Journal of Engineering and Technology Management 69 (2023) 101763

Contents lists available at ScienceDirect

Journal of Engineering and Technology Management

journal homepage: www.elsevier.com/locate/jengtecman

Exploring the probability of firm cooperation in innovation: The role of technological intensity, knowledge intensity, and size

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ARTICLE INFO

JEL classifications:
M13
O32
O36

Keywords:
Cooperation
Knowledge-intensity
Open innovation
Size
Technological intensity
Universities and research institutes

ABSTRACT

This study explores the probability of a company cooperating in innovation, in particular with universities and research institutes, in relation to its technological and knowledge intensity, and its size. It uses data from the Community Innovation Survey (CIS) conducted in Spain in 2014. While size is the relevant variable to explain propensity to collaborate with universities and research institutes in the case of manufacturing firms, knowledge intensity better explains the probability of service firms cooperating with these institutions. Regional analysis is relevant for the appropriate translation of European innovation policies to specific innovation patterns of manufacturing and service firms.

1. Introduction

Open Innovation (OI) is the practice of businesses and organisations sourcing ideas from external sources as well as internal ones (Chesbrough, 2003). Since Chesbrough's seminal work, the most researched topics in the OI literature have been context dependency, which includes the internal and external characteristics affecting performance, and the collaborative framework that companies adopt when opening up their innovation processes, which deals with two main aspects: collaboration partners and the stages of collaboration (Bigliardi et al., 2021).

Regarding context dependency, and as an external characteristic, industry was the first to be considered for analysis. Chesbrough and Crowther (2006) point out that early adopters of OI concepts were the high-tech manufacturers (e.g., electronics, the automotive industry, biotechnology, etc.). Later, Gassmann et al. (2010) highlighted the evolving trend in the OI literature from high to low technology intensity industries. Nowadays, OI is present in a wide range of manufacturing and services industries (e.g., food, software, financial services, etc.) (Vincenzi and da Cunha, 2021; Chesbrough, 2011; Mina et al., 2014).

In terms of the internal context, the most studied characteristic in the OI literature is company size (Huizingh, 2011). While early empirical studies suggested that most OI adopters were large companies (e.g., Keupp and Gassmann, 2009; Lichtenthaler and Ernst, 2009; Bianchi et al., 2011), more recent studies have shown that over the last fifteen years many SMEs have adopted OI (Hossain, 2015; Odriozola-Fernández et al., 2019; Usman et al., 2018).

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https://doi.org/10.1016/j.jengtecman.2023.101763
Received 20 April 2021; Received in revised form 25 April 2023; Accepted 17 July 2023
Available online 25 July 2023

Cooperation, or the active participation with other enterprises or organisations in innovation activities, is at the very centre of OI (Obradović et al., 2021). It is not clear whether cooperation is of equal interest for all companies, regardless of the industry and size (Alarcón et al., 2019; Cainelli et al., 2020). In the first part of this study, we analyse these characteristics to determine which of them best explains firms' cooperation / non-cooperation decision. While the majority of studies on cooperation focus on either manufacturing or services industries (Bravo et al., 2020; Carree et al., 2019; Cruz-Cázares et al., 2013; Obradović et al., 2021; Trigo and Vence, 2012), there are some studies that include both types of firm (Carvalho et al., 2018; Cruz-Cázares et al., 2018; Lara et al., 2020). Following Obradović et al. (2021)'s call for more research exploring manufacturing and services industries separately, this study provides an updated analysis of the probability of cooperation, treating the two groups independently and yielding different results.

Some studies find differences in the type of innovation results according to the type of cooperation partner. For instance, Belderbos et al., (2004) point out that cooperation with competitors and suppliers is mainly concerned with incremental innovations, while cooperation with universities is often related to radical innovations. Moreover, Lee and Miozzo (2019) find that knowledge-intensive business services (KIBS) and science-based manufacturing firms are active collaborators of universities for innovation, while Arranz et al. (2008) support that it is firms with limited knowledge and technological resources that establish complementary agreements with universities and research institutions, motivated by financial incentives and seeking external technology sources. For their part, Trigo and Vence (2012) argue that the nature of the service activity affects both the choice of partner and the cooperation intensity. Consequently, within the cooperation framework, it is unclear which companies' contextual characteristics are most relevant with regards to the propensity to cooperate with different partners, and particularly with universities and research institutes (Figueiredo and Ferreira, 2022; Maietta, 2015).

The second part of this study investigates whether manufacturing firms' and service companies' propensity to cooperate with universities and research institutes or with other partners is related to their technological / knowledge intensity and / or their company size. Given the positive relationship between a firm's performance and cooperation (Laursen and Salter, 2006; Van Beers and Zand, 2014; Wang et al., 2015), and in particular cooperation with universities and research institutes (Cunningham and Link, 2015; Kobarg et al., 2018; Lara et al., 2020; Laursen and Salter, 2004), it is important to understand which characteristics drive cooperation for both manufacturing and service firms.

In 2015, the European Commission set OI as one of the three main policy goals for EU research and innovation (European Commission, 2018). Differences in cooperation in innovation across industries should be clearly accounted for at European policy level and appropriately translated into regional settings (Camagni and Capello, 2013; Fedirko and Fedirko, 2021). In this regard and using Community Innovation Survey (CIS) data from Spain from 2010 to 2012, Lara et al. (2020) find significant differences between services and manufacturing firms in innovation performance related to cooperation with universities and research institutes. The recent review by Bigliardi et al. (2021) calls for more research in this line, with the aim of improving policymaking. The current study, using data from the CIS conducted in Spain from 2012 to 2014, with a sample size of 11,262 firms, expands on the previous results to understand which characteristic best explains cooperation with manufacturing and service firms in general, and more specifically with universities and research institutes. This study uses Chi-square tests and logistic regression models. The results point out that size is the relevant variable to explain propensity to collaborate with universities and research institutes in the case of manufacturing firms and that knowledge intensity better explains the probability of service firms cooperating with these institutions.

The document is organized as follows: the literature is reviewed in the second section; the methodologies are briefly described in the third section; the results are presented in the fourth section; and the fifth section contains the discussion and conclusions.

2. Literature review

2.1. OI and cooperation in manufacturing vs. service firms

OI was traditionally considered to be the domain of manufacturing firms, with most academic work dedicated to companies of this type (Laursen and Salter, 2006; Lichtenthaler and Ernst, 2009; Love et al., 2014; Obradoviç et al., 2021). Chesbrough (2011) later pointed to the importance of OI in services, leading to the emergence of service-centred OI studies (for example, Vincenzi and da Cunha, 2021) and studies that covered both manufacturing and services firms (see Oumlil et al. 2020, or West and Bogers, 2017, for a review). The debate in the literature as to whether innovation in services differs from innovation in manufacturing firms is still ongoing (Cainelli et al., 2020; Lara et al., 2020; Alarcón et al., 2019). In this line, Mina et al. (2014) find that service firms are more active open innovators, are more involved in informal OI practices and place more importance on scientific and technical knowledge than manufacturing firms. A meta-analysis by Nguyen et al. (2021) also finds that OI has a stronger effect on innovation output in service firms than in manufacturing firms.

Cooperation also differs between manufacturing and service companies (Tether and Tajar, 2008; Bravo et al., 2020. For instance, Tether (2005) suggests that the first are more likely to use "hard" sources of knowledge and technology (e.g., equipment and computer software), while the second tend to emphasize "softer" attributes (e.g., human skills and operating and cooperating practices). Hipp et al. (2015) explore the similarities and differences in innovation between Knowledge-intensive Business Services (KIBS) among the EU member countries, highlighting their relatively high innovative profile with respect to manufacturing firms, as well as their cooperative nature towards external partners in the realisation of their innovation processes. This study includes both manufacturing and services firms and seeks to determine the differences in cooperation in innovation between the two groups.

2.2. OI, cooperation and technological / knowledge intensity

Industries are often classified by their technology intensity (in the case of manufacturing firms) or knowledge intensity (in the case of service firms) (European Commission, 2022). For instance, Hirsch-Kreinsen (2008) finds that the innovation pattern of low- and medium-low-tech firms differs markedly from that of high and medium-high-tech firms due to the lack of internal R&D capabilities, their specific knowledge base, and the latter's few structured innovation processes. Moreover, Segarra-Ciprés et al. (2012) show that R&D intensive firms explore external sources of knowledge more than less R&D intensive firms, and Hagedoorn (2002) finds a positive relationship between partnerships' research orientation and the research intensity of the sectors involved, with a strong market-oriented motivation in low-tech industries.

Moreover, technology and knowledge intensity have often appeared as elements affecting cooperation (Bogers et al., 2017; Abulrub and Lee, 2012; Saunders and Radicic, 2022). In this line, Lazzarotti et al. (2017) find that technological trends are relevant to move firms towards collaboration with both scientific and business partners, and Segarra-Blasco and Arauzo-Carod (2008) find that a firm's propensity to engage in cooperation activities is greater for firms in sectors with high R&D intensity in the case of manufacturing firms cooperating with competitors, universities and public centres. Arranz et al. (2008), however, find that small and low R&D intensive firms tend to benefit more from R&D cooperation.

In the case of services, Vence and Trigo (2010) perform an extended intra-sectoral analysis, finding notable differences in innovation intensity and cooperation patterns among services firms. Their study highlights the high degree of innovativeness and cooperation of the KIBS, considered the leading service sector in terms of cooperation and innovation (Hipp et al., 2015), while suggesting that there are significant differences among all KIBS categories. Likewise, Segarra-Blasco and Arauzo-Carod (2008) and Tether and Tajar (2008) identify differences in cooperation related to firms' technological intensity.

2.3. OI, cooperation and firm size

Both Segarra-Blasco and Arauzo-Carod (2008) and Tether and Tajar (2008) include firm size as one of the elements affecting cooperation. In fact, firm size is considered a relevant variable affecting cooperation in most of the innovation literature (Huizingh, 2011). Small and medium-sized enterprises (SMEs) have limited financial resources but are more flexible, proactive and market-oriented and less bureaucratic, all of them characteristics that facilitate innovation (Acs and Audretsch, 1987; Brunswicker and Vanhaverbeke, 2015; Cohen and Klepper, 1996). However, large firms have more resources to innovate and to support risky activities (Tsai, 2001) and can benefit from economies of scale in R&D, production and marketing (Stock et al., 2002).

The effect of size on OI produces different results. The first empirical studies suggested that the majority of OI adopters were large companies (Keupp and Gassmann, 2009; Lichtenthaler and Ernst, 2009; Bianchi et al., 2011; Galati and Bigliardi, 2017), while several later publications have shown that SMEs have also embraced OI (Usman et al., 2018). Some factors were thought to hinder the OI adoption process in SMEs, including lack of knowledge, collaboration, organisation and financial and strategic barriers (Bigliardi and Galati, 2016). Overall, the results are inconclusive. Van de Vrande et al. (2009) find that medium-sized firms are more heavily involved in OI on average than their smaller counterparts, while Spithoven et al. (2013) find that the effects of OI in SMEs often differ from those in large firms. Furthermore, Jang et al. (2017) show that large firms are inclined to conduct OI more actively than SMEs, and especially outbound OI, which involves the external exploitation of internal ideas in different markets. More recently, Bravo et al., 2020 also find differences between KIBS' and manufacturing firms' behaviour regarding innovation intensity and the size of the firms. Specifically, Bravo et al. (2020) find an inverse relationship between the size of KIBS and their effort in terms of R&D.

With regards to collaboration, Segarra-Blasco and Arauzo-Carod (2008) find that size is positively correlated for all types of cooperation partners, with higher effects for cooperation with universities, public centres and customers and suppliers. Focusing on manufacturing firms, Lazzarotti et al. (2017) find that size is relevant but depending on the type of partner, with larger companies more easily interacting with scientific partners. Meanwhile, Jang et al. (2017) suggest that large firms collaborate with diverse partners in percentages that double the figures of SMEs.

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

Hypothesis 1. The cooperation propensity of manufacturing firms is related to their technological intensity (low-tech, high-tech) and firm size (SMEs, large firms).

Hypothesis 2. The cooperation propensity of service firms is related to their knowledge intensity (LKIS, KIS) and firm size (SMEs, large firms).

2.4. Cooperation with universities and research institutes

2.4.1. Manufacturing firms that cooperate with universities and research institutes

Since Pavitt's taxonomy (Pavitt, 1984) of innovative firms, universities and research centres have been considered as the main sources of knowledge and technology for science-based companies. More recently, in the OI context, Fernández López et al., (2015) and Saunders and Radicic (2022) have considered technological intensity as one of the determinants for cooperation with universities and research centres. However, based on a sample of Eastern European firms, the latter finds no evidence that cooperation with universities and research centres increases a firms' innovation intensity or commercial success. Conversely, Radicic and Pinto (2019) find that cooperation with universities and technological centers is positively associated with technological innovations. However, their sectoral analysis according to technological intensity shows that cooperation with suppliers increases the propensity for

technological innovation in industries with a higher degree of technological intensity, while cooperation with universities increases the likelihood of innovation in industries with a lower degree of technological intensity. Conversely, Bekkers and Bodas Freitas (2008) sustain that the industrial sector of the firm does not significantly explain the differences in the importance of a wide variety of channels through which knowledge between universities and industry might be transferred.

Regarding size, Jang et al. (2017) find that the percentage of large firms cooperating with universities is almost triple the percentage of SMEs, while Lara et al. (2020) likewise find that large firms cooperate more with universities and research institutes than SMEs. Moreover, they point out that firms that have collaborated with universities and research institutes reach a higher average innovation performance than firms collaborating with other partners. In a study analysing manufacturing firms, Santoro and Chakrabarti (2002) find that size matters in terms of the types of relationships between firms and universities and the types of technology-centred strategic initiatives that firms pursue. In this regard, large firms have higher intensity knowledge transfer and stronger research support relationships to improve skills and knowledge and gain more access to university facilities to advance non-core technologies. In contrast, small firms have higher intensity technology transfer, stronger cooperative research relationships and access to university facilities to advance core technologies.

2.4.2. Services firms that cooperate with universities and research institutes

The literature on the relationship between universities and services firms has produced different results. Some researchers have shown that service firms are less likely than manufacturing firms to cooperate with universities for innovation but are more likely to do so with clients and suppliers (Tether, 2005), while Mina et al. (2014) conclude that services firms are more active open innovators than manufacturers, attaching more importance to scientific and technical knowledge than to market knowledge. In this regard, Trigo and Vence (2012) argue that the nature of the service activity affects both the choice of partner and the cooperation intensity. The article also finds two groups among the firms that cooperate the most: the group that cooperates in techno-scientific knowledge (with universities and technology centres) and the group that intensively interacts with clients.

Further regarding the nature of the service activity, Segarra-Blasco and Arauzo-Carod (2008) show that KIBS firms are more likely to collaborate with universities in innovation than other firms, considering universities to be an essential knowledge source for new-to-market innovations (Rodriguez et al., 2017). Lee and Miozzo (2019) similarly distinguish among KIBS according to their knowledge base and modes of organisational learning, finding that science-based KIBS and KIBS engaged in a doing, using and interacting mode of organisational learning are active collaborators with universities for innovation, and that they benefit from this collaboration. Bravo et al. (2020) also find that universities and technology centres are the main providers of knowledge for KIBS. However, Love et al., (2011) find that the interaction between KIBS firms and universities does not improve their innovation performance.

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

Hypothesis 3. Cooperation propensity with universities and research institutes or with other partners in manufacturing firms differs depending on their technological intensity and firm size.

Hypothesis 4. Cooperation propensity with universities and research institutes or with other partners in services firms differs depending on their knowledge intensity and firm size.

3. Materials and methods

3.1. Data and population

This study used data from the CIS conducted in Spain between 2012 and 2014. The survey in Spain is mandatory and data is collected using two methods: sample and census. This last method is carried out for larger enterprises (200 + employees) and R&D performers, while the sample is used for smaller enterprises. The CIS2014 applies the concepts and methodology of the Oslo Manual (Manual, 2005). The harmonised survey provides a thorough understanding of the different issues regarding innovation in firms. This

Table 1
Description of the population and samples.

Description	*N*	*%*	*%*	*%*
CIS 2014 target population	68,683	100		
CIS 2014 sample	27,092	39.4	100	
Study sample (firms that innovated)	11,262	16.4	41.6	100
Manufacturing firms	5936	8.6	21.9	52.7
Low and Medium-Low technological intensity firms (HTCH)	4156	6.0	15.3	36.9
Medium High and High technological intensity firms (LTCH)	1780	2.6	6.6	15.8
Services firms	5326	7.7	19.7	47.3
Less knowledge-intensive services (LKIS)	1726	2.5	6.4	15.3
Knowledge-intensive services (KIS)	3600	5.2	13.3	32.0
Firms with less than 250 employees (SMEs)	9806	14.3	36.2	87.0
Firms with more than 250 employees (Large)	1456	2.1	5.4	13.0
Core NACE Industry Categories (2 digits)	B-C-D-E (excluding construction)			
Core NACE Services Categories (2 digits)	46-H-J-K-71–72–73			

study uses data related to product and process innovations, cooperation for innovation activities, cooperation partners, firm size, technological intensity and knowledge intensity.

Table 1 summarises the description of the data.

The number of firms surveyed in Spain CIS2014 (CIS sample) during the period was 27,092 (39.4% of the study population). The firms that introduced technological innovations (product or process) represented 34% of the CIS sample, while 2546 firms (9.4% of the CIS sample) abandoned the product and process innovation activities before completion, and 5991 (22.1% of the CIS sample) were involved in ongoing innovation activities at the end of 2014. Following the objective of the article, the study sample included the firms that conducted innovation activities in the years in question (whether they introduced product or process innovations, abandoned innovation activities or were involved in ongoing innovation activities), totalling 11,262 (41.6% of the CIS sample). There were 5936 manufacturing firms (52.7% of the study sample), of which around 70% were low-tech industries (LTCH) and the remaining 30% high-tech industries (HTCH). There were 5326 services firms (47.3% of the study sample). Most of these services firms (67.6%) were more knowledge-intensive services (KIS), while the remaining 32.4% were less knowledge-intensive services (LKIS). Regarding firm size, small and medium-sized firms (SMEs) accounted for 87% of the study sample (9806 firms), while the remaining 13% were large firms.

3.2. Research design

3.2.1. Dependent variables: cooperation and cooperation groups

As shown in Table 2, the firms that cooperated in any innovation activities with other enterprises or organisations accounted for 4293 (38.1% of the study sample. The remaining 61.9% did not cooperate.

Following Lara et al. (2020), we classified the firms that cooperated into two categories: the group of firms that cooperated with universities and research institutes, and the group of firms that cooperated with other partners, including customers, suppliers, competitors and consultants.

3.2.2. Independent variables: technological intensity, knowledge intensity and firm size

As shown in Table 1 and 2 and following Eurostat's aggregation of the manufacturing industry (based on the NACE Rev. 2 classification), the firms were grouped into four categories according to their technological intensity: high-technology, medium-high-technology, medium-low-technology and low-technology. For the statistical analysis, these groups were further regrouped into two categories: low-technology and high-technology industries. In the same line as Eurostat's aggregation of firms in the services sector (based on the NACE Rev. 2 classification), the firms were grouped according to whether they were less or more knowledge intensive. Regarding size, and following Eurostat' classification, the firms were grouped into two categories according to the number of employees: a) firms with under 250 employees, which are small and medium-sized firms (SMEs); and b) firms with more than 250 employees, which are large firms.

3.3. Procedure

In the first stage of analysis, this study used the Chi-Square to test the relationships between cooperation and technological intensity (LTCH/HTCH) and size (SMEs/Large) in the case of the manufacturing firms, and between cooperation and knowledge intensity (LKIS/KIS) and size in the case of the services firms. Sirkin (2006) corroborates that the Chi-Square statistic is commonly used for testing the relationship between categorical variables in a contingency table.

The hypotheses about these relationships were then tested by carrying out a logistic regression model for each group (manufacturing and services). Hosmer et al. (2013) underline that this methodology is well-suited for describing and testing hypotheses about relationships between a categorical outcome variable and one or more categorical or continuous predictor variables.

For the regression model, the categorical outcome variable is the cooperation, represented by (0/1), and the categorical predictor variables are technological intensity (LTCH/HTCH) or knowledge intensity (LKIS/KIS) and firm size (SMEs/Large), represented by (0/

Table 2
Dependent and independent variables.

Variables	*Description*	*Type of variable*	*Categories*	*N*	*%*
Cooperation	Firms that did NOT cooperate with other firms or organisations on innovation activities	Dependent variable	(0) N_COOP	6969	61.9
	Firms that cooperated with other firms or organisations on innovation activities		(1) COOP	4293	38.1
Cooperation groups	Firms that cooperated with other partners (NO Universities - NO Research Institutes)	Dependent variable	(0) OTHRS	1788	65.6
	Firms that cooperated with both Universities AND Research Institutes (NO other partners)		(1) UNI_RSI	937	34.4
Manufacturing firms by technological intensity	Low and Medium-Low technological intensity firms	Independent variable	(0) LTCH	4156	36.9
	Medium-High and High technological intensity firms		(1) HTCH	1780	15.8
Services firms by knowledge intense	Less knowledge intensity services	Independent variable	(0) LKIS	1726	15.3
	Knowledge intensity services		(1) KIS	3600	32.0
Firm size	Firms with less than 250 employees	Independent variable	(0) SMEs	9806	87.0
	Firms with more than 250 employees		(1) Large	1456	13.0

1). In the second stage, the analysis was replicated using cooperation groups as the outcome variable, their being: a) other partners (OTHRS); and b) universities and research institutes (UNI-RSI), both represented with (0/1).

4. Results

4.1. Cooperation: technological intensity, knowledge intensity and firm size

4.1.1. Descriptive analysis and Chi-square test

Table 3(a) shows the cooperation of the manufacturing firms by technological intensity. About 36.8% of the manufacturing firms cooperated in innovation activities, with high-tech firms cooperating more (39.8%) than low-tech ones (35.5%). Further, high-tech firms (HTCH) had a 1.2 times higher risk (odds ratio) of cooperating than the low-tech ones (LTCH).

Table 3(b) shows the cooperation of services firms according to knowledge intensity. About 44% of the knowledge intensive firms (KIS) cooperated with other enterprises or organisations, while 30.5% of the less knowledge-intensive services (LKIS) did so: knowledge-intensive services (KIS) had a 1.8 times higher risk (odds ratio) of cooperating than the less knowledge-intensive services (LKIS).

Table 3(c) shows the firms' cooperation by size. Around 51.6% of the large firms cooperated with other enterprises or organisations in innovation activities for 36.1% of the SMEs. Further, the large firms had a 1.89 times higher risk (odds ratio) of cooperating than the SMEs.

In Table 4, the Chi-square test values indicate a statically significant relationship ($p < 0.05$) between cooperation and technological intensity, knowledge intensity and firm size.

4.1.2. Logistic regression models

We obtained the following logistic regression model of the manufacturing firms' cooperation by the technological intensity and firm size (Table 5a):

Predicted logit of (Cooperation) = −0·705+1·126*(Size)+0·137*(Technological Intensity)

The probability of a manufacturing firm cooperating is positively related to the firm size and to the technological intensity (both significant at p = <0.05). The 1.126 coefficient indicates that large manufacturing firms cooperate more than SMEs and the 0.137 coefficient indicates that the high technological intensity firms cooperate more than the low technological intensity ones. Since both variables are dichotomic and of the same values (0.1), we can compare the β*s* in a straightforward way: the firm's size (1.126) contributes more to explaining the cooperation of manufacturing firms than their technological intensity (0.137).

The logistic regression model of cooperation applied to the services firms showed the following results (Table 5b):

Predicted logit of (Cooperation) = −0·896+0·320*(Size)+0·611*(Knowledge-Intensity)

According to the model, the probability of service firms cooperating is positively related to knowledge intensity and firm size. Given the same firm size, the knowledge-intensive firms (KIS) were more likely to cooperate than the less knowledge-intensive firms (LKIS); and given the same knowledge intensity, large firms were more likely to cooperate than SMEs. By comparing the two β*s*, we obtained that knowledge intensity (0.611) contributes more to explaining the cooperation of services firms than their size (0.320).

These types of variables and analysis also allow us to calculate the probabilities for the four combinations of the explicative variables (Table 6). The cooperation probability of a large knowledge-intensive firm was 0.508, while the probability of a less

Table 3
Contingency table of cooperation by technological intensity, knowledge intensity and firm size.

		(a) *Technological Intensity*			(a) *Knowledge Intensity*			(a) *Firm Size*		
		Low + Medium-low Tech (LTCH)	Medium-high + High Tech (HTCH)	Total	Less Knowledge-Intense (LKIS)	Knowledge-intense (KIS)	Total	SMEs	Large	Total
Did not cooperate (N_COOP)	N	2681	1072	3753	1200	2016	3216	6264	705	6969
	% within cooperation	71.4	28.6	100	37.3	62.7	100	89.8	10.2	100
	% within intensity	64.5	60.2	63.2	69.5	56.0	60.4	63.9	48.4	61.9
Cooperated (COOP)	N	1475	708	2183	526	1584	2110	3542	751	4293
	% within cooperation	67.6	32.4	100	24.9	75.1	100	82.5	17.5	100
	% within intensity	35.5	39.8	36.8	30.5	44.0	39.6	36.1	51.6	38.1
Total	N	4156	1780	5936	1726	3600	5326	9806	1456	11,262
	% Total	70.0	30.0	100	32.4	67.6	100	87.1	12.9	100
	% within intensity	100	100	100.0	100	100	100	100	100	100

Table 4
Chi-square test and symmetric measure summary of cooperation by technological intensity, knowledge intensity and firm size.

	(a) Technological intensity	*(b) Knowledge intensity*	*(c) Firm Size*
N	5936	5326	11,262
Pearson Chi-Square	9.839	89.210	128.439
Degrees of freedom (df)	1	1	1
Phi	0.041	0.129	0.107
p-value[*]	*0.002*	*< 0.001*	*< 0.001*

[*] Level of significance= 0.05

Table 5
Logistic regression model for the firm's cooperation[*].

(a) *Manufacturing firms*					
N = 5936	*B*	*S.E.*	*Wald*	*p-value*[**]	*Odd Ratio*
Firm size (Large)	1.126	0.089	160.645	< 0.001	3.083
Technological intensity (HTCH)	0.137	0.059	5.317	0.021	1.147
Constant	-0.705	0.034	431.815	< 0.001	0.494
(a) *Services firms*					
N = 5326	*B*	*S.E.*	*Wald*	*p-value*[**]	*Odd Ratio*
Firm size (Large)	0.320	0.077	17.410	< 0.001	1.377
Knowlegde intensity (KIS)	0.611	0.063	94.993	< 0.001	1.842
Constant	-0.896	0.055	262.235	< 0.001	0.408

[*] Dependent variable codes: Cooperated (1), Did not cooperate (0)
[**] Level of significance = 0.05

Table 6
Cooperation probabilities for manufacturing and service firms.

PROBABILITIES OF COOPERATION				
	a) Manufacturing firms		*b) Services firms*	
	LTCH	HTCH	LKIS	KIS
SMEs	0.33	0.36	0.29	0.43
Large firms	0.60	0.63	0.36	0.51

Table 7
Contingency table of the cooperation group B (Universities and research institutes | Other partners) by technological intensity, knowledge intensity and firm size.

		(a) *Technological Intensity*			(a) *Knowledge Intensity*			(a) *Firm's Size*		
		Low + Medium-low tech (LTCH)	Medium-high + High tech (HTCH)	Total	Less Knowledge-Intense (LKIS)	Knowledge-intense (KIS)	Total	SMEs	Large	Total
Cooperation with Universities and research institutes (UNI_RSI)	N	275	158	433	74	430	504	765	172	937
	% within cooperation	63.5	36.5	100	14.7	85.3	100	81.6	18.4	100
	% within intensity	32.6	37.0	34.1	19.0	40.4	34.7	34.4	34.2	34.4
Cooperation with Other partners (OTHRS)	N	569	269	838	315	635	950	1457	331	1788
	% within cooperation	67.9	32.1	100	33.2	66.8	100	81.5	18.5	100
	% within intensity	67.4	63.0	65.9	81.0	59.6	65.3	65.6	65.8	65.6
Total	N	844	427	1271	389	1065	1454	2222	503	2725
	% within cooperation	66.4	33.6	100	26.8	73.2	100	81.5	18.5	100
	% within intensity	100	100	100	100	100	100	100	100	100

knowledge-intensive SME was 0.289.

4.2. Cooperation with universities and research institutes or other partners: technological intensity, knowledge intensity and firm size

4.2.1. Descriptive analysis and Chi-square test

Table 7(a) contains the descriptive data of manufacturing firms' cooperation with universities and research institutes or with other partners, according to their technological intensity. The high-tech industries cooperated more with universities and research institutes (37%) than the low-tech industries (32.6%). Table 7(b) shows that service firms that were knowledge-intensive cooperated more with universities and research institutes (UNI-RSI) (40.4%) than the less knowledge-intensive firms (19%). Furthermore, LKIS (81%) cooperated with other partners (OTHRS) more than KIS (59.6%). Regarding firm size, Table 7(c) shows that the firms that cooperated with universities and research institutes (UNI_RSI) or other partners accounted for 2725 (63.4%) of the total number of cooperating firms. Most of them (81.5%) were SMEs, and the remaining 18.5% were large firms. SMEs cooperated with other partners (OTHRS) in around 65.6% of the cases, and the percentage was similar in the case of the large firms, at 65.8%. Cooperation with universities and research institutes (UNI_RSI) was also similar between the SMEs (34.4%) and the large firms (34.2%).

Table 8 contains the results of the Chi-square test and the summary of the symmetric measure for the cooperation groups. Technological intensity and firm size are not significant ($p < 0.05$) to explain cooperation with universities, whereas knowledge intensity is.

4.2.2. Logistic regression models

We obtained the following logistic regression model (Table 9a) for cooperation of the manufacturing firms with universities and research institutes (coded with 1) and other partners (coded with 0), according to the variables technological intensity and size:

Predicted logit of (Cooperation UNI_RSI) = −0·806+0·761*(Size)

According to the model, the probability of manufacturing firms cooperating with universities and research institutes (UNI-RSI) is positively related to the firm size ($p = <0.05$) and not significantly related to the technological intensity ($p = 0.216$). Large firms are more likely to cooperate than SMEs. The risk (odds ratio) of large firms cooperating with universities and research institutes is 2.14 times higher than the risk of SMEs doing so.

The predicted probability of cooperating with UNI-RSI for large firms was 0.488, and for SMEs it was 0.308 (See Table 10). In terms of service firms' cooperation with universities, research institutes (coded with 1) and other partners (coded with 0), we obtained the following logistic regression model (Table 9b):

Predicted logit of (Cooperation UNI_RSI) = −1·299 to 0·637 * (Size) + 1·006 * (Knowledge-intensity)

According to the model, the probability of service firms cooperating with universities and research institutes (UNI-RSI) is related to the firm size and the knowledge intensity (both $p = <0.05$ significance). According to the model, knowledge intensity affects cooperation with universities and research institutes more than size. Moreover, it affects cooperation positively, whereas size is inversely related to cooperation. Knowledge intensity increases the probability of cooperation with universities and research centres (2.733 higher risk when size is kept constant), while large size decreases the risk of cooperation (0.529 less risk) when knowledge intensity remains constant.

The probability of large knowledge-intensive services firms (KIS) cooperating with universities and research institutes (UNI-RSI) is 0.28. Meanwhile, less knowledge-intensive firms that are large have a 0.12 probability of cooperating with universities (UNI_RSI).

5. Discussion and conclusion

The results support accepting the first hypothesis, meaning that the cooperation propensity of manufacturing firms is positively related to both technological intensity and firm size. This finding is consistent with those of other studies comparing OI in large companies and SMEs. For example, Segarra-Ciprés et al. (2012) find that firms in higher technology-intensive sectors cooperate more than those in low technology-intensive sectors and that size (as log of employees) is also positively related to cooperation. For their part, Arranz et al., (2008) show that R&D cooperation is more significant in the case of firms belonging to high-tech sectors and cooperation is positively related to firm size. Moreover, our results allow the effects of size and technological intensity to be compared. It was observed that large manufacturing firms are three times more likely to cooperate than SMEs, while high-tech companies are 1.4 times more likely to cooperate than low-tech companies. Therefore, according to the results of this study, firm size better explains

Table 8
Chi-square test and symmetric measure summary for the cooperation groups: Universities and research institutes | Other partners.

	(a) Technological intensity	*(b) Knowledge intensity*	*(c) Firm Size*
N	1271	1454	2725
Pearson Chi-Square	2.466	57.359	0.10
Degrees of freedom (df)	1	1	1
Phi	0.044	0.199	0.002
*p-value**	*> 0.05*	*< 0.001*	*> 0.05*

* Level of significance= 0.05

Table 9
Logistic regression model for the cooperation group *: Universities and research institutes | Other partners.

(a) *Manufacturing firms*					
N = 1271	*B*	*S.E.*	*Wald*	*p-value**	*Odd Ratio*
Firm size (Large)	0.761	0.149	26.030	*< 0.001*	2.141
Constante	-0.806	0.067	144.950	*< 0.001*	0.447
(a) *Service firms*					
N = 1454	*B*	*S.E.*	*Wald*	*p-value**	*Odd Ratio*
Firm size (Large)	-0.637	0.159	16.005	*< 0.001*	0.529
Knowledge-intensive (KIS)	1.006	0.145	48.395	*< 0.001*	2.733
Constant	-1.299	0.134	94.648	*< 0.001*	0.273

* *Level of significance = 0.05
* Dependent variable codes: Universities and Research Institutes (1), Other partners (0)

Table 10
Cooperation probabilities with universities and research institutes / other partners of manufacturing and services firms.

Probabilities of cooperation with universities and research institutes				
	a) *Manufacturing firms*		a) *Service firms*	
	LTCH	HTCH	LKIS	KIS
SMEs	0.31	0.31	0.21	0.43
Large firms	0.49	0.49	0.12	0.28

cooperation than technological intensity in the case of manufacturing firms.

We also found support for accepting the second hypothesis. The cooperation propensity of the services companies was positively related to their knowledge intensity and firm size, a finding that is consistent with those of other studies. For example, Trigo and Vence (2012) pointed out that the nature of the service activity affects both the type of partner chosen and the intensity of the cooperation, while also finding that cooperation for innovation is not a common practice in Spanish service companies (59% were low intensity in cooperation, while 60.4% of innovative service firms in our sample did not cooperate). In a similar line, Mina et al., (2014) state that engagement in OI increases with the size of the company and the expenditure on R&D. Moreover, according to our results, knowledge-intensive services firms (KIS) are twice as likely to cooperate than less knowledge-intensive services companies (LKIS). Meanwhile, large services firms are 1.3 times more likely to cooperate than services SMEs. Thus, according to the results of our study, knowledge intensity contributes more to explaining the cooperation of services companies than their size.

We partially accepted the third hypothesis because cooperation propensity with universities and research institutes in manufacturing industries is not significant in terms of technological intensity, but it is in terms of firm size: large firms are more likely to cooperate with universities and research centres than SMEs. The risk (odds ratio) of large firms cooperating with universities and research institutes is 2.14 times higher than for SMEs. This finding is consistent with other studies highlighting the differences between SMEs and large firms in cooperation with universities. For instance, Laursen and Salter (2004) find that a firm's capability to draw from university research increases with the organisation's size. However, in contrast with the results of our study, Santoro and Chakrabarti (2002) do find a role for technology intensity in cooperation with universities, besides the effect of size, distinguishing four main components in the industry and university relationship (research support, cooperative research, knowledge transfer, and technology transfer) and showing that larger firms use knowledge transfer and research support relationships to build non-core technological areas. In contrast, SMEs focus on core technological areas through technology transfer and cooperative research relationships, particularly those in high-tech industrial sectors. Similarly, Brunswicker and Vanhaverbeke (2015) argue that SMEs adopt different external knowledge sourcing strategies depending on their internal practices for managing innovation. Thus, SMEs with 'technology-oriented' and 'full-scope searcher' strategies interact intensely with universities and research organisations.

We found support to accept the fourth hypothesis. Cooperation propensity with universities and research institutes in services firms is significant for both knowledge intensity and firm size. However, concurring with Bravo et al. (2020), the sign of the relationship is negative for firm size. Moreover, we note that given the same firm size, the knowledge-intensive services firms (KIS) were 2.7 times more likely to cooperate with universities and research institutes than the less knowledge-intensive services companies.

The results of this study differ from those of Wong and He (2005), showing a significantly lower incidence of collaboration with universities and research institutes for KIBS (22% - 40,4% in our study) than for manufacturing firms (49% - 34,1% in our study). However, the results are consistent with those of other studies. For instance, Freel (2006) shows that a high innovativeness level in SMEs (knowledge-intensive services and manufacturing firms) is related to cooperative relationships between KIBS and universities. Similarly, Lee and Miozzo (2019) determine that science-based KIBS firms, like science-based manufacturing firms, are active collaborators with universities for innovation. A high innovativeness level is also consistent with the typology of cooperation for services firms created by Trigo and Vence (2012). Firms intensive in the techno-scientific flow of information have a high probability of cooperating with technology institutes, universities and suppliers. Moreover, we find that the probability of small KIS firms cooperating with universities and research centres is low (0.43) compared to the probability of cooperating with other partners (0.57).

In summary, this study contributes to verifying that the propensity to cooperate in innovation activities for the Spanish data is related not only to firm size but also to technological intensity in the case of manufacturing companies, and to knowledge intensity in

the case of service companies. Size is more relevant in explaining cooperation than technological intensity in the case of manufacturing firms, whereas knowledge intensity is more relevant than size in explaining cooperation in service firms. Regarding cooperation with universities and research centres, size alone is relevant in the case of manufacturing firms, whereas both knowledge intensity and size are relevant in the case of service firms, although size shows a negative sign. Learning about the relationship with cooperation, and in particular cooperation with universities and research centres, allows the same actors to better characterise the parties involved and to thereby better spot the opportunities to improve knowledge creation and transfer processes.

By gaining knowledge of specific regional settings, political decision makers can refine the design of policies aimed at promoting cooperation in manufacturing and in service firms, targeting according to size in the first case and according to knowledge-intensity level in the second. The simplicity of the results may facilitate their being considered in policy making. Some EU reports, including the EU innovation scoreboard and the OI yearbook 2018, fail to clearly point out the differential features that this article highlights.

Despite the contributions, this study is not without limitations. First, the limited use of explanatory and control variables needs to be overcome when conducting future research. Other explanatory variables of the internal context, such as organisational structures and strategies used for knowledge management, can be added to both the general cooperation model and to the cooperation model with universities and research centres. Second, reverse causality could be tested throughout the analysis to enhance reliability of the results. Moreover, further research with more updated data and with data from other geographical areas should also be pursued to learn about other regional settings. Last, it may be interesting to inquire more about the determinants and results of services firms' cooperation, which constitute knowledge sources for their clients, including manufacturing firms themselves.

Declaration of Competing Interest

The author declares that they have no known competing financial interests or personal relationships that would have influenced the literature and work reported in this paper.

Acknowledgements

The authors are grateful for the Research Grant from the Generalitat de Catalunya 2021 SGR 01589 and the Open Access funding provided thanks to the CRUE-CSIC agreement with Elsevier.

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