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INNOVATION PERFORMANCE OF THE FIRMS THAT HAVE COOPERATED WITH UNIVERSITIES AND RESEARCH INSTITUTES IN SPAIN

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Abstract

This study compares the innovation performance of the firms that have succeeded in developing product innovations in cooperation with universities with those that have done so in cooperation with research institutes. The two groups are further compared to the group of firms that cooperated with other types of partners. The results show no differences between the firms that cooperated with universities and those that cooperated with research institutes, while firms that cooperated with universities and research institutes outperformed the firms that cooperated with other partners in the introduction of products that were new to the market. These results are mantained for both SMEs and large firms, although large firms were more likely to cooperate with universities and research institutes. These results would validate considering universities and research institutes as a joint category in empirical studies, as well as distinguish cooperation with both types of institutions from cooperation with other partners.

Keywords: Cooperation; firms-universities-research institutes; inter-organizational relations; innovation performance.

Introduction

In the era of Open Innovation (OI), firms increasingly rely on external sources for innovation by seeking a wider range of external knowledge and resources (Chesbrough,

2006). According to the Oslo Manual (OECD/Eurostat, 2005), the innovation activities of an enterprise depend in part on the diversity and structure of its links with information, knowledge, technologies and business practice sources. Each link connects the enterprise with other agents in the innovation system: universities, authorities, competitors, suppliers and customers.

Cooperation in innovative activities may be beneficial for the innovation performance of firms in terms of knowledge, information, competence and eventually, risk sharing (see, for instance, the review Belderbos *et al.*, 2012; and, more recently, West *et al.*, 2014; Belderbos *et al*., 2018; Xie *et al.*, 2018; see also Oliveira and Lumineau, 2019, for a review on the negative dimensions of collaborations).

Industries collaborate with each type of partner for different purposes; for instance, customer cooperation is more frequent when bringing new products to the market or making product improvements, while supplier collaboration is often undertaken to reduce costs (Belderbos *et al.*, 2004; Belderbos *et al*., 2018; de Faria *et al.*, 2010; Santamaria and Surroca, 2011). On the other hand, when firms cooperate with universities they are seeking privileged access to new knowledge (Belderbos *et al*., 2004; Monjon and Waelbroeck, 2003). Besides education, creation and transfer of knowledge are among the main purposes of universities. Research institutes (both private and public) also contribute to knowledge creation and the implementation of public policies on innovation, and they are important agents in the national innovation systems in many European countries. The increasing importance of knowledge, more widely shared, as envisaged by OI (Bogers *et*

al., 2018) makes the more relevant the role of universities and research institutes in innovation systems.

Studies involving large databases are necessary in order to learn how firms select parties with which to collaborate (Huizingh, 2011). Most empirical studies about industry cooperation consider universities and research institutes as a joint category (Belderbos *et al*., 2004, Belderbos *et al*., 2018; Guzzini and Iacobucci, 2017; Tsai, 2009); very few articles place them in separate categories (see for instance, Chen *et al.*, 2017).

The goal of this study is to compare the innovation performance of the firms that have succeeded in developing product innovations in cooperation with universities with the innovation performance of those that have cooperated with research institutes. The two groups are further compared with the innovation performance of firms that cooperated with other partners. The study includes large, medium and small-sized firms (SMEs).

Specifically, the research questions are: a) Is there a difference in innovation performance between the firms with product innovations that cooperated with universities and higher education institutions, and the firms with product innovations that cooperated with public and private research institutions?; and, b) Is there a difference in the innovation performance of the firms with product innovations that cooperated with both universities and/or public and private research institutes compared to firms with product innovations that cooperated with other partners? Additionally, differences within pairs of cooperation groups owing to the size of the firms are considered in the analysis.

The paper is organized as follows: Section 2 addresses the literature review, section 3 briefly describes the methods, section 4 presents the results, section 5 discusses the results and last, section 6 draws the conclusions.

Literature Review

The Inter-Organizational Relationships (IOR) approach focuses on the properties and the overall pattern of relations between and among organizations that are pursuing a mutual interest while also remaining independent and autonomous (Cropper *et al*., 2008).

In this setting, collaboration between universities / research institutes and industries (UIC) is an inter-organizational relationship that focuses on two roles: interdependency and interaction. The approach of interdependency refers to how to acquire and exchange the resources that one part lacks (Faems *et al.*, 2007), while the view of an interaction process considers that new knowledge is created, and not only transferred, because neither of the partners previously possessed this knowledge (Galati and Bigliardi, 2019; Hardy *et al*., 2003). In this approach, the sources of innovation do not reside exclusively inside firms; instead, they are commonly found in the interstices between firms, universities, research laboratories, suppliers and customers (Powell *et al*., 1996). Following this perspective, the new knowledge is created through an on-going social interaction between the actors during the collaboration lifetime. In this regard, Ortiz *et al.* (2018) highlights inter-organizational relationships as a precursor of knowledge identification capabilities and knowledge acquisition strategies. Also in this line, Deken *et al.* (2018) examines how resource complementarity is jointly constructed in interactions through recursive cycles

with multiple potential partners and Bigliardi *et al.* (2015) points out that while universities and research centres are focused on research projects that are not likely to lead to immediate pay-offs, cooperation with these institutions could lead to positive effects on innovative performance in the long run.

The present study aims to contribute to the understanding of the inter-organizational relationship between firms-universities-research institutes in Spain focusing on the outcomes (firm's innovation performance) of the cooperation.

Collaboration between Industries and Universities and Research Institutes

"Universities-industries collaboration refers to the interaction between any part of the higher education system and industry aiming mainly to encourage knowledge and technology exchange" (Ankrah and AL-Tabbaa, 2015, p. 387).

Some positive outcomes derived from UIC relationships are contribution to local/regional economic development, the creation of business opportunities, new or improved products/processes, patents, and prototypes. Specifically, the benefits for universities are technological advancement and/or research activities in certain areas, and exposing students and faculties to practical problems/new ideas, among others; for industries the benefits are improvement of innovation capacity, access to new knowledge and leading-edge technologies and research infrastructure (Ankrah and AL-Tabbaa, 2015).

Nevertheless, other studies mention potential negative effects of UIC. Galati and Bigliardi (2017) points out that differences in organizational culture and goals between universities

and research centers and firms may limit the effectiveness of collaborations. Furthermore, Lin (2017) affirms that the number of industry collaborations and academic innovations is curvilinear, meaning that at some point a high number of industry collaborations negatively affect academic innovation performance. On the other hand, the potential benefits of UIC may not be accessible to all firms. Mohnen *et al*. (2018) supports the idea that a certain level of research and innovation is a pre-condition for firms to collaborate with universities.

In Spain in 2012, there were 76 Universities (MEC, 2012). Their expenditure on R+D represented 27.7% of the total amount invested in R+D in the country, while companies contributed with 53% of this total (INE, 2012). Universities dedicated 39% of their general budget to R+D, with most (49.7%) funding coming from their own resources, 37.8 % from public programs, 11.9% from contracts with third parties and less than 1% from patronage (MEC, 2012). Out of the total amount of funds from contracts with third parties, 30% corresponded to collaborative research (university-company), reaching 168 million euros in 2012 (CRUE RedOTRI, RedUGI, 2012).

Like universities, research institutes are important agents in National Innovation Systems; in some countries, such as Russia, Germany and China, they are manifestly superior in R&D abilities and knowledge creation compared with other sectors (Chen *et al*., 2017).

In the case of Spain, the Law on the Promotion and Coordination of Scientific and Technical Research gave six research centres attached to various Ministerial Departments (MSI, 2011) the category of Public Research Organism (PRO). These nationwide bodies differ widely in terms of their scientific and technological capacity, as well as their size

and structure. Together they comprise a network of 175 research centers, which are involved in activities in approximately 29 different areas of research and have around 16,000 highly qualified, experienced staff. They are mainly financed with public funds from the General State Budget, the National Research Plan's competitive public calls, the Autonomous Regions, and contracts with the private sector. According to the PROs annual reports, total R+D expenditure for the year 2012 rose to 1297.62 million euros, of which 105.46 million euros (8%) came from agreements and contracts with third parties.

Research institutes (public or private) are often categorized alongside universities, handled as one or the same affiliate group when cooperation relations with firms are discussed in the literature. For example, Guzzini and Iacobucci (2017) does this when analysing the relationship between project failure and innovation performance in German firms in collaboration with universities and research centres (joint category). Belderbos *et al*. (2004) analyses the impact of R&D cooperation on Dutch firms' performance and mentions that cooperation with universities and research institutes (considered a joint category) positively affects growth in sales per employee of products and services new to the market.

Some features are common to universities and research institutes regarding collaboration with industries. For instance, Tsai (2009) shows that absorptive capacity is a contingent in the collaborative relationship between firms and research organizations (universities and research centres included).

Interestingly, Chen *et al*. (2017) focuses on research institutes and explores how their position in collaborative networks with industries and/or universities influences their

scientific performance. The study analyses three collaborative networks: Universities-Research Institutes (UR), Industries-Research institutes (IR) and Industries-Universities-Research institutes (IUR) which, based on their characteristics, are considered as homogeneous, heterogeneous and hybrid, respectively. The findings show that belonging to an UR collaborative network negatively affects the scientific performance of research institutes, whereas the opposite is true when research institutes participate in IR and IUR networks.

Based on the above observations, it is not clear whether it is appropriate without previous statistical tests to consider universities and research institutions as a joint category. Hence, we put forward the following hypotheses:

Hypothesis 1: There is a statistically significant difference in the innovation performance of the firms with product innovations that cooperated only with universities and the firms that cooperated only with research institutes.

Hypothesis 2: There is a statistically significant difference in the innovation performance of the firms with product innovations that cooperated with universities and other partners (but not with research institutes) comparted to the firms that cooperated with research institutes and other partners (but not with universities).

Collaboration with other partners

A large number of studies analyse the performance of cooperation in innovation from a portfolio perspective (Belderbos *et al*., 2004, Belderbos *et al*., 2012, Belderbos *et al*.,

2018; de Faria *et al*., 2010; Duysters and Lokshin, 2011, Miotti and Sachwald, 2003; van Beers and Zand, 2014; Veugelers and Cassiman, 2005), by including different partnership types in their analyses (competitors, customers, suppliers, universities and research institutes). The results among these studies differ. For example, Miotti and Sachwald (2003) points out that vertical cooperation with suppliers or clients positively influences the propensity of firms to introduce new products to the market. Patenting is positively influenced by cooperation with public institutions, and cooperation with competitors occurs to share R&D costs in high tech sectors. Duysters and Lokshin (2011) warns that alliance complexity has an inverse U-shaped relationship with innovative performance; complexity facilitates learning and innovativeness, but each organization has a certain management capacity to deal with complexity which sets limits on the number of alliances that it can manage.

Belderbos *et al*. (2004) suggests that when the firms belong to a group, they tend to increase their R&D cooperation with customers and suppliers but not with universities or research institutes. In a more recent study, the same authors find that prior consistent R&D collaboration with universities and research institutes is a significant antecedent for starting R&D collaboration with all other types of partners (Belderbos *et al*., 2018).

Segarra-Blasco and Arauzo-Carod (2008) affirms that internal R&D and agreements with customers, suppliers and competitors, increase a firm's propensity for R&D cooperation with universities. Specifically, these authors support the idea that cooperation with universities also means cooperation with clients and suppliers, and above all with other public research centres.

Based on the above explanation, we put forward the following hypothesis:

Hypothesis 3: There is a statistically significant difference in the innovation performance of the firms with product innovations that cooperated with both universities and research institutions in comparison with the firms that cooperated with other partners.

Firm size and innovation performance

Traditionally, firm size has been reported to be an important explanatory variable of innovation behaviour (see, for instance, Becheikh *et al*., 2006). Large companies have more resources to innovate and support risky activities (Tsai, 2001) and can benefit from economies of scale in R&D, production and marketing (Stock *et al.*, 2002). On the other hand, small and medium sized enterprises (SMEs) have less resources, but are more flexible, less bureaucratic and more proactive and market oriented, which facilitates innovation (Acs and Audretsch, 1987; Kamien and Schwartz, 1975; Cohen and Klepper, 1996).

Size is the most often firm characteristic studied in OI (Huizing, 2011). Whereas inicial empirical studies suggested that most OI adopters were large firms (van de Vrande *et al.*, 2009; Bigliardi and Galati, 2016), later research showed that SMEs were increasingly practicing OI activities (Lee *et al*., 2010; van de Vrande *et al*., 2009; Brunswicker and Venhaverbeke, 2015; Martinez-Conesa *et al.*, 2017). Moreover, within the SMEs group, van de Vrande *et al.* (2009) finds that medium-sized firms were more open than small enterprises and Bigliardi and Galati (2016), in a study that includes firms of different sizes

among the group of SMES, finds that micro-enterprises were the group that implemented the most numerous OI practices among SMEs. Also start-ups have been found to engage in OI activities (Usman and Vanhanverbeke, 2017).

However, firms of different size face different challenges and expect different benefits from OI activities. In this line, van de Vrande *et al.* (2009) shows that SMEs' OI activities were mainly related to market related targets; the main barriers to OI activities being organizational and cultural issues; and Spithoven *et al.* (2013) finds SMEs that collaborate with partners are more likely to launch new products and services, this not being the case for large firms.

Focusing on cooperation, Jang *et al.* (2017) shows that the percentage of large firms that cooperate with other partners is larger (double or more) than the percentage of firms for the case of SMEs, and Agostini and Nosella (2019) points out that firm size is a moderator variable for analysing the relationship between alliance characteristics and firm performance. Colombo *et al.* (2012) shows that SMEs tend to establish alliances with third parties seeking to complement their limited R&D with external knowledge or to obtain access to complementary assets. With regards to the challenges posed by collaboration, like diverting managers'time, knowledge leakages or investments in absorptive capacity, the study finds that these may be more relevant in the case SMEs.

With regards to cooperation with universities and research centers, Jang *et al.* (2017) finds that the percentage of large firms that cooperates with universities almost triples the percentage of SMEs that do so, and Narula (2004) suggests that SMEs may not have enough technological assets and expertise to be of interest for technological partners like

universities and research centers. Moreover, Tsai (2009) suggests that when the absorptive capacity of new technology in SMEs is low, collaborations with research organizations (universities and research institutes) are not properly assimilated by the firms.

Based on the above discussion, we put forward the following hypotheses:

Hypothesis 4: There is a statistically significant difference in the size of the firms that cooperated only with universities and those firms that cooperated only with research institutes.

Hypothesis 5: There is a statistically significant difference in the size of the firms that cooperated with universities and other partners (but not with research institutes) comparted to the firms that cooperated with research institutes and other partners (but not with universities).

Hypothesis 6: There is a statistically significant difference in the size of firms that cooperated with both universities and research institutions in comparison with the firms that cooperated with other partners.

Additionally, hypotheses 1, 2 and 3 are tested separately for the group of SMEs and the group of large firms.

Methodology

This study used the database of the Community Innovation Survey (CIS) for Spain for the period 2010-2012, conducted among enterprises of different sizes and with at least 10 employees from a wide range of sectors according to Core NACE categories.

The CIS2012 concepts and methodology are based on the 2005 third edition of the Oslo Manual. The harmonized survey provides an understanding of the types of innovation performed by enterprises: product, process, organizational and marketing, among other important aspects in the development of an innovation such as the objectives, strategies and obstacles, the sources of information, co-operation, expenditure and the turnover of the new products and process.

The pertinent aspects for this study were product innovations and cooperation with partners, specifically with universities and research institutes, and innovation performance.

In 2012, there were a total of 76 Spanish universities, of which 50 (66%) were public and 26 (44%) private. Research and knowledge transfer can be channeled through research units that are part of these universities. There were 395 of these units, of which 351 (88%) belonged to public universities and the rest to private universities (MEC, 2012). With regards to research institutes, in 2012 there was a network of 175 centers belonging to six public research organisms (MSI, 2011). The universities, together with national research centers, are important agents in the Spanish Science, Technology and Innovation System and carry out most of the activities programmed within the National Plan for Scientific Research, Development and Technological Innovation.

The total number of firms that developed product innovations during the period of study was 6,638, representing 21% of the total firms surveyed in the Spanish CIS2012. From among these, the firms that performed innovation activities in cooperation with other enterprises within their enterprise group, suppliers, clients from private or public sectors, competitors, consultants, universities and public or private research institutes accounted for 45%, representing the 2,989 firms which are hereafter considered as the study population.

The firms were organised into eight independent cooperation groups (See Table 1).

-----Include table 1 about here-----

Throughout the study, six of the cooperation groups are organised into 3 pairs to test for differences within each pair: 1) firms that cooperated only with universities (UNI_ONLY) and firms that cooperated only with research institutes (RSI_ONLY); 2) firms that cooperated with universities (TOTAL_UNI) and firms that cooperated with research institutes (TOTAL_RSI); 3) firms that cooperated both with universities and research institutes (UNI-RSI) and firms that cooperated with other partners (OTHR_ONLY) that were neither universities nor research institutes.

Innovation performance was operationally defined as the total turnover from new or significantly improved products introduced that were new to the market or new to the firm. Both categories were measured for each cooperation group.

Cooperation refers to cooperation between the firms and universities, research institutes and other types of partners, including other enterprises within the enterprise group, suppliers, clients from private or public sectors, competitors and consultants.

Table 2 describes the operationalization of the variables used in the study.

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Following the literature, differences in the innovation performance of firms by size was also tested whithin pairs of the cooperation groups. . The firms were grouped into four categories according to the number of employees: 1) firms with under 50 employees, 2) firms with 50 to 249 employees (both considered as small firms), 3) firms with 250 to 449 employees (or medium size firms) and, 4) firms with more than 500 employees (large firms). An ordinal variable was constructed that assigned the values 1 to 4 to the above groups: the groups 1 and 2 correspond to SMEs and the groups 3 and 4 correspond to large firms. The number of firms for each size category and cooperation group is described in Table 3.

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Albeit the majority of the literature suggests a positive relationship between size and innovativeness, industry characteristics seem to play a role on the relative innovative advantage in favour of large or small firms (Acs and Audretsch, 1987, Veugelers and Cassiman, 1999; Bigliardi and Galati, 2016). Also Huizing (2011) considers industry as a most influencial context characteristic in OI. To this extent, the results obtained were controlled using the variable sector. For this control, the firms were grouped according to the economic activities established in the NACE code. The categories of the firms by sector are: a) agricultural sector (code 1 to14), b) manufacturing sector (codes 15 to 37) and, c) services sector (code 38 and up); a special group of companies with two codes, (14-15) and (37-39), have been included in the manufacturing sector. The distribution of firms for each sector and cooperation group is described in Table 4.

-----Include table 4 about here-----

A Mann-Whitney U test was performed to contrast the previous hypotheses. Also called the Mann–Whitney–Wilcoxon, this is a non-parametric test of the null hypothesis since it does not require the assumption of normal distributions. It is considered a robust method specially designed for small subsamples (Llach and Nordqvist, 2010).

The Mann-Whitney U test with a level of significance of 0.5 was applied to test both categories of innovation performance: turnover from the new products introduced that were new to the market and new to the firm between cooperation groups. These categories are numeric continuous variables with no symmetric distributions.

Results

Innovation performance between cooperation groups

The statistical results obtained for the innovation performance variable in both categories, turnover from the new products introduced that were new to the market (TURNMAR) and turnover from the new products introduced that were new to the firm (TURNIN), show that there are no significant differences between the group of firms that cooperated only with universities (UNI_ONLY) and the group of firms that cooperated only with research institutes (RSI_ONLY).

No statistically significant differences were observed between the group of firms that cooperated with universities (TOTAL_UNI) and the group of firms that cooperated with research institutions (TOTAL_RSI).

However, a relevant result was found between the last two cooperation groups: the mean obtained for firms that cooperated with both universities and research institutes (UNI_RSI) and the mean for firms that cooperated with other partners (OTHR_ONLY), specifically in the category of TURNMAR, were 0.237 and 0.164, respectively. The Mann-Whitney U test yielded a p-value <0.001, signifying that the means above are statistically different.

Table 5 shows the results obtained in the Mann-Whitney U test applied to the two categories, TURNMAR and TURNIN, for the innovation performance variable between all the pairs of cooperation groups.

-----Include table 5 about here-----

Innovation performance of cooperation groups by firm size

According to the number of employees, more than 80% of the firms that cooperated only with universities (UNI_ONLY) or only with research institutes (RSI_ONLY) were small companies. The distribution is not significantly different according to the Mann-Whitney U test applied with 95% confidence, where the p-value reached 0.592.

In the following two cooperation groups, the total number of firms that cooperated with universities (TOTAL_UNI) and the total number of firms that cooperated with research institutes (TOTAL_RSI), most of the firms are small. The distribution of the firms by size is not statistically different between the groups, according to the Mann-Whitney U test applied with 95% confidence, which resulted in a p-value of 0.619.

Finally, for the last pair of cooperation groups, the percentage of large firms (500 and more employees) is higher in the UNI_RSI group (14,3%) than in the OTHR_ONLY group (9,8%), and the percentage of small firms (with less than 50 employees) is higher in the OTHR_ONLY group (46,6%) than in the UNI_RSI group (41,8). The Mann-Whitney U test applied with 95% significance obtained a p-value of 0.005. Thus, there is a statistically significant difference in the distribution of the firms by the number of employees between the UNI_RSI and OTHRS_ONLY groups.

Table 6 shows the results of the Mann-Whitney U test for the distribution of the firms by the variable size for each cooperation pair.

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With regards to the innovation performance between the cooperation groups by firm size, the results in Table 7 show that no differences were found within the pairs 1 and 2 of cooperation groups. On the other hand, both SMEs and large firms that cooperated with universities and research institutes obtained better innovation results with regards to turnover from products that are new to the market. The Mann-Whitney U test applied with 95% of significance yielded a p-value < 0.001 for the TURNMAR category for both SMEs and large firms.

-----Include table 7 about here-----

Innovation performance of cooperation groups by sector

Despite most of the firms that cooperated only with universities (UNI_ONLY) belonging to the service sector (53%), and most of the firms that cooperated only with research institutes (RSI_ONLY) belonging to the manufacturing sector (52%), the statistical

analysis shows that there are no significant differences between these two groups in either of the innovation categories, TURNMAR and TURNIN.

The distribution of the firms by sector did not affect the results of innovation in the companies that cooperated with the total universities group (TOTAL_UNI) or those that cooperated with the total research institutes group (TOTAL_RSI) in all the sectors.

Last, there were statistically significant differences between the firms which cooperated with UNI_RSI in comparison with the firms that cooperated with OTHRS_ONLY.

This is observed for the innovation category TURMAR in both the manufacturing and the services sectors. The values obtained in the Mann-Whitney U test applied with 95% significance reached p-values of 0.002 and < 0.001, respectively.

Table 8 shows the results of the statistical analysis by sector for both categories of innovation and each cooperation group.

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Discussion

According to the results, the first hypothesis of this study is rejected: there are no statistically significant differences for the innovation performance of the firms with product innovations that cooperated only with universities and the firms that cooperated only with research institutes.

It is important to note that the hypothesis is rejected for both categories of innovation: turnover from the products that were new to the market and turnover from those that were new to the firm. These results would support the practice of considering universities and research institutes as a joint category in empirical studies (as, for example, Belderbos *et al*., 2004, Belderbos *et al*., 2018; Guzzini and Iacobucci, 2017; Tsai, 2009).

The second hypothesis of the study is also rejected: there are no statistically significant differences in the innovation performance of the firms that achieved product innovations in cooperation with universities and other partners (but not with research institutes) and the firms that did so in cooperation with research institutes and other partners (but not with universities). Again, the hypothesis is rejected for both innovation categories: turnover from the products that were new to the market and those that were new to the firm.

The results for the second hypothesis can be considered to confirm those of the first hypothesis, given that the second hypothesis also compares universities and research institutes, albeit this time including other types of cooperation partners in the analysis. This double comparison adds robustness to the statistical analysis. It also reflects the fact that cooperation firms are often involved in cooperation with more than one partner (144 firms cooperating only with universities vs. 465 firms cooperating with universities and other partners, and 200 firms cooperating only with research institutes vs. 580 firms cooperating with research institutes and other partners). This is in accordance with the line of the literature that sees collaboration with a portfolio of partners as leading to more synergies and the intake of complementary, multidisciplinary knowledge which

contributes to the production and sale of innovative products (Veugelers and Cassiman, 2005). However, it is also worth to note that a high number of links and a diversity of partners could negatively affect the performance of the organizations if appropriate managerial capacity is lacking (Belderbos *et al*., 2006; Duysters and Lokshin, 2011). This latter is a major challenge for the case of many small firms, as further discussed below.

Next, the results partially support the third hypothesis. There are statistically significant differences for the first innovation category (new to the market), between the firms that cooperated with both universities and research institutions and the firms that cooperated with other partners. This result would corroborate the idea that when firms cooperate with universities and/or research institutes, they do so to access privileged knowledge that could lead to novel products (Belderbos *et al*., 2012; Monjon and Waelbroeck, 2003).

With regards to firm size, hypotheses 4 and 5 are not supported: the analysis finds that there are no significant differences in size between the firms that cooperated only with universities and the firms that cooperated only with research institutes; neither are there significant differences in size between the firms that cooperated with universities and other partners and the firms that cooperated with research institutes and other partners. This validates considering universities and research institutes as a joint category in empirical studies similar to this one when using samples of SMEs or large firms alone.

Nevertheless, the distribution of firms by size was different between the group of firms that cooperated with both universities and research institutes and the group of firms that cooperated with other partners: larger firms are more likely to cooperate with universities and research institutes than SMEs are. Hypothesis 6 is thus supported. These results are

in line with those in, for instance, Jang *et al.* (2017), Narulla (2004), Veugelers and Cassiman (2005) or Tsai (2009).

With regards to the relationship between innovation performance and firm size, the results show that cooperation with universities and research institutes is more beneficial than cooperation with other agents for both SMEs and large firms with regards to reach a higher turnover from products that are new to the market. The results of the tests of the hypotheses 1, 2 and 3 are thus maintained for the groups of SMEs and large firms.

The control analysis by sector corroborates the decision to partially accept the third hypothesis, albeit only in two out the three sectors analysed: there is a statistically significant difference for the first category (products new to the market) of the innovation performance in the manufacturing and services sectors, between the group of firms that cooperated with universities and research institutions in comparison with the group of firms that cooperated with other partners. These results support the view that industry plays a relevant role in explaining OI (Huizing, 2011).

Conclusions

Firms are continually searching for sources to increase their innovative capacity. To do so, they collaborate with different partners for different purposes. When firms collaborate with universities and research institutes, they are seeking access to new knowledge and cutting-edge technologies and research infrastructure, which can be transformed into novel or improved products.

This article uses the database of the Community Innovation Survey (CIS 2012) for Spain, and analyses 2,989 firms that obtained product innovations and collaborated with partners (suppliers, customers, competitors, universities and research institutes).

Universities and research institutes are important agents of the national innovation systems, performing a significant part of the activities in science, technology and innovation in their respective economies. Although universities and research institutes share some institutional goals, they also display some differences: besides research and knowledge transfer, universities also have educational goals, whereas research institutes tend to have more specific infrastructure, organization and budgets to perform research. Despite these differences, it is common to find empirical studies that consider cooperation with universities and research institutes as a joint category. This study tests whether universities and research institutes should be treated as separate categories in studies using data similar to the CIS data.

The results of the statistical analysis show no support for hypotheses 1 and 2, i.e., no statistically significant differences were found between the firms that collaborated with universities and the firms that cooperated with research institutes. These results make an academic contribution because they support the practice of considering universities and research institutes as a joint category in empirical studies in Spain using data similar to the CIS data. On the other hand, hypothesis 3 is partially accepted when it comes to product innovations that are new to the market: firms collaborating with universities and research institutes have higher average innovation performance than firms collaborating with other agents. Thus, cooperation with universities and research institutes is arguably

better than cooperation with the other partners. These results are maintened when tested for the groups of SMEs and large firms separately. Control by sector corroborates the decision to partially accept this hypothesis in the manufacturing and service sectors.

With regards to the role of size, there is no significant difference in size between the firms that cooperated with universities and the firms that cooperated with research institutes (hypotheses 4 and 5). However, large firms tend to cooperate more with universities and research institutes than SMEs do (hypothesis 6).

With regards to implications for firms, it is clear from this study that universities and research institutes together can comprise a broad network of potential co-operators in innovation for both SMEs and large firms, especially when introducing products that are new to the market. Furthermore, policy makers should take into account the distinctive role that universities and research institutes play when cooperating with firms that develop new products. The recent deployment of the "Industrials PhD" program in Spain, which places PhD students in jobs with local companies and start-ups in product development during their studies, is in line with this approach.

An important limitation of this study is that the data is quite old. This limitation needs to be overcome with future research with more recent data. Data limitations also hindered the use, for instance, of parametric tests that would have allowed to jointly consider the effects of sector, size and cooperation on the innovation performance of firms. Such an analysis would have helped bring light to the view that industry characteristics play a role on the relative innovative advantage in favour of large or small firms (Acs and Audretsch,

1987, Veugelers and Cassiman, 1999; Bigliardi and Galati, 2016). These newer databases should, ideally, be from different countries and cover an extended period of time.

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Tables

Table 1

Cooperation groups

No.	Name	Description	N
1	UNI_ONLY	Firms in cooperation Only with universities	144
2	UNI_OTHR	Firms in cooperation with universities and other partners (NO Research institutes)	321
3	TOTAL_UNI	Total number of firms in cooperation with universities (Only universities + universities and other partners)	465
4	RSI_ONLY	Firms in cooperation Only with research institutes	200
5	RSI_OTHR	Firms in cooperation with research institutes and other partners (NO universities)	380
6	TOTAL_RSI	Total number of firms in cooperation with research Institutes (Only research institutes + Research institutes and other partners)	580
7	UNI_RSI	Firms in cooperation with both universities and research institutes (NO other partners)	697
8	OTHR_ONLY	Firms in cooperation with other partners (NO universities - NO research Institutes)	1137

Table 2

Table of variables

Variables	Indicators	Results	Type of variable
Product innovations	New or significantly improved goods or services.	Product innovations (Pro_innv)	Categoric nominal
Cooperation	Cooperation in innovation activities with other enterprises or institutions.	Cooperation	Categoric nominal
		No cooperation	
Cooperation groups	Firms with product innovations performed in cooperation with universities, research institutes, and other partners: other enterprises within the enterprise group, clients, suppliers or consultant partners.	UNI_ ONLY	Categoric nominal
		RSI_ ONLY	
		TOTAL_UNI	Categoric nominal
		TOTAL_RSI	
		UNI_RSI	Categoric nominal
		OTHR_ONLY	
Innovation performance	Turnover from the new products introduced that were new to the market.	TURNMAR (%)	Numeric continuous
	Turnover from the new products introduced that were new to the firm.	TURNIN (%)	Numeric continuous
Firm size	(1) Firms with less than 50 employees	<50	Ordinal
	(2) Firms with 50 to 249 employees	50-249	Ordinal
	Total number of firms with less than 250 employees (1+2)	SMEs	Ordinal
	(3) Firms with 250 to 499 employees	250-499	Ordinal
	(4) Firms with more than 500 employees	>500	Ordinal
	Total number of firms with more than 250 employees (3+4)	Large	Ordinal
Sector	Firms grouped according economic activities established in the statistical classification of economic activities in the European Community NACE rev.2.	Agricultural sector (codes from 1 to 14)	Categoric nominal
		Manufacturing sector (codes from 15 to 37)	Categoric nominal
		Services sector (codes from 38 and up)	Categoric nominal

Table 3

Cooperation groups by the firm size.

	TOTAL		UNI_ONLY		RSI_ONLY		TOTAL_UNI		TOTAL_RSI		UNI_RSI		OTHR_ONLY	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
< 50	1373	45,9	83	57.6	106	53.0	249	53.5	283	48.8	291	41.8	530	46.6
50-249	1022	34.2	44	30.6	76	38.0	135	29.0	222	38.3	238	34.1	398	35.0
SMEs	2395	80.1	127	88.2	182	91.0	384	82.5	505	87.1	529	75.9	928	81.6
250-499	273	9.1	14	9.7	13	6.5	44	9.5	48	8.3	68	9.8	98	8.6
> 500	321	10.7	3	2.1	5	2.5	37	8.0	27	4.7	100	14.3	111	9.8
Large	594	19.8	17	11.8	18	9.0	81	17.5	75	13.0	168	24.1	209	18.4
Total	2989	100	144	100	200	100	465	100	580	100	697	100	1137	100

Table 4

Cooperation groups by sector of the firms.

	TOTAL		UNI_ONLY		RSI_ONLY		TOTAL_UNI		TOTAL_RSI		UNI_RSI		OTHR_ONLY	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Agriculture	335	11	21	15	34	17	51	11	90	16	62	9	120	11
Manufac-turing	1242	42	47	33	104	52	152	32,7	293	51	272	39	482	42
Services	1412	47	76	53	62	31	262	56,3	197	34	363	52	535	47
Total	2989	100	144	100	200	100	465	100	580	100	697	100	1137	100

Table 5

Mann-Whitney U test for the innovation performance categories between the cooperation groups.

	UNI_ONLY	RSI_ONLY	TOTAL_UNI	TOTAL_RSI	UNI_RSI	OTHR_ONLY
			TURNMAR			
N	144	200	465	580	697	1137
Mean	0.217	0.202	0.226	0.189	0.237	0.164
Std. Dev.	0.334	0.319	0.317	0.296	0.308	0.278
Mann-Whitney U test*	13748.500		296696.000		963736.500	
p-value	*0.455*		*0.158*		*<0.001*	
			TURNIN			
N	144	200	465	580	697	1137
Mean	0.236	0.239	0.214	0.200	0.186	0.231
Std. Dev.	0.338	0.348	0.310	0.305	0.267	0.332
Mann-Whitney U test*	13930.500		300049.000		629628.000	
p-value	*0.596*		*0.488*		*0.363*	

*Level of significance=0.5

Table 6

Mann-Whitney U test for the distribution of firms by size between the cooperation groups.

	UNI_ONLY	RSI_ONLY	TOTAL_UNI	TOTAL_RSI	UNI_RSI	OTHR_ONLY
< 50	83	106	249	283	291	530
50-249	44	76	135	222	238	398
SMEs	127	182	384	505	529	928
250-499	14	13	44	48	68	98
> 500	3	5	37	27	100	111
Large	17	18	81	75	168	209
Total	144	200	465	580	697	1137
Mean	1.56	1.59	1.72	1.69	1.97	1.82
Std. Dev.	0.76	0.73	0.93	0.81	1.04	0.95
Mann Whitney U-Test*	13966.500		132660.000		367286.000	
p-value	*0.592*		*0.619*		*0.005*	

*Level of significance=0.5

Table 7

Mann-Whitney U test for the innovation performance categories between cooperation groups by firm size.

		UNI_ ONLY	RSI_ ONLY	TOTAL_ UNI	TOTAL_ RSI	UNI-RSI	OTHR_ONLY
SMEs							
TURNMAR	N	127	182	384	505	529	928
	Mean	0.2326	0.2025	0.2376	0.1989	0.2524	0.1728
	Std. Dev.	0.3416	0.3173	0.3245	0.3029	0.3178	0.2860
	Mann Whitney U-Test*	11368.000		92357.000		196321.500	
	p-value	*0.799*		*0.211*		*<0.001*	
TURNIN	Mean	0.2255	0.2542	0.2146	0.2047	0.1817	0.2252
	Std. Dev.	0.3279	0.5569	0.3086	0.3083	0.2644	0.3232
	Mann Whitney U-Test*	11535.500		94951.500		234065.000	
	p-value	*0.977*		*0.588*		*0.134*	
Large							
TURNMAR	N	17	18	81	75	168	209
	Mean	0.0994	0.1961	0.1728	0.1196	0.1899	0.1237
	Std. Dev.	0.2532	0.3492	0.2747	0.2319	0.2686	0.2364
	Mann Whitney U-Test*	114.000		2760.000		13529.000	
	p-value	*0.207*		*0.310*		*<0.001*	
TURNIN	Mean	0.3147	0.0789	0.2110	0.1708	0.2001	0.2547
	Std. Dev.	0.4092	0.18547	0.3171	0.2806	0.2748	0.3684
	Mann Whitney U-Test*	97.000		2890.000		16730.500	
	p-value	*0.057*		*0.596*		*0.427*	

*Level of significance=0.5

Table 8

Mann-Whitney U test for the innovation performance categories between cooperation groups by sector.

		UNI_ ONLY	RSI_ ONLY	TOTAL_ UNI	TOTAL_ RSI	UNI-RSI	OTHR_ONLY
Agriculture Sector							
	N	21	34	51	90	62	120
TURNMAR	Mann Whitney U-Test*	313.000		2183.500		3530.000	
	p-value	*0.389*		*0.613*		*0.559*	
TURNIN	Mann Whitney U-Test*	337.000		2165.500		3292.000	
	p-value	*0.723*		*0.572*		*0.197*	
Manufacturing Sector							
	N	47	104	152	293	272	482
TURNMAR	Mann Whitney U-Test*	1805.000		*20611.500*		56943.500	
	p-value	*0.007*		*0.180*		*0.002*	
TURNIN	Mann Whitney U-Test*	2342.000		*21551.500*		64844.500	
	p-value	*0.675*		*0.572*		*0.804*	
Services Sector							
	N	76	62	262	197	363	535
TURNMAR	Mann Whitney U-Test*	2125.000		23430.500		68164.000	
	p-value	*0.310*		*0.085*		*<0.001*	
TURNIN	Mann Whitney U-Test*	2208.500		24735.500		91601.500	
	p-value	*0.512*		*0.430*		*0.139*	

* Level of significance=0.5