation on commercial success: an additional cooperative partner is associated with reductions of between 2.8 and 6.9 percent in the probabilities of a firm being in one of the three lower categories and increases of between 4.5 and 6.0 percent in the probabilities of being in one of the three higher categories. (Once again, there is no statistically significant effect with respect to the median category).

Insert Table 4 about here

CONCLUSIONS

In this study we investigate how cooperation with different partners affects the innovation performance of SMEs in traditional manufacturing industries in the EU. Innovation performance is measured in two ways: as the introduction of technological and non-technological innovations; and as innovative sales, which reflect the commercial success of technological innovations. Additionally, we report the impact of breadth of cooperation on both types of innovation performance.

Summary statistics for our sample established that vertical cooperation (with customers and suppliers) is much more common than horizontal cooperation (with competitors). However, our estimates show that both can promote innovation. Accordingly, while this is not a major feature of our study, this evidence suggests that both resource-based and transaction costs perspectives receive support from our data and estimates.

Table 5 summarizes all of the estimated effects of cooperation reported in this study, by setting out the statistically significant effects of different types of cooperation on the different measures of innovation performance. Our study provides three substantive conclusions. The first is that cooperation promotes innovation by SMEs in traditional manufacturing industry. This is demonstrated most clearly by the uniformly positive impact of the additional partnerships (*Breadth*) on both the types of innovation enacted and on the commercial success of technological innovation: additional partners are associated with firms enacting higher levels of product, process and organizational innovation as well as with reduced probabilities of achieving low levels of increased innovative sales and increased probabilities of achieving higher levels of innovative sales. Moreover, the estimated magnitudes (see Table 4) suggest that these estimated commercial effects are economically substantial. Our estimates hint at but do not provide statistically significant support for the commonly observed non-linear ("inverted-U") relationship between the breadth of cooperation and innovation performance.

Insert Table 5 about here

We conjecture that this might be because cooperation is less well established among SMEs in traditional manufacturing industries than among firms more generally, in which case the number of partnerships may be starting from a low base and thus less subject to diminishing returns. Nonetheless, irrespective of whether the effect is linear or non-linear in relation to current levels of cooperation, these findings emphasize the importance of diverse and extensive cooperative networks for European SMEs in traditional manufacturing industry. For owners and managers, the message is that innovation performance can be enhanced if a portfolio approach to cooperation is adopted. A portfolio approach to cooperation promotes both innovation and its commercialization.

The second conclusion is that among the individual types of cooperation the performance effects are heterogeneous. First, with respect to types of enacted innovation, most of the estimated positive effects (four from seven) arise from cooperation either with Higher Education Institutions (such as universities) or with other public-sector knowledge providers. This is consistent with public support measures designed to promote partnerships between SMEs and external knowledge providers (through for example, "innovation vouchers"). Secondly, our estimates consistently indicate that cooperation with customers, private-sector knowledge providers and, albeit not so strongly, HEIs promote technological innovation with commercial impact, but do not provide evidence for positive performance effects from other types of partner.

In spite of our particular focus on SMEs in traditional industries, our findings on the innovation effects of particular forms of cooperation are broadly in line with studies using less restrictive samples. First, contrary to some studies (e.g. Nieto and Santamaria, 2010; Lasagni, 2012; Tomlinson and Fai, 2013), we found that vertical cooperation with customers and suppliers has no impact on product and process innovations; yet in common with Miotti and Sachwald (2003) we find that cooperation with customers has a highly positive impact on innovative sales. Second, our finding of a positive effect of horizontal cooperation with competitors on product innovation but not on process innovation is not completely consistent with Tomlinson and Fai (2013), who report an insignificant effect of cooperation with competitors on both forms of technological innovation. Third, our finding that cooperation with public sector knowledge providers is positively associated with product, process and organizational innovations is consistent with Lasagni (2012), who found a positive influence of cooperation with research organizations on product innovation. Likewise, our converse finding that cooperation with public sector knowledge providers does not enhance the commercial success of technological innovations is consistent with Zeng *et al*. (2010). Finally, concerning non-technological innovations, our findings partly coincide with Sánchez–Gonzáles (2014), who reports a positive impact of each cooperative partner (suppliers, customers, competitors, experts, and universities), but are more in line with Pippel (2014), who found heterogeneous performance effects of cooperation on non-technological innovations.

The third conclusion arises from the finding that all four types of innovation have significant common unobserved factors (Table 3) such that if a positive change in an unobserved influence at firm level (e.g. a change in management) increases one type of innovation then it will increase the other three types as well. This provides unambiguous evidence that all four types of innovation activities are complementary. For policy makers this suggest that public support programs to promote SME innovation in traditional manufacturing industry should be demand-led (i.e. flexible with respect to SME needs) rather than supply led (i.e. narrowly prescriptive with respect to one or other aspect of technological or non-technological innovation). Correspondingly, owners and managers are best advised to take a holistic approach to innovation (i.e. to be aware that innovation in one area may well require complementary innovations elsewhere).

As well as new findings for our variables of interest, the estimated effects of the control variables are either consistent with the existing literature (e.g. on the effects of competition and absorptive capacity) or suggest further lines of enquiry (e.g. with respect to the “lock in” effects of established innovative capacities). We find that very high levels of competitive pressure tend to reduce firms' innovativeness, which is in line with the Industrial Organization literature. We also find that established absorptive capacity can have both positive and negative impacts, depending on the type of innovation. This finding might be relevant for owners and managers, as it may indicate an adverse "lock-in" effect.

We recognize some inherent limitations to our study. First, because our dataset is restricted to SMEs, it is not possible to compare the results between small and large firms. Second, although – within the limitations of cross-section survey data – we control for firms' time-invariant characteristics, panel data with at least four or five waves would be required to explore the medium- and long-run effects of cooperation for innovation (Belderbos *et al*., 2004b; Pittaway *et al*., 2004; Aschhoff and Schmidt, 2008). Finally, the survey questionnaire did not contain a question on the intensity of cooperative ties, which may enable exploration of depth of cooperation of innovation effects.

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Table 1. Multivariate probit model: dependent variables *Product innovation, Process innovation, Organizational innovation, Marketing innovation*

	Model 1				Model 2			
Independent variables	**Product innovation**	**Process Innovation**	**Organizational Innovation**	**Marketing innovation**	**Product innovation**	**Process innovation**	**Organizational innovation**	**Marketing innovation**
Size	0.000	0.004	0.008**	-0.001	-0.000	0.004	0.007**	-0.001
	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)
Export	0.000	-0.008*	0.002	0.003	-0.000	-0.007*	0.003	0.002
	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)
Competition	-1.068***	-0.675***	-0.188	-0.354	-0.963***	-0.699***	-0.242	-0.341
	(0.251)	(0.252)	(0.245)	(0.220)	(0.247)	(0.241)	(0.237)	(0.219)
Resources	0.203	0.798***	0.505**	0.520***	0.375*	0.861***	0.559***	0.456**
	(0.212)	(0.256)	(0.208)	(0.201)	(0.220)	(0.262)	(0.199)	(0.195)
Capacity_product	1.290***	0.282	-0.042	0.518*	1.217***	0.304	0.016	0.438
	(0.340)	(0.318)	(0.278)	(0.289)	(0.355)	(0.314)	(0.262)	(0.285)
Capacity_process	-1.057***	0.477	0.515	-0.394	-0.934***	0.393	0.440	-0.346
	(0.331)	(0.378)	(0.324)	(0.299)	(0.330)	(0.361)	(0.330)	(0.300)
Capacity_org	0.419	-0.845**	-0.446	0.590	0.224	-0.854**	-0.317	0.619*
	(0.423)	(0.391)	(0.367)	(0.366)	(0.379)	(0.382)	(0.340)	(0.352)
Capacity_marketing	0.407	0.507	0.261	0.214	0.337	0.593	0.196	0.213
	(0.399)	(0.378)	(0.350)	(0.331)	(0.417)	(0.380)	(0.339)	(0.327)
Coop_within group	0.308	-0.031	-0.067	0.554*				
	(0.320)	(0.380)	(0.370)	(0.291)				
Coop_suppliers	0.203	0.266	0.655***	0.171				
	(0.216)	(0.288)	(0.227)	(0.239)				
Coop_customers	0.176	0.305	0.319	0.286				
	(0.216)	(0.307)	(0.240)	(0.249)				
Coop_competitors	1.101**	0.954	0.199	0.260				
	(0.532)	(0.612)	(0.356)	(0.334)				
Coop_private sector	0.188	0.342	0.618**	0.302				
	(0.336)	(0.271)	(0.284)	(0.235)				
Coop_HEIs	0.648**	0.102	0.222	0.139				
	(0.312)	(0.262)	(0.252)	(0.227)				
Coop_public sector	1.209**	0.749**	0.748**	-0.029				
	(0.585)	(0.336)	(0.309)	(0.281)				
Breadth					0.429**	0.404**	0.464***	0.258
					(0.195)	(0.182)	(0.176)	(0.161)

Breadth_square					-0.010	-0.025	-0.013	-0.011
					(0.045)	(0.041)	(0.042)	(0.036)
Constant	0.081	0.223	-0.627**	-0.631**	0.015	0.033	-0.788**	-0.569*
	(0.350)	(0.370)	(0.315)	(0.317)	(0.323)	(0.359)	(0.313)	(0.307)
Industry DVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country DVs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No of obs.	254				254			
Log pseudolikelihood	-381.20				-391.28			
Wald χ^2(108)	517.88***				400.96***			
LR test on $\rho_{21}=\rho_{31}=\rho_{41}=\rho_{32}=\rho_{42}=\rho_{43}=0$; χ^2(6)=75.09***					LR test on $\rho_{21}=\rho_{31}=\rho_{41}=\rho_{32}=\rho_{42}=\rho_{43}=0$; χ^2(6)=73.58***			

Notes: Robust standard errors in parentheses. The number of draws is 16. *** p<0.01, ** p<0.05, * p<0.1.

Table 2. Correlation coefficients for Models 1 and 2

Correlation coefficients	Model 1	Model 2
ρ_{21}	0.792*** (0.081)	0.762*** (0.076)
ρ_{31}	0.518*** (0.114)	0.488*** (0.124)
ρ_{41}	0.556*** (0.096)	0.522*** (0.101)
ρ_{32}	0.560*** (0.157)	0.582*** (0.163)
ρ_{42}	0.549*** (0.142)	0.523*** (0.125)
ρ_{43}	0.552*** (0.103)	0.499*** (0.110)

Notes: *** p<0.01; ρ_{21} denotes the correlation coefficient between the error terms of two equations *Process innovation and Product innovation*; ρ_{31} denotes the correlation coefficient between the error terms of equations *Organizational innovation and Product innovation*; ρ_{41} denotes the correlation coefficient between the error terms of equations *Marketing innovation and Product innovation*; ρ_{32} denotes the correlation coefficient between the error terms of equations *Organizational innovation and Process innovation*; ρ_{42} denotes the correlation coefficient between the error terms of equations *Marketing innovation and Process innovation;* ρ_{43} denotes the correlation coefficient between the error terms of equations *Marketing innovation and Organizational innovation.*

Table 3. Ordered logit model: dependent variable - innovative sales.

Independent variables	Model 3	Model 4
Size	-0.002	-0.003
	(0.002)	(0.002)
Export	0.002	0.003
	(0.004)	(0.004)
Competition	-0.706**	-0.668**
	(0.336)	(0.340)
Resources	0.518*	0.473*
	(0.285)	(0.270)
Capacity_product	0.867**	0.979***
	(0.351)	(0.327)
Capacity_process	0.518	0.502
	(0.369)	(0.350)
Capacity_org	0.805	0.743
	(0.502)	(0.469)
Capacity_marketing	-0.362	-0.335
	(0.403)	(0.379)
Coop_within group	0.047	
	(0.377)	
Coop_suppliers	0.364	
	(0.318)	
Coop_customers	1.176***	
	(0.334)	
Coop_competitors	-0.404	
	(0.499)	
Coop_private sector	0.616**	
	(0.286)	
Coop_HEIs	0.474*	
	(0.269)	
Coop_public sector	0.309	
	(0.334)	
Breadth		0.657***
		(0.231)
Breadth_square		-0.033
		(0.051)
Constant1	-2.231***	-2.152***
	(0.501)	(0.494)
Constant2	-0.672	-0.596
	(0.444)	(0.445)
Constant3	0.509	0.553
	(0.446)	(0.451)
Constant4	1.149***	1.172***
	(0.445)	(0.452)
Constant5	2.128***	2.119***
	(0.440)	(0.439)
Constant6	3.118***	3.089***
	(0.458)	(0.446)
Industry DVs	Yes	Yes
Country DVs	Yes	Yes
No of obs.	261	261
McFadden pseudo R^2	0.124	0.114
Log pseudolikelihood	-438.98	-443.93
LR χ^2	χ^2 (27) = 126.71***	χ^2 (22) =107.69***

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Marginal effects for Model 3

Independent variables	Outcome 1 Innovative sales 0%	Outcome 2 Innovative sales 1-5%	Outcome 3 Innovative sales 6-10%	Outcome 4 Innovative sales 11-15%	Outcome 5 Innovative sales 16-25%	Outcome 6 Innovative sales 26-50%	Outcome 7 Innovative sales >50%
Size	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Export	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Competition	0.035*	0.080*	0.059**	-0.007	-0.056*	-0.057**	-0.053**
	(0.020)	(0.044)	(0.024)	(0.012)	(0.030)	(0.025)	(0.023)
Resources	-0.020*	-0.051*	-0.051*	-0.005	0.034*	0.045*	0.048*
	(0.011)	(0.028)	(0.029)	(0.006)	(0.019)	(0.026)	(0.028)
Capacity_product	-0.030**	-0.079***	-0.088**	-0.016	0.047***	0.076**	0.090**
	(0.012)	(0.031)	(0.037)	(0.014)	(0.016)	(0.033)	(0.045)
Capacity_process	-0.018	-0.049	-0.053	-0.008	0.031	0.046	0.051
	(0.012)	(0.032)	(0.039)	(0.011)	(0.020)	(0.034)	(0.040)
Capacity_org	-0.025*	-0.069**	-0.083	-0.020	0.037***	0.072	0.090
	(0.013)	(0.035)	(0.053)	(0.024)	(0.013)	(0.045)	(0.071)
Capacity_marketing	0.016	0.040	0.033	-0.002	-0.028	-0.030	-0.029
	(0.021)	(0.047)	(0.033)	(0.007)	(0.034)	(0.032)	(0.029)
Coop_within group	-0.002	-0.005	-0.005	-0.000	0.003	0.004	0.004
	(0.015)	(0.038)	(0.037)	(0.003)	(0.026)	(0.033)	(0.034)
Coop_suppliers	-0.014	-0.036	-0.036	-0.003	0.024	0.032	0.034
	(0.012)	(0.031)	(0.033)	(0.006)	(0.020)	(0.029)	(0.032)
Coop_customers	-0.042***	-0.109***	-0.115***	-0.020	0.062***	0.101***	0.122***
	(0.015)	(0.031)	(0.035)	(0.014)	(0.020)	(0.031)	(0.042)
Coop_competitors	0.019	0.045	0.035	-0.003	-0.032	-0.033	-0.031
	(0.028)	(0.060)	(0.037)	(0.012)	(0.044)	(0.038)	(0.034)
Coop_private sector	-0.022**	-0.058**	-0.063**	-0.010	0.036**	0.055**	0.062*
	(0.011)	(0.026)	(0.030)	(0.010)	(0.015)	(0.026)	(0.035)
Coop_HEIs	-0.018*	-0.046*	-0.048*	-0.005	0.031*	0.042	0.045
	(0.010)	(0.026)	(0.028)	(0.007)	(0.017)	(0.025)	(0.027)
Coop_public sector	-0.012	-0.030	-0.031	-0.004	0.020	0.027	0.029
	(0.012)	(0.032)	(0.035)	(0.007)	(0.020)	(0.030)	(0.034)

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Industry and country DVs included.

Table 5. Effects of cooperation partnerships on innovation outcomes

	Types of innovation				**Commercial impact of technological innovation**							
	Techno		**Non-techno**		**Change**	**Change in innovative sales by category**						
Types of cooperative partnership	Prod	Proc	Org.	Mkt.	Inn. sales	0%	1-5%	6-10%	11-15%	16-25%	26-50%	>50%
Coop_within group				+								
Coop_suppliers			+									
Coop_customers					+	-	-	-		+	+	+
Coop_competitors	+											
Coop_private sector			+		+	-	-	-		+	+	+
Coop_HEIs	+				+	-	-	-		+		
Coop_public sector	+	+	+									
Breadth	+	+	+		+	-	-	-		+	+	+

Notes: + denotes a statistically significant positive effect; - a statistically significant negative effect; and blank indicates no statistically significant effect

Source: Types of innovation – Table 1; Change in innovative sales – Table 3; and Change in innovative sales by category – Tables 4 and A3.

Appendix 1. Descriptive statistics

Variables	Mean	Standard deviation	Minimum	Maximum
Product innovation	0.811	0.399	0	1
Process innovation	0.827	0.379	0	1
Organizational innovation	0.681	0.467	0	1
Marketing innovation	0.610	0.489	0	1
Innovative sales	4.180	1.924	1	7
Size	35.563	45.205	0	230
Competition	0.232	0.423	0	1
Export	19.858	30.239	0	100
Resources	0.362	0.482	0	1
Capacity_product	0.264	0.442	0	1
Capacity_process	0.209	0.407	0	1
Capacity_org	0.134	0.341	0	1
Capacity_marketing	0.165	0.372	0	1
Coop_within_group	0.122	0.328	0	1
Coop_suppliers	0.323	0.468	0	1
Coop_customers	0.335	0.473	0	1
Coop_competitors	0.087	0.282	0	1
Coop_private sector	0.236	0.426	0	1
Coop_HEIs	0.307	0.462	0	1
Coop_public sector	0.205	0.404	0	1
Breadth	1.614	1.512	0	6
Leather industry	0.043	0.204	0	1
Ceramic industry	0.075	0.264	0	1
Textile industry	0.118	0.323	0	1
Mechanical/metallurgy industry	0.295	0.457	0	1
Automotive industry	0.106	0.309	0	1
Food processing industry	0.169	0.376	0	1
Other manufacturing industries	0.193	0.395	0	1
Spain	0.193	0.395	0	1
France	0.094	0.293	0	1
Germany	0.110	0.314	0	1
Italy	0.165	0.372	0	1
Netherlands	0.102	0.304	0	1
Portugal	0.055	0.229	0	1
United Kingdom	0.280	0.450	0	1

Appendix 2. Correlation matrix

Independent variables	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1. Size	1.000															
2. Competition	0.092	1.000														
3. Export	0.267***	-0.115**	1.000													
4. Resources	0.052	-0.103*	0.087	1.000												
5. Capacity_product	0.018	-0.085	0.107*	-0.033	1.000											
6. Capacity_process	0.072	0.029	-0.067	-0.064	0.529***	1.000										
7. Capacity_org	0.037	-0.050	0.036	0.014	0.435***	0.437***	1.000									
8. Capacity_marketing	0.038	-0.111*	-0.084	-0.004	0.400***	0.583***	0.456***	1.000								
9. Coop_within_group	0.238***	0.041	-0.041	-0.044	0.056	0.155***	0.065	0.173***	1.000							
10. Coop_suppliers	0.071	-0.126**	0.045	0.108*	0.099*	0.044	0.079	0.084	0.228***	1.000						
11. Coop_customers	-0.022	-0.056	-0.035	0.102*	0.054	0.129**	0.015	0.157***	0.199***	0.414***	1.000					
12. Coop_competitors	-0.074	-0.079	-0.105*	0.092	-0.065	-0.004	-0.058	0.018	0.092	0.067	0.193***	1.000				
13. Coop_private_sector	0.106*	-0.101*	0.150***	0.018	0.139**	0.160***	0.190***	0.200***	0.089	0.220***	0.128**	0.069	1.000			
14. Coop_HEIs	0.016	-0.103*	0.133**	0.096*	0.054	0.123**	0.058	0.183***	0.077	0.147***	0.206***	0.095*	0.334***	1.000		
15. Coop_public sector	0.061	-0.069	0.138**	0.124**	0.086	0.049	0.064	0.138**	0.016	0.062	-0.032	0.035	0.192***	0.342***	1.000	
16. Breadth	0.102*	0.091	-0.140**	0.141**	0.127**	0.183***	0.120**	0.265***	0.419***	0.621***	0.608***	0.354***	0.564***	0.627***	0.439***	1.000

Notes: ***p<0.01; **p<0.05; * p<0.1

Appendix 3. Marginal effects for Model 4

Independent variables	Outcome 1 Innovative sales 0%	Outcome 2 Innovative sales 1-5%	Outcome 3 Innovative sales 6-10%	Outcome 4 Innovative sales 11-15%	Outcome 5 Innovative sales 16-25%	Outcome 6 Innovative sales 26-50%	Outcome 7 Innovative sales >50%
Size	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Export	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Competition	0.034	0.077*	0.054**	-0.006	-0.051*	-0.054**	-0.053**
	(0.021)	(0.044)	(0.023)	(0.011)	(0.029)	(0.025)	(0.025)
Resources	-0.019*	-0.048*	-0.045*	-0.004	0.030*	0.041*	0.046
	(0.011)	(0.028)	(0.027)	(0.006)	(0.017)	(0.024)	(0.028)
Capacity_product	-0.035***	-0.091***	-0.096***	-0.019	0.047***	0.085***	0.109**
	(0.012)	(0.030)	(0.034)	(0.013)	(0.015)	(0.030)	(0.045)
Capacity_process	-0.019	-0.049	-0.050	-0.007	0.029	0.044	0.052
	(0.012)	(0.032)	(0.036)	(0.010)	(0.018)	(0.032)	(0.039)
Capacity_org	-0.025*	-0.067*	-0.075	-0.017	0.033***	0.065	0.085
	(0.013)	(0.035)	(0.049)	(0.020)	(0.012)	(0.041)	(0.067)
Capacity_marketing	0.016	0.037	0.029	-0.001	-0.025	-0.028	-0.028
	(0.020)	(0.045)	(0.030)	(0.006)	(0.031)	(0.031)	(0.029)
Breadth	-0.028**	-0.069***	-0.062***	-0.003	0.045**	0.056***	0.060***
	(0.012)	(0.026)	(0.023)	(0.007)	(0.018)	(0.021)	(0.023)
Breadth_sq	0.001	0.003	0.003	0.000	-0.002	-0.003	-0.003
	(0.002)	(0.005)	(0.005)	(0.000)	(0.004)	(0.004)	(0.005)

Notes: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; Industry and country DVs included.