Universitat de Girona

PARTNERS IN INNOVATION: COOPERATION BETWEEN FIRMS, UNIVERSITIES AND RESEARCH INSTITUTES

Giovanna Lara Burbano

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DOCTORAL THESIS

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2022

DOCTORAL PROGRAMME IN LAW, ECONOMICS AND BUSINESS

Supervised by:

Josep Llach, PhD

Anna Arbussà, PhD

Presented to obtain the degree of PhD at the University of Girona

Universitat de Girona

Josep Llach and Anna Arbussà, professors at the University of Girona

WE DECLARE:

The thesis entitled *Partners in innovation: Cooperation between firms, universities and research institutes*, presented by Giovanna Lara Burbano to obtain a doctoral degree, has been completed under our supervision.

For all intents and purposes, we sign this document.

LIST OF PUBLISHED AND PEER-REVIEWED RESEARCH ARTICLES DERIVED FROM THE THESIS

Article No. 1

Title:	Innovation performance of the firms that have cooperated with universities and research institutes in Spain
Authors:	Giovanna Lara, Josep Llach and Anna Arbussà
Journal:	International Journal of Innovation Management
Journal metrics:	SCImago Journal Rank (SJR) (2020): 0.57; Q2 Journal Citation Indicator (JCI) (2020): 0.52; Q3
Acceptance date:	26th July 2019
Publication date:	05th September 2019
DOI:	https://doi.org/10.1142/S136391962050053X
Citation:	Lara, G., Llach, J. and Arbussà, A. (2020), 'Innovation performance of the firms that have cooperated with universities and research institutes in Spain', *International Journal of Innovation Management*, World Scientific Pub Co Pte Lt, Vol. 24 No. 06, p. 2050053.

Article No. 2

Title:	Cooperation propensity with universities and research institutes according to technological and knowledge intensity
Authors:	Giovanna Lara, Anna Arbussà and Josep Llach
Journal:	Journal of Engineering and Technology Management
Journal Metrics:	SCImago Journal Rank (SJR) (2020): 0.83; Q1 Journal Citation Indicator (JCI) (2020): 0.61; Q2
Submission date:	20th April 2021
Acceptance date:	Under review
Publication date:	
DOI:	
Citation:	

Article No. 3

Title:	Open Innovation in times of Covid-19: The case of Project Oxygen
Authors:	Giovanna Lara
Journal:	European Accounting and Management Review
Journal metrics:	Latindex catalogue 2.0
Acceptance date:	08th October 2020
Publication date:	09th December 2020
DOI:	10.26595/eamr.2014.7.1.3
Citation:	Lara, G. (2020). Open Innovation in Times of Covid-19: The case of Project OxyGEN. *European Accounting and Management Review*, 7(1), 47-65.

INTERMEDIATE CONTRIBUTIONS

Date/Place	Conference	Article	Proceedings
12th-13th July 2018 Girona, Spain	12th International Conference on Industrial Engineering and Industrial Management CIO 2018	Product innovation in Spain: Measuring the innovation performance of the firms in collaboration with universities and research institutes	ISBN 9788499844848
07th–10th June 2020 Berlin, Germany	ISPIM Innovation Conference "Innovation in Times of Crisis"	Open Innovation and Open Hardware: The case of Project OxyGEN	ISBN 978-952-335-466-1
30th November to 2nd December 2021 Valencia, Spain	ISPIM Innovation Conference “Reconnect, rediscover, reimagine”	Contextual dependence in firms’ cooperation with universities and research institutions	ISBN 978-952-335-691-7

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Josep Llach, as co-author of the following articles:

1. Innovation performance of the firms that have cooperated with universities and research institutes in Spain
2. Cooperation propensity with universities and research institutes according to technological and knowledge intensity

Accepts that Mrs Giovanna Lara Burbano presents the cited articles as the principal author and as part of her doctoral thesis. The articles cannot, therefore, form part of any other doctoral thesis.

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Anna Arbussà, as co-author of the following articles:

1. Innovation performance of the firms that have cooperated with universities and research institutes in Spain
2. Cooperation propensity with universities and research institutes according to technological and knowledge intensity

Accepts that Mrs Giovanna Lara Burbano presents the cited articles as the principal author and as part of her doctoral thesis. The articles cannot, therefore, form part of any other doctoral thesis.

For all intents and purposes, I sign this document.

DEDICATORIA

A René y Magdalena,
mis raíces, mi ejemplo y mi fortaleza;

a Kairos y José,
mis frutos, mi motivación y mi energía.

AGRADECIMIENTOS

El doctorado es uno de los mayores retos que me propuse alcanzar dentro de mi vida personal y profesional. Este objetivo me llevó a cruzar al otro lado del océano, descubrir un nuevo país, una cultura y una lengua diferentes. Fue un viaje que inicié con ilusión hace cuatro años y que ahora estoy completando con éxito gracias al apoyo de muchas personas que estuvieron a mi lado durante este largo camino y a quienes agradezco profundamente.

En primer lugar, quiero expresar mi sincero agradecimiento a mis directores, los doctores Josep Llach y Anna Arbussà, por aceptar el reto de la dirección de la tesis. Sus conocimientos, experiencias y estilos son diferentes y complementarios, una amalgama de teoría, pragmatismo y exigencia que pusieron de manifiesto su gran calidad profesional y personal.

El trabajo de investigación es intenso y no tiene una ruta determinada, se trata más bien de un proceso heurístico (ensayo-error) en el que iba analizando datos hasta encontrar una respuesta 'válida', mientras surgían nuevas preguntas y muchas dudas, que sólo pudieron ser resueltas con la ayuda de mis directores. Sus valiosos aportes durante la revisión de los artículos me permitieron alcanzar el nivel académico requerido para su publicación.

El proyecto de tesis también requirió adquirir nuevos conocimientos y habilidades, los mismos que he ido desarrollando poco a poco como resultado de la reflexión y la motivación. Gracias Josep y Anna por vuestra paciencia, ánimo y compromiso para guiarme durante todo el proceso hasta conseguir el resultado final.

Durante estos dos últimos años, tuve la oportunidad de compartir mis conocimientos con alumnos de distintas facultades, como profesora invitada en la Universidad de Girona. Quiero darle

las gracias a la doctora Gerusa Giménez, Directora del Departamento de Organización, Dirección de Empresas y Diseño de Producto, por confiar en mi capacidad y permitirme tener esta experiencia tan enriquecedora. Y gracias a los profesores del departamento Manel, Xavi, Fernando, Susi, Pilar, Mónica, Xavier y Daniel por su amistad y apoyo permanentes.

A mis colegas del doctorado Dalilis, Prasanna, Ricardo, Alexandra y Jakeline, gracias por compartir sus experiencias en este camino de formación como investigadores, me sirvieron para ir encontrando el mío propio. Les deseo muchos éxitos en sus carreras y espero que más adelante podamos unir esfuerzos y descubrir nuevos horizontes.

Tuve la suerte de encontrar un lugar bonito y cómodo donde vivir que se convirtió en mi casa en Girona, gracias a Janina, por abrirme las puertas de la suya y brindarme su amistad y confianza cada día. Tenía mucha ilusión de aprender el catalán y eso fue posible gracias a Ramón que me llevó a descubrir los lugares más bonitos de Cataluña y conocer su cultura. Ja pots dir "que sóc una catalana d'adopció".

Finalmente, quiero dar las gracias a mis padres, Magdalena y René, y a mis hijos, Kairos y José, por su apoyo y amor incondicionales. Aunque estamos a más de ocho mil kilómetros de distancia, puedo decir que nunca estuvimos separados, estoy segura de que sabrán valorar este esfuerzo y compartirlo conmigo.

Giovanna

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ABBREVIATIONS

CIS	Community Innovation Survey
EARTO	European Association of Research and Technology Organizations
EURAB	European Research Advisory Board
IP	Intellectual Property Rights
KIS	Knowledge-Intensive Services
LKIS	Less knowledge-intensive services
NACE	Nomenclature generale des Activites economiques dans les Communautes europeennes. Statistical classification of economic activities in the European Community
OECD	Organization for Economic Cooperation and Development
OI	Open Innovation
PRO	Public Research Organisations
R&D	Research and Development
RTO	Research and Technology Organization
TTO	Transfer Technology Office

RESUM

L’objectiu de la tesi és explorar la cooperació de les indústries manufactureres i les empreses de serveis amb universitats i instituts de recerca. En concret, la seva propensió a cooperar en activitats d’innovació i l’impacte d’aquesta cooperació en els resultats de la pròpia innovació.

Per assolir aquest objectiu s’han realitzat dos estudis empírics i un cas d’estudi. Un dels estudis empírics i el cas ja han estat publicats en revistes internacionals de recerca. Els estudis empírics es basen en dades de l’enquesta *Community Innovation Survey* (edicions 2012 i 2014) per el cas de les empreses d’Espanya que van llançar al mercat innovacions de producte i de procés en cooperació amb diferents socis durant el període d’estudi. Respecte el cas d’estudi, aquest es va realitzar mitjançant entrevistes als socis de l’empresa que varen desenvolupar la innovació i enquestes als membres de la comunitat d’innovació de 32 països que van participar en la co-creació del producte.

Els resultats obtinguts en el primer estudi mostren diferències significatives en els resultats de la innovació de les empreses que han cooperat amb universitats i instituts d’investigació quan es tracta d’innovacions de productes nous per al mercat. L'anàlisi contextual realitzat per mida de la firma i sector confirmen aquests resultats.

En el segon estudi, mitjançant un model de regressió logística, es demostra que la probabilitat que una indústria manufacturera cooperi amb universitats i centres de recerca esta més

relacionada amb la mida de l'empresa que amb la seva intensitat tecnològica. En canvi, en el cas de les empreses de serveis la probabilitat de cooperació augmenta com major intensitat de coneixement tingui, independentment de la seva mida.

Finalment, com a resultat de l'anàlisi del cas d'estudi s'identifiquen les pràctiques organitzatives i estratègiques que faciliten els processos d'innovació d'entrada (inbound) i de sortida (outbound), així com la co-creació amb la comunitat d'innovació.

Fruit dels resultats obtinguts en els tres estudis, la tesi fa contribucions per acadèmics, directius d'empresa i *policy-makers* amb l'objectiu de promoure i enfortir la cooperació amb universitats i instituts de recerca.

Paraules clau: Cooperació industria – universitat – institut de recerca; relacions interorganitzacionals; innovació oberta; innovació de producte; innovació de serveis; intensitat tecnològica; intensitat de coneixement; mida de l'empresa; cas d'estudi; Covid-19.

RESUMEN

El objetivo de la tesis es explorar la cooperación de las industrias manufactureras y las empresas de servicios, en particular con universidades e institutos de investigación, su propensión a cooperar en actividades de innovación y su impacto en el desempeño de innovación. Además, analizar un caso de éxito de cooperación para la innovación en un contexto de crisis.

Para alcanzar este objetivo se llevaron a cabo dos estudios empíricos y un caso de estudio; dos de ellos se encuentran publicados y han sido compilados para su presentación en la tesis. Los estudios empíricos utilizaron datos de la Encuesta de Innovación de la Comunidad CIS 2012 y CIS 2014, aplicada a empresas en España que realizaron innovaciones de producto y proceso en cooperación con diferentes socios durante el período de estudio. Por otra parte, en el caso de estudio se realizaron entrevistas a los socios de la empresa española que desarrolló la innovación y se aplicaron encuestas a los miembros de la comunidad de innovación que participó en la co-creación e impulsó la innovación en 32 países.

Los resultados obtenidos en el primer estudio mostraron diferencias significativas en el desempeño de innovación de las firmas que cooperaron con universidades e institutos de investigación cuando se trata de innovaciones de producto nuevas para el mercado. El análisis realizado por tamaño de la firma y sector confirmó estos resultados.

El modelo de regresión logística realizado en el segundo estudio reveló que la probabilidad que una industria manufacturera coopere con universidades y centros de investigación está más relacionada con el tamaño de la firma que con su intensidad de tecnología. En cambio, una empresa de servicios de alto conocimiento intensivo es más probable de cooperar que una empresa de menor intensidad de conocimiento, independientemente de su tamaño.

Por último, como resultado del análisis del caso de estudio se identificaron las prácticas organizacionales y estrategias que facilitaron los procesos de innovación de entrada (inbound) y de salida (outbound), así como la co-creación con la comunidad de innovación.

La tesis hace algunas contribuciones para académicos, directivos de empresa y tomadores de decisiones para que promuevan y fortalezcan las relaciones de cooperación con universidades e institutos de investigación.

Palabras clave: Cooperación industria-universidad-institutos de investigación; relaciones inter-organizacionales; innovación abierta; innovación de producto; innovación de servicios; intensidad tecnológica; intensidad de conocimiento; tamaño de la firma; caso de estudio; Covid-19.

SUMMARY

The thesis aims to explore the cooperation of manufacturing industries and service companies, with universities and research institutes, their propensity to cooperate in innovation activities and their impact on innovation performance. In addition, analyse a successful case of cooperation for innovation in a context of crisis.

Two empirical studies and a case study were carried out to achieve the objective; two of them are published, and they have been compiled for presentation in the thesis. The empirical studies used data from the Community Innovation Survey CIS 2012 and CIS 2014, applied to companies in Spain that carried out product and process innovations in cooperation with different partners during the study period. On the other hand, in the case study, we conducted interviews to the partners of the Spanish company that developed the innovation and surveys were applied to the members of the innovation community that participated in the co-creation and promoted the innovation in 32 countries.

The results obtained in the first study showed significant differences in the firms' innovation performance that cooperated with universities and research institutes when it comes to product innovations new to the market. The analysis carried out by firm size and sector confirmed these results.

The logistic regression model carried out in the second study revealed that the probability that a manufacturing industry cooperates with universities and research institutes is more related to its size than

to its technology intensity. In contrast, a knowledge-intensive service company is more likely to cooperate than a less knowledge-intensive company, regardless of size.

Finally, as a result of the case study analysis, the organisational practices and strategies that facilitated the inbound and outbound innovation processes and co-creation with the innovation community were identified.

The thesis makes some contributions for academics, practitioners, and decision-makers to promote and strengthen cooperative relationships with universities and research institutes.

Keywords: Industry-university-research institutes cooperation; inter-organizational relationships; open innovation; product innovation; service innovation; technological intensity; knowledge intensity; firm size; case study; Covid-19.

C h a p t e r I

"There is nothing in the research process more important than a good question".
J. R. Latham

INTRODUCTION

1. Research justification

In the collaborative framework of open innovation (hereafter OI), some studies have shown that engaging in inter-organisational collaboration with various partners is beneficial for firms' innovation (Ahuja, 2000; Faems *et al*., 2005), and so they have emphasized the importance of a portfolio approach to collaboration. However, other studies have shown that a broad and thorough search for innovation sources (Laursen and Salter, 2006) and complexity of alliances (Duysters and Lokshin, 2011) is curvilinearly related to innovative performance. Furthermore, de Leeuw *et al*. (2014) showed that a lower level of partner diversity is needed to achieve optimal productivity and radical innovative performance.

Other studies have shown that the innovation results differ according to the collaborating partner. For instance, Kang K. and Kang J. (2010) found that R&D collaborations with customers and universities positively affected product innovation; the opposite is true with suppliers and competitors. On the other hand, Un and Asakawa (2015) pointed out that findings from product innovation studies do not necessarily apply to process innovation. They found

that R&D collaborations with suppliers and universities positively impact process innovation, customer collaborations had no impact, and competitors' collaborations negatively. So, the first research question arises: Who is it better to cooperate with?.

The firms see the cooperation with universities as a vehicle for innovation through knowledge transfer; consequently, they are willing and motivated to engage in cooperation agreements with them, however, some barriers will have to be overcome (Figueiredo and Ferreira, 2022).

Some studies have found that specific characteristics (e.g., firm size, firm age, R&D intensity) are determinants in industries-universities cooperation (Laursen and Salter, 2004; Segarra-Ciprés *et al*., 2012; Mohnen, *et al*., 2018) and that absorptive capacity moderates this relationship with innovation performance. Beyond the determinants, Fernández-López *et al*. (2019) argued that many firms showed interest in cooperating with universities, only small percentage ended up cooperating. Thus, cooperation should be analised in two processes, firs the interest in cooperating and the final decision to cooperate.

We observed that some studies, particularly those using CIS database (e.g., Belderbos *et al.*, 2006; Duysters and Lokshin, 2011; Guzzini and Iacobucci, 2017) have considered research institutes in the same category of universities to analyse the cooperation relationships with firms, despite the fact they have different characteristics (e.g., infrastructure, budgets, functions). In this sense,

Arnold *et al.* (2010) pointed out that research institutes and universities increasingly overlap and cooperate to produce knowledge; they are "complements, not substitutes", who have different fundamental skills and abilities. Nevertheless, few studies have explored them separately (Chen *et al.*, 2020; Giannopoulou *et al.*, 2019), recognising and exploring their differences.

Several studies have focused on the cooperation only with universities (e.g., Baba *et al.*, 2009; Wang and Shapira, 2012; Janeiro *et al.*, 2013), but research institutes are also important scientific partners for firms in national innovation systems. As a result, other research questions emerge: could we consider universities and research institutes in the same category?, and there are possible differences on the firm's innovation performance in cooperation with research institutes when compared to universities? Thus, to overcome this research gap, the first article of the thesis analyses these cooperation partners separately.

Another critical issue in OI is context-dependency, the internal and external characteristics that affect the adoption of the OI approach. Chesbrough and Crowther (2006) noted that the early adopters of OI concepts were high-tech industries, although many industries and services use them nowadays. Arbussà and Llach (2018) found that the degree of openness and the innovation strategy in manufacturing companies are context-dependent on the environment's level of technological development in which the firm operates.

Besides technological intensity, firm size is the most studied characteristic in the literature (Huizingh, 2011). Early empirical studies have suggested that most OI adopters are large companies (e.g., Bianchi, *et al.*, 2011; Keupp and Gassmann, 2009; Lichtenthaler and Ernst, 2009). However, other studies have shown that SMEs also adopt many OI practices (e.g., Spithoven *et al.*, 2013; van de Vrande *et al.*, 2009) while organising and managing OI in an entirely different way from large companies (Usman *et al.*, 2018). Spithoven *et al.* (2013) found that SMEs are more effective in using different OI practices simultaneously when introducing new products on the market, whereas this is minor the case for large firms.

Contextual characteristics affect the propensity of firms to cooperate in the first place and seem to affect the choice of partner and the intensity of their cooperation. So then, we raise another research question: is cooperation with universities and research institutes equally interesting for all types of firms?

Mainly, when it comes to cooperation with universities, some studies show intra-sectoral and inter-sectoral differences. For instance, Tether and Hipp (2002) pointed out that the intensity of enterprises' cooperation relations in the high-tech sector with external partners (e.g., suppliers, customers and particularly scientific institutions, consultants and other specialised organisations) is more pronounced than in the low-tech sector. Hirsch-Kreising (2008) remarked that while firms' size explains these differences, other key factors are the high risk and uncertainty of far-reaching or even

radical innovations and the absorptive capacity. On the other hand, Johnston (2021) pointed out that organisational, spatial, and technological proximities between actors positively influence university-low-tech industry links formation.

Few empirical studies have focused on the relationship between service companies and universities (e.g., Bekkers and Bodas Freitas, 2008; Freel, 2006; Janeiro *et al*., 2013; Lee and Miozzo, 2019), and they have shown different results. Bekkers and Bodas (2008) found that the sector did not influence the preference given by firms to a wide range of channels used by universities and research institutes to transfer knowledge. However, Janeiro *et al*. (2013) showed that a high-intensity level is critical to developing links between service firms and universities. More recently, Lee and Miozzo (2019) findings suggested that KIBS firms co-created knowledge with universities differently than manufacturing firms.

Mascarenhas *et al*. (2018) suggested that one area of interest in strategic alliances for innovation would be to analyse more closely how collaborative links develop initially so that future research could focus on the process of partner selection. To fill this research gap and complement the first article's findings, we look again into Spanish firms' this time to closely analyse their contextual characteristics (sector and size) in relation to their propensity to cooperate with academia. Consequently, the propensity to collaborate with universities and research institutes for innovation is the focus of the second article.

The health crisis caused by the Covid-19 pandemic prompted numerous developments due to the climate of openness. A large amount of information (e.g., MIT, Humanitarian Data Exchange, EU open data portal) was released and shared between scientists, researchers, companies, and government officials worldwide to launch a variety of scientific initiatives to find an effective response to the disease (Chesbrough, 2020).

Brem *et al.* (2021) have noted that our ability to cope with the Covid-19 pandemic improves through technological (e.g., 3D printing, flexible manufacturing systems, big data analytics) and social developments (e.g., e-learning, videoconference, webcast). In addition, the time-to-market was significantly shortened in response to the crisis, as in the case of medical ventilators.

They also have pointed out that cross-sector innovation has seen a significant increase as companies in a wide variety of industries find themselves with excess capacity due to reduced economic activity and decide to use this resource to help overcome the crisis (e.g., Dyson, Ford, GM, Tesla, NASA).

However, Elsahn and Siedlok (2021) explain that the success of firms' resourcing depends on the interrelations among three dimensions: a) Objects which refer to the tangible and intangible assets that a company owns or can access; b) Interpretative frames used to deploy those objects in a different context; and c) Product architecture and regulatory characteristics of the product resourced.

In this sense, the most challenging context for resource redeployment involves highly complex products with integral architecture such as medical ventilators. They also have argued that when resource redeployment is too difficult for one firm because of a product's architecture, coordination among firms is necessary. In turn, it might require coordination or prior experience of working with partners across knowledge domains (Siedlok *et al*., 2015).

We decided to investigate the characteristics above with a case study about the collaboration between a knowledge-intensive service firm that developed medical emergency ventilators (product innovation) in the context of the Covid-19 pandemic. The firm searched for cooperation with different partners (a university, a research institute, suppliers) and led an innovation community to co-create and boost this innovation in 32 countries. This case study allows us to analyse characteristics and organisational practices that drive collaborative innovation and illustrate the cooperation relationship we are studying.

2. Objectives and research questions

2.1. General objective

The main objective of the thesis is to explore the cooperation between manufacturing industries and service firms with universities and research institutes, their propensity to cooperate for innovation activities, and its impact on innovation performance. In addition, analyse a successful case of cooperation for innovation in a context of crisis.

With this in mind, we carry out two empirical studies and one case study, their specific objectives and research questions are mentioned below.

2.2. Specific objectives and research questions

The first empirical study aims to compare companies' innovation performance that succeeded in developing product innovations in cooperation with universities with those companies that cooperated with research institutes. The analysis also compares these two groups' performance with the companies that cooperated with other types of partners.

Specifically, the research questions of this study are:

(1.1) Is there a difference in the innovation performance of firms with product innovations that have cooperated with universities and higher education institutions and the performance of firms with product innovations that have cooperated with public and private research institutions?

(1.2) Is there a difference between the innovation performance of the firms with product innovations that have cooperated with both universities and/or public and private research institutes and that of firms with product innovations that have cooperated with other partners?

Additionally, differences within pairs of cooperation groups owing to the size of the firms are considered in the analysis and the sector is used as a control variable.

The second study aims to explain the probability of a company (manufacturing or services company) cooperating, according to its technological intensity, knowledge intensity or size. In particular, we are interested in explaining whether the manufacturing industries' or service companies' propensity to cooperate with universities and research institutes or other partners is related to these categories of contextual characteristics.

The study addresses the following research questions:

(2.1) Which contextual characteristics (technological / knowledge intensity, size) are statistically significant in the cooperation propensity of manufacturing and service companies?

(2.2) Which contextual characteristics (technological / knowledge intensity, size) are statistically significant in the cooperation propensity with universities and research institutes or other partners?

Finally, the case study aims to analyze the project OxyGEN from the perspective of open innovation. The research questions address in this case study are:

(3.1) Which characteristics, organizational practices and strategies applied by Protofy were remarkable in carrying out the product innovation (low-cost emergency ventilator) during the Covid-19 pandemic and interacting with the innovation community built around this project?

(3.2) Which characteristics and practices used by the members of the OxyGEN project community facilitated the co-creation and promotion of this innovation?

Figure 1 shows the relationship between objectives and research questions and each study in the thesis.

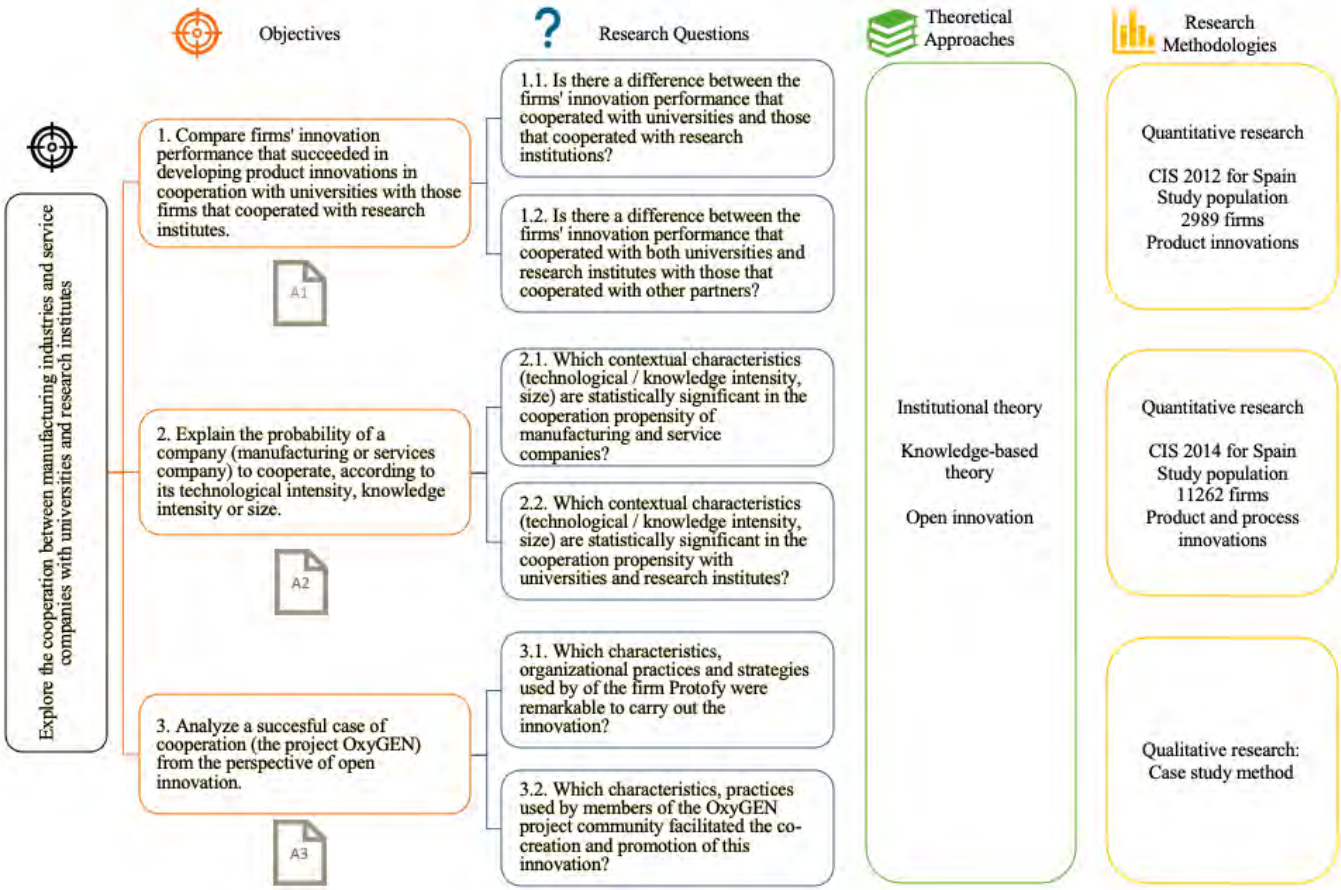

Figure 1. *Objectives, research questions, theoretical approaches, and research methodologies of the thesis studies.*
Own elaboration

3. Thesis structure

The thesis comprises the following chapters. Second chapter addresses the conceptual and theoretical framework; the methodology used in the three studies is briefly described in the third chapter; preprint versions of each empirical studies are included in the fourth and five chapters, the case study is in the sixth chapter, and finally the seventh and eighth chapters present the discussion and conclusions drawn of the thesis.

Figure 2 represents the thesis structure.

Figure 2. *Thesis structure*
Own elaboration

Chapter II

"There is nothing more practical than a good theory."
Kurt Lewin

CONCEPTUAL AND THEORETICAL FRAMEWORK

1. What is innovation?

Innovation is a powerful explanatory factor behind differences in performance between firms, regions, and countries (Fagerberg, 2003).

Numerous studies have been carried out from different fields of knowledge (for example, economics, sociology, engineering, psychology) to understand the phenomenon of innovation, and each discipline has defined innovation from a different perspective (Adams *et al.*, 2006; Damanpour and Schneider, 2006).

For instance, Gopalakrishnan and Damanpour (1997) described the different perspectives of economy, technology management and organizational sociology. Economists view innovation at a high level of aggregation or abstraction, viewing it as one factor causing increased productivity and economic growth at the industrial level, and they generally focus on product and process innovations. Technologists focus on the processes of generation or improvement of new technologies and, like economists, study technological innovations. In this group, they distinguished between contextual technologists and organizational technologists. The

former try to understand the relationship between technological change at the industry level and adaptations at the company level to these changes, while organizational technologists are interested in the factors that influence the generation of technological innovations at the level of organizational subunits such as the R&D department. Finally, sociologists are primarily concerned with organizational characteristics that are compatible with the adoption of innovation within organisations. These authors added that each group addresses a limited aspect of innovation, but remarked that both focus and broad definitions, and the outcome and process views, provide useful insights.

As a result of this conceptual review, Gopalakrishnan and Damanpour (1997) defined innovation as a response mechanism to environmental events to ensure organisational survival and an organisational resource that can inspire managerial choice and selection between two critical aspects of innovation, timing and magnitude.

More recently, Baregheh *et al.* (2009) carried out a content analysis of 60 definitions of "innovation" from seven different disciplines and identified as key attributes: nature of innovation, type of innovation, stages of innovation, social context; means of innovation; and objective of innovation. Building on these attributes, they proposed the following integrative definition: "*Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, services or processes, in order to advance,*

compete and differentiate themselves successfully in their marketplace".

In addition to the perspective of academic disciplines, the member countries of the Organization for Economic Cooperation and Development (OECD) have adopted the definition of the Oslo Manual for carrying out statistical studies on innovation at the national and regional levels, such as the Community Innovation Survey (CIS) in the European Union. This manual defines innovation as "*...the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations"* (OECD and Eurostat, 2005).

The empirical studies of the thesis used the CIS database; therefore, they adopted this definition of innovation from the Oslo Manual and the different types of innovation, which are described below.

1.1. Types of innovations

The Oslo Manual (2005) distinguishes four types of innovations: product innovation, process innovation, marketing innovation and organizational innovation. They are defined as follows:

Product innovation *is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials or other functional characteristics.*

Process innovation *is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software*.

Both product and process innovations are closely related to technological innovations.

Marketing innovation *is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing*.

Organisational innovation *is the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations.*

Table 1 shows type of innovations, definitions, and subcomponents.

According to these definitions, the first study of the thesis focused on companies that introduced product innovations *(new or significantly improved goods and services)* on the market. On the other hand, the second study also included companies that implemented process innovations *(new or significantly improved production or delivery methods)* in the firm's operation. Both are regarded as technological innovations since firms implemented new technology into their business.

The case study analysed a product innovation and the organisational innovations implemented in the firm to co-create that product with an innovation community.

Table 1. Types of innovations, definitions, and subcomponents

Type of innovation	Subcomponents	Definition	Includes
Product innovation	-Goods -Services	New or significantly improved goods and services with respect their characteristics or intended uses.	-Technical specifications -Changes in materials, components, incorporated software, and other functional characteristics that enhance performance.
Process innovation	-Production -Delivery and Logistics -Ancillary services, including purchasing, accounting, and ICT services	New or significantly improved production or delivery methods.	-Production methods involve the techniques, equipment and/or software used to produce goods or services. -Delivery methods concern the logistics of the firm and encompass equipment, software, and techniques to source inputs, allocate supplies within the firm, or deliver final products
Marketing innovation	-Design of products -Product placement and packaging -Product promotion -Pricing	Implementation of a new marketing methods.	-The new marketing method can either be developed by the innovating firm or adopted from other firms or organisations. -New marketing methods can be implemented for both new and existing products. -Product design changes here refer to changes in product form and appearance that do not alter the product's functional or user characteristics.
Organisational innovation	-Business practices -Workplace organization -External relations	Implementation of a new organisational method in the firm's business practices, workplace organisation or external relations	-New methods for organising routines and procedures for the conduct of work. -New methods for distributing responsibilities and decision making among employees for the division of work. -New concepts for the structuring of activities, such as the integration of different business activities.

Source: Oslo Manual, 2005.
Own elaboration

1.2. Novelty of innovations

All types of innovations involve a grade of novelty. The Oslo Manual (2005) distinguish three relevant concepts related to the novelty of the innovations: new to the firm, new to the market and new to the world. The innovation developer (firm or other firms) and the diffusion of innovation are related to these novelty concepts.

The minimum grade of an innovation is "*new to the firm*". Other firms may have already implemented a product, process, marketing or organisational innovation. However, if it is new to the firm (or, in the case of product and process: significantly improved), it is an innovation for that firm.

An innovation is "*new to the market or new to the world*", whether other firms have already implemented it, or whether the firm is the first to introduce innovation on its market or industry or worldwide to have implemented it. Firms that first develop an innovation (new to the market or new to the world) are drivers of innovation in the economy. Even though, it depends on the adoption of innovations by other firms.

Following these definitions, the first study of the thesis analyses the product innovations introduced by firms and developed in cooperation with other partners. These innovations were new to the firm or new to the market. Both categories were used to measure innovation performance of firms, as explained in section 4.

2. The innovation system: How does innovation occur?

Beyond the concept of innovation, Fagerberg (2003) argued that a central finding in the innovation literature is that a firm does not innovate in isolation but depends on extensive interaction with its environment.

The introduction of concepts like "system" and "networks" reflect the systemic nature of innovation. There is not a consensus on the definition of the innovation system, however, Granstrand and Holgersson (2020) carried out an extensive literature review and stated, *"Innovation system is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors*".

In this definition, the authors explained that *"artifacts"* include products and services, tangible and intangible resources, technological and non-technological resources, and other types of system inputs and outputs, including innovations. The *"complementary and substitute relations"* refers to collaborative and competitive relations. Finally, ***"innovative performance"*** is used rather than innovations or innovativeness to facilitate the operationalization of the concept in economic terms.

The Oslo Manual (2005) has remarked that the innovation system changes the focus of policy towards the interplay of institutions and the interactive processes at work in the creation of

knowledge and its diffusion and application. Furthermore, it states that the innovative activities of a company depend in part on the variety and structure of its links with sources of knowledge, technologies, practices and resources. Connecting the company with other actors in the innovation system such as government laboratories, universities, policy departments, regulators, competitors, suppliers and customers.

3. Innovation performance: How is innovation measured?

Measuring innovation is related to the performance of enterprises, industries, and the economy. At the level of firms, the impact of innovations on enterprise performance ranges from effects on turnover and market share to changes in productivity and efficiency. And, at the industry and national levels, some effects are changes in competitiveness and total factor productivity, knowledge spillovers of firm-level innovations, and an increase in the amount of knowledge flowing through networks (OECD and Eurostat, 2005).

Dewangan and Godse (2014) conducted an extensive literature review about innovation performance measurement (IPM) schemes and observed a consensus on adopting a multi-dimensional approach. However, they also found a significant divergence of opinions on the dimensions and methods used. For instance, Adams *et al*. (2006) proposed categories, such as inputs, knowledge management, innovation strategy, organization and culture, portfolio management, project management, and commercialization. At the same time, Ojanen and Voula (2006) listed several methods of

categorization: based on measurement, perspective, the purpose of measurement, measurement level, R&D type, and process phase. Derived from their research, the authors suggested a set of guiding principles for developing a robust IPM scheme that distinguishes between the measurement of invention (including innovation) and exploitation.

On the other hand, the four types of innovations defined in the latest (3rd ed.) Oslo Manual, the degrees of novelty and diffusion constitute the basis of the indicators used by the OECD to measure the performance of innovation at the level of the firms. There are five indicators categories: technological innovation, non-technological innovation, the measure of innovation inputs, innovation outcomes, and relevant aspects of innovation policies (OECD, 2009).

The first category concerns product and process innovations, degree of novelty and whether the firms developed innovations partially or fully in-house. The second measures the implementation of marketing and organizational innovations. The measure of innovation inputs includes the total R&D expenditures and the distribution of innovation expenditures.

The quantitative innovation output indicators measure the impact and scope of innovation activity. The two indicators measure the output of product innovations in terms of share turnover: the first measures the share of turnover due to product innovations new to the firm, and the second measures the percentage of turnover due to product innovations new to the market.

The last group is composed of indicators that focus on aspects relevant for developing of policies such as: internationalization, cooperation, and intellectual property rights. These indicators measure the active firms in foreign markets, firms that have collaborated with foreign partners on innovation; share of firms that have collaborated with public research institutions and other types of partners.

Based on these categories of indicators, the first empirical study of the thesis focuses on the innovation output indicators to measure the impact on the firms' innovation performance. Mainly this study compares both sub-categories (share of turnover due to product innovations new to the firm or new to the market) between firms that cooperated with universities and research institutions to find possible differences.

4. Inter-organisational relations and innovation

Inter-organisational relations (IORs), by definition, is concerned with relationships between and among organizations. They can be public, business, or non-profit, and the relationships can range from dyadic, involving just two organisations, to multiple, involving huge networks of many organisations (Cropper *et al*., 2008).

The most common form of IORs are interactive relations which involve the flow of knowledge (e.g., tacit and explicit) and resources (e.g., tangibles and intangibles) between organizations, the actors who manage these flows and coordinate the relationship and

the structure which facilitate or limit their capacity for joint action (Cropper *et al.*, 2008).

The analysis of IORs is performed at the micro and macro levels. The micro-level includes the analysis of groups and individuals and the impact on the processes, **performance**, dynamic development, effectiveness, or type of results of the IORs. On the other hand, the macro-level comprises the IORs institutional environment (the legal, political, economic, national, cultural, spatial, and historical contexts). The micro and macro contexts in which IORs operate may or not change over time and may be related to the particular historical context in which they occur (Cropper *et al.*, 2008).

Within the context of innovation, Powell *et al.* (1996) argued that when an industry's knowledge base is complex and expanding and sources of expertise are widely dispersed, the place of innovation will be found in learning networks rather than individual companies. Moreover, Faems *et al.* (2005) supported there is a positive relationship between inter-organizational collaboration and innovative performance. At the same time, the impact on innovation performance differs depending on the nature of the partner(s) involved and strongly suggests the adoption of a portfolio approach.

Since the previous definition of an innovation system (e.g., Granstrand and Holgersson, 2020) and the positive relationship between inter-organizational relationships and innovation performance (e.g., Faems *et al.*, 2005). The first study also compares

the innovation performance of companies that have cooperated with universities and research institutes with the innovation performance companies that cooperated with other types of partners to find possible differences between those cooperation groups.

5. Theoretical approaches for firms' cooperation

About inter-organizational relationships in the context of innovation, a question naturally arises: What are the motivations of companies to initiate such relationships? To answer this question, we reviewed the most widely used theoretical approaches in the organizational management literature and propose how they contribute to the issue of firms´ cooperation. These approaches are the institutional theory, the resource-based theory, the transaction cost theory, and the knowledge-based theory.

5.1. Institutional Theory

The institutional theory asserts that normative pressures from external sources (e.g., the state, other collective institutions) and internal pressures influence organizations. These pressures lead them to adopt certain legitimate elements (e.g., standard operating procedures, professional certifications) and state requirements that increase their probability of survival (Zucker, 1987).

In this sense, Furusten (2013) argued that managers make the possible decisions within the institutional framework of their organizations, regardless of whether they agree or are aware of them. Thus, knowledge of the institutional environment will increase the probability of making more appropriate decisions.

Suddaby (2010) argued that institutionalism is the dominant theory for studying macro-organizational phenomena and cautions that it may have extended far beyond its core purpose: understanding how organizational structures and processes acquire meaning and continuity beyond their technical goals.

From institutional theory, the companies search to engage in collaborative relationships because they allow them to acquire legitimacy and achieve institutional insertion. For instance, some benefits to a business from collaboration with an university in R&D activities are the increase of the R&D business productivity; the increase of the probability of an R&D project commercialization, and a business's economies of technological scope (Cunningham and Link, 2015).

On the other hand, several initiatives have been implemented by OECD member countries and public research organizations (PROs) to foster the transfer and strengthen the commercialisation of public research results. For example: legislative initiatives related to commercialisation and patenting, encouraging industry engagement by granting licenses on IP rights free of charge, legislative and administrative procedures targeting research personnel and faculty, and formation of bridging and intermediaries organisations in the form of technology transfer offices (TTOs) (OECD, 2013).

5.2. Resource-based Theory

In 1991, Barney stated, *"sustained competitive advantage derives from the resources and capabilities that firm controls which are*

valuable, rare, imperfectly, and not substitutable. These resources and capabilities can be viewed as bundles of tangible and intangible assets, including a firm's management skills, its organizational processes and routines, and the information and knowledge it controls". Ten years later, Barney (2001) stated that the resource-based view of the firm was the most influential framework for understanding strategic management.

Some authors have revisited the starting premise of RBT to extend it and find new opportunities for future research. For instance, Fiol (2001) questioned if it is possible to achieve a sustainable competitive advantage based on any particular core competency, no matter how inimitable. The author argued '*the skills/resources of organizations and the way organizations use them must constantly change to produce continuously changing temporary advantages*'. Furthermore, Harrison *et al* (2001) pointed out that the integration of complementary resources provides opportunities for a company to create permanent competitive advantages over time, improve learning and develop new capacities. However, to achieve unique synergy, resources must be integrated and managed effectively.

Firms can access, exchange, or internalize supplementary or complementary resources through alliances. Thus, investigation the role of alliance partners from a resource and capabilities perspectives can reveal insights on how different partners affects the benefits obtained from alliance portfolios (Wassmer, 2010).

5.3. Transaction Cost Theory

Transaction cost theory (Williamson 1979, 1986) posited that the optimum organizational structure is one that achieves economic efficiency by minimizing the costs of exchange. The theory suggests that each type of transaction produces coordination costs of monitoring, controlling, and managing transactions. Changes in these variables should shift the weighting in decision-making between in-house production and use of the market.

The variables used as cost evaluation mechanisms are the frequency of exchange, the specificity of the assets, the uncertainty and the threat of opportunism. The first variable refers to the frequency in which the transactions between the parties occur; the specificity variable refers to the site, physical asset or human asset; the uncertainty refers to factors in the environment that could increase time or changes in processes. Finally, the threat of opportunism is attributed to human nature (Williamson, 1979).

Cooperation may reduce transaction costs through better control and monitoring of technology transfer than on arm's length markets, while the inherent reciprocal relationship and between partners with complementary capabilities can minimize opportunism (e.g., Pisano, 1990).

In this sense, the transaction-cost theory contributes to explain how firms govern the collaborative innovation relationship. However, Yasuda (2005) compared the resource-based theory and the transaction-cost theory in their suitability to explain four types of

strategic alliances in high-technology industries and concluded that the former theory prevails over the transaction-cost theory.

5.4. Knowledge-based Theory

According to Grant (1996), the firm is an institution for integrating knowledge. This approach is distinguished from other theories by two assumptions: first, knowledge creation is an individual activity and second, the primary role of firms is in the application of existing knowledge to the production of goods and services.

The foundations this theory builds upon are the characteristics of knowledge and two fundamental assumptions about the role of knowledge within a firm. Grant (1996) argued that pertinent characteristics for the generation of value are transferability, aggregation capacity and appropriability. On the other hand, the assumptions to take into account are specialization in knowledge acquisition and knowledge requirements for production. The first, given that the human brain has a limited capacity to create new knowledge, store it and process it, therefore knowledge acquisition requires greater specialization; and the second, recognizing that production implies the transformation of inputs into outputs (goods and services), from this theory, the knowledge is both the critical input and the main source of value.

The knowledge-based theory has implications for the analysis of organisational capability and the principles of organisational design, particularly for hierarchical structures and the distribution of

decision-making throughout the company, as well as enables a discussion on the boundaries of the firms.

The organisational capability level is dependent on the integration of specialized knowledge, thus, Grant (1996) suggested that the managerial task will be to maximize the use of norms, directives and other coordination mechanisms to optimize the knowledge transfer and individual or team problem-solving according to the complexity of the task.

The boundaries of the firms are analyzed in terms of the relative efficiency of the use of knowledge. For example, production stages can be vertically integrated when one of them requires access to the knowledge used in the other stage. Conversely, if they are independent stages in the use of knowledge, they can be efficiently conducted by separate companies linked by a market interface.

Furthermore, efficient knowledge utilization requires multiproduct firms, Grant and Baden-Fuller (1995) explained that companies can be characterized as both product domain and knowledge domain. Efficient knowledge utilization requires congruence between the knowledge domain of the firms and its product domain. As there is no perfect congruence, it creates opportunities for knowledge acquisition through strategic alliances.

Apart from lack of congruence, there are two other aspects of knowledge-product linkages conducive to inter-firm collaboration: uncertainty and the dynamics of early-mover advantage. Grant and Baden-Fuller (1995) explained that both occur when technological

changes are rapid, the firms have greater uncertainty about the knowledge that they need to integrate into products and the processes of knowledge acquisition and integration must be fast to obtain an advantage, so in these circumstances, cooperation with other companies is more beneficial.

Consequently, the knowledge-based theory explains how specialized knowledge is distributed into the organization and how it is applied in production. In addition, it contributes to understanding how knowledge acquisition and integration drives inter-firm cooperation.

Table 2 presents a summary of the theoretical approaches and their contribution for firms' cooperation.

Table 2. Summary of theoretical approaches for firms' cooperation

Theories	Focus	Contribution for firms' cooperation	Main Authors
Institutional Theory	Normative pressures from external sources (e.g., the state, other collective institutions) and internal pressures influence organizations to adopt certain legitimate elements and state requirements.	How do firm acquire legitimization and institutional insertion?	Zucker, 1987; Suddaby, 2010
Resource-Based Theory	Sustained competitive advantage derives from the resources and capabilities that a firm control which are valuable, rare, imperfectly imitable, and not substitutable.	How do firm access to supplementary or complementary resources through alliances?	Barney, 1991; Penrose 1995; Wernerfelt, 1994.
Transactional Cost Theory	The optimum organizational structure is one that achieves economic efficiency by minimizing the costs of exchange.	How do firms govern the collaborative innovation relationship?	Williamson 1979, 1986 Pisano, 1990
Knowledge-Based Theory	Knowledge creation is an individual activity, and the primary role of firms is in the application of existing knowledge to the production of goods and services.	How specialized knowledge is distributed into the organization and how does it apply in production? How does knowledge acquisition and integration drive inter-firm cooperation?	Grant, 1996; Grant and Baden-Fuller (1995)

Own elaboration.

Obradović *et al.* (2021) conducted a systematic review of open innovation literature and confirmed the diversity of theoretical approaches used within the manufacturing industry context. The most frequently approaches were the knowledge-based view, supply chain management, and the resource- based view, while transaction cost economics theory and the institutional theory were the least studied theories. The results also showed that resource-based and knowledge-based views have been often studied together, along with topics such as open strategy, innovation, and collaboration.

Considering above explanations, the theoretical approaches that framework the thesis's studies are the institutional theory and knowledge-based theory. First, because the cooperation relationship between firms (manufacturing industries and services companies) with universities and research institutes (PROs) has been influenced by the policies and incentives at the institutional level.

On the other hand, firms have a set of tangible and intangible resources, the most important are people, who have the knowledge and skills to manage these resources and therefore are essential in generating a competitive advantage. The knowledge-based theory helps us to understand the cooperation relationship between firms, universities, and research institutes because from this perspective, firms acquire and integrate knowledge in their production to generate product or process innovations. During this process, knowledge is not only transfer but created.

6. Open Innovation: A new approach of innovation

Since Chesbrough's (2003) seminal work, the concept of open innovation (hereafter OI) has evolved. He stated, *"… valuable ideas can come from inside or outside the company and can also go to market from inside or outside the company"*, to explain the change in companies' practices that move from the earlier "closed innovation model" towards a logic of an open innovation model.

Later, Chesbrough (2006) expanded the concept and adds that *"Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively"*. This critical conceptual distinction proposes that spillovers are transformed into inflows and outflows of knowledge which can purposively manage. For that, firms can develop processes to move external knowledge into their own innovation activities and create mechanisms for transferring knowledge to other organizations.

Building on these previous concepts, extensive research has been conducted in the past decade to understand this paradigm better. For instance, Lichtenthaler (2011) explained: *"Open innovation is defined as systematically performing knowledge exploration, retention, and exploitation inside and outside an organization's boundaries throughout the innovation process"*.

Once again, Chesbrough and Bogers (2014) provided an updated definition: *"we define open innovation as a distributed innovation process based on knowledge flows intentionally managed*

across organisational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model". Following this definition, the authors remark that innovation refers to developing and commercialising new or improved products, processes, or services. Simultaneously, the knowledge flows across the permeable organisational boundary representing openness.

Finally, Chesbrough (2017) explained that the organization's business model helps to determine what knowledge to bring from outside and what internal knowledge could find a route outside the organization in the future. That is the operative concept of open innovation.

6.1. Types and mechanisms of open innovation

Chesbrough and Bogers (2014) explained that knowledge spillovers generally follow two directions across the boundaries of the organization "*the purposive inflow and outflow of knowledge"*. The outside-in or the **inbound OI** allows firms to acquire new knowledge, new ideas, and new technologies from outside of the firm. The mechanisms used to manage inbound innovation are scouting, licensing IP, university research programs, funding startups, collaborating with suppliers and customers, utilizing nondisclosure agreements, crowdsourcing, competitions and tournaments, and communities.

On the other hand, the inside-out or the **outbound OI** implies moving knowledge from inside the firm out to other organizations in the surrounding environment. The mechanisms for managing

outbound innovation include out-licensing IP and technology, donating IP and technology, spin-outs, corporate venture capital, corporate incubators, joint ventures and alliances.

Gassmann and Enkel (2007) identified a third type of open innovation. It is a couple of outside-in and inside-out flows of knowledge. The mechanisms for managing the linking inbound and outbound innovation are strategic alliances, joint ventures, consortia, networks, ecosystems, and platforms, all involving complementary partners.

Later, Dahlander and Gann (2010) defined two inbound processes, sourcing and acquisition, two outbound processes, disclosure and sale processes. They find advantages and disadvantages for each of them. For instance, there are benefits from buying or in-source external ideas to the organisation, but to search for and evaluate them expertise is required. On the other hand, one of the companies' concerns when disclosing information to the outside environment is intellectual property. For this, companies used to adopt both formal methods (such as protection of patents, trademarks or copyrights) and informal methods (deadlines of delivery, advantages of being the first to act, blocks) within their appropriability strategies. The premise is that openness does not always reduce the probability of success (Henkel, 2006; von Hippel, 2005).

Figure 3 shows the model of open innovation by Chesbrough and Bogers, 2014.

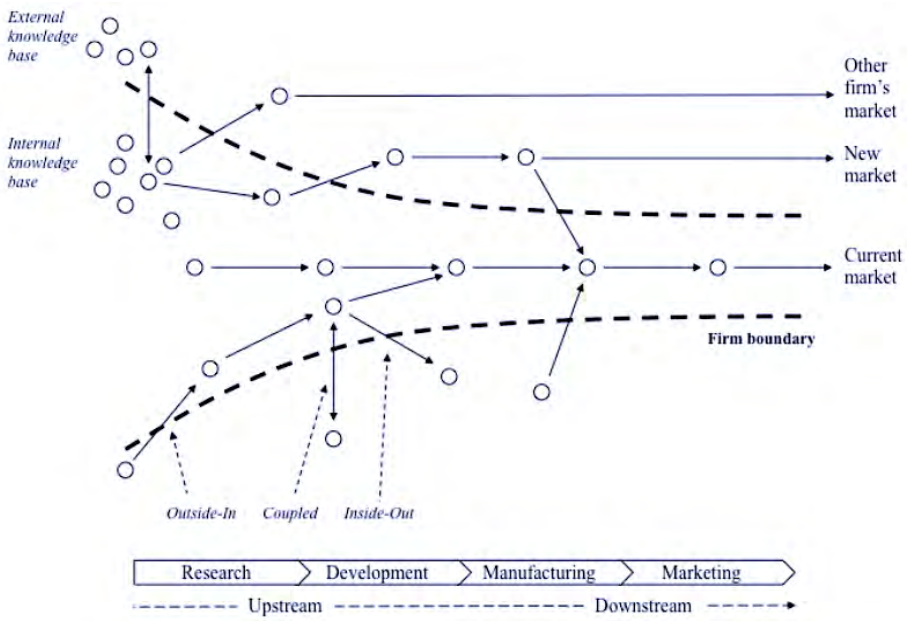

***Figure 3**. Open Innovation model by Chesbrough and Boger (2014)*

7. Cooperation and innovation performance

After Chesbrough's open innovation (OI) definition in 2003, many researchers performed empirical studies to link this new paradigm and innovation performance (Greco *et al*., 2015).

A fundamental contribution to the OI literature is the study carried out by Laursen and Salter (2006). They examined the relation of "openness" in determining the company's innovation performance. To do this, they operationalized the openness with two variables: breadth and depth. The first refers to the number of external sources that the company searches to carry out the innovation and the second

variable is the extensive use of those external sources. These authors found that both indicators (breadth and depth) have a curvilinear relationship with companies' innovation performance.

Greco *et al*. (2015) systematically reviewed literature in European countries for a decade (2003 to 2013), creating a new taxonomy to analyse these pieces of evidence. They classified external and internal OI actions according to the concepts of search breadth and search depth introduced by Laursen and Salter (2006) as components of the openness of an individual firms' strategies.

The Greco's model measured the impact of OI actions on the following types of innovation performance: Increase on radical or incremental product innovation, increase on new to the firm product innovation, and increase on product or process innovations in general terms. These types of innovation performance were related with external sources of innovation: customers, suppliers, research institutions (universities and research institutions) and competitors.

The authors found that process innovation is more likely to benefit from coupled OI activities than inbound activities. Moreover, the effect of coupled actions (collaboration) on product and process innovations performance was always positive. On the other hand, the effect of the outbound OI activities was infrequent.The actions analysis by sources showed that actions with suppliers were likely more practical and efficiency-driven than customers. Moreover, interactions with research institutions were always positive, not so

with competitors, because they share knowledge and establish relations win to win but maintain their competitive advantages.

Other studies have explained how the different types of cooperation (networks, alliance portfolios) influence the innovation performance based on the OI approach. For example, Duysters and Lokshin (2011) explored the decision of companies to form alliance portfolios with different types of partners: competitors, clients, suppliers and university and research centres, which can be foreign or national alliances. The results show that the complexity of the alliance has an inverse U-shaped relationship with innovative performance. Although complexity facilitates learning and innovation, each organization has a certain management capacity to deal with complexity, implying a limit in the portfolio of alliances that firms could deal with properly to obtain benefits. Moreover, de Leeuw *et al*. (2014) found that a lower level of partner diversity in a firm's alliance portfolio is needed to achieve optimal productivity and radical innovative performance. However, the opposite is true for incremental innovative performance; a higher level of portfolio diversity appears to give the best performance. ***Figure 4*** shows the

relationship between alliance portfolio diversity and innovation performance by de Leeuw *et al.*, 2014.

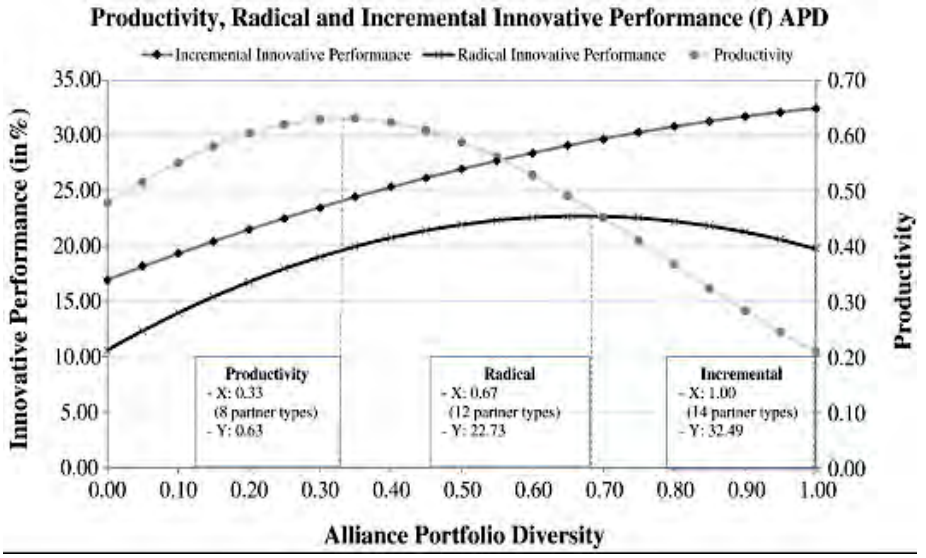

***Figure 4**. Relationship between alliance portfolio and innovation performance (de Leeuw et al., 2014)*

8. Cooperation with different types of partners

The cooperation studies have showed that the impact of cooperation on firm performance differs according to the types of partners. For instance, Belderbos *et al*. (2004) argued that the cooperation between **competitors and suppliers** focuses on incremental innovations, improving the productivity performance of companies, while cooperation with **universities and research institutions** are fundamental to create innovative products that are novel in the market, improving the growth of companies. Moreover, Kang K. and Kang J. (2010) found that R&D collaborations with **customers and**

universities positively affect product innovation, whereas R&D collaborations with **suppliers and competitors** have an inverted-U shape relationship with product innovation. Un *et al*. (2010) also found that collaborating with competitors had a negative impact on radical innovations and innovations new to the firm, and Elche-Hotelano (2011) showed that relations with customers and suppliers had a negative effect on product and process innovation.

On the other hand, Un and Asakawa (2015) argued that prior insights from studies of product innovation do not necessary apply to process innovation. They found that R&D collaborations with suppliers and universities appear to have a positive impact on process innovation, R&D collaborations with customers appear to have no impact, and R&D collaborations with competitors appear to have a negative impact.

9. Cooperation with universities and research institutes

Cooperation between companies and universities is perceived as a vehicle to improve innovation through knowledge exchange, consequently, a significant number of studies analyze this relationship from different perspectives (Ankrah and AL-Tabbaa, 2015). In the thesis we focus on studying the effects of cooperation with universities and research institutes in the firms' performance and determinants that could affect this relationship.

9.1. Manufacturing industries in cooperation with universities and research institutes

As Cohen *et al*. (2002) stated, the influence of public research (universities and government R&D labs) is critical to industrial R&D in a small number of industries; it significantly affects industrial R&D across the manufacturing sector.

Previous studies have highlighted the mutual benefits of cooperation between industries and universities (Cunningham and Link, 2015) but also warn that there are inter-sectoral differences in the association and investigate its determinants and drivers. For instance, Arranz and Fernández (2008) found that R&D cooperation is more significant in companies belonging to high-tech sectors. They also pointed out that firm size and permanent R&D capacity are essential factors in the propensity to sign R&D agreements. The existence of public funds represents the promotion of innovation, has a positive influence and is significant in the probability of cooperating in Spanish companies, the impact of each variable being very similar.

On the other hand, Maietta (2015) analyzed the effect of collaboration in a low-tech industry (food and drink (F&D) firms). The author found that this type of firm collaborates with universities and public research labs to access new ideas and government funding, develop internal expertise and reduce time to market with new technologies, particularly for process innovation and new market penetration.

Hirsch-Kreinsen (2008) explained that low-medium-tech (LMT) and high-medium-tech (HMT) industries have 'modes of innovation' that clearly differ in terms of important causes and determinants, such as key factors, their specific knowledge base, company capabilities and competencies, or network relationships. However, these factors are interdependent and mutually supportive.

9.2. Services companies in cooperation with universities and research institutes

Few empirical studies have focused on the relationship between service companies and universities. Among them, there is an important discussion about service companies' interest in this type of cooperation. For example, Tether and Tajar (2008) found significant differences in the types of providers of specialized knowledge used by manufacturing and service companies as sources of information in innovation activities. Furthermore, they noted that although service companies are more likely than manufacturers to use expertise providers, they are more likely to hire consultants. At the same time, their links with research organizations (universities and government research labs) are weaker.

On the other hand, Janeiro *et al.* (2013) explored innovative service firms that adopted universities as innovation sources. As a result, they found that the services firms with a high level of **'innovation success'**, those considered **'innovation leaders'** (radical innovations), and firms belonging to the KIBS sector (**innovation intensity**) are more likely to develop links with **universities**. In this

model, the innovation success represents a firm's success in obtaining positive outcomes from its innovation activities such as entry into new markets, an increasing market share, and reduced unit labour costs. The innovation intensity considers the investment in activities, equipment, and staff in R&D.

9.3. Cooperation with universities or research institutes

Different names are used in the literature to refer to research and technology organizations (RTO) such as public institutes, research institutes, technological institutes (Gulbrandsen, 2011).

Several studies categorized RTOs alongside universities (e.g., Belderbos *et al*., 2006; Duysters and Lokshin, 2011; Guzzini and Iacobucci, 2017), but they have different concepts and accomplish different roles in National Innovation Systems. The European Association of Research and Technology Organizations (EARTO) defines RTOs as organizations with the *"central mission of harnessing science and technology at the service of innovation, improving quality of life and generating economic competitiveness"*. Its main activity is *"to provide research and development, technology and innovation services to companies, governments and other clients…"* (EURAB, 2005).

Research institutes and universities increasingly overlap and cooperate to produce knowledge; they are "complements, not substitutes", who have different fundamental skills and abilities (Arnold *et al*., 2010).

In this line, Giannopoulou *et al.* (2019) analyzed the distinct role of RTOs versus universities regarding firms' innovation performance. They found that firms that see RTOs as a more important source of knowledge than universities are more likely to develop service innovation, invest less in internal R&D but are less likely to introduce world-first innovations. On the other hand, firms that consider RTOs and universities important external knowledge sources are less likely to report introducing process and organizational innovations.

Chen *et al.* (2020) supported that the scientific performance of research institutes is significantly affected by their network positions in the research collaboration networks with industries or/and universities. Specifically, in the "University-Research Institute" collaboration network, the research institutes' degree centrality has an inverted U-shaped effect on their scientific performance. The authors have explained that this effect occurs in the UR collaboration network, where both research institutes and universities operate in similar institutional systems that generate more homogeneous resources. Conversely, in both "Industry-Research Institute" and "Industry-University-Research Institute" collaboration networks, the research institutes' degree centrality positively affects their scientific performance.

9.4. Determinants in the cooperation between industries, universities, and research institutes

The main internal and external characteristics, mentioned in the literature, as determinants in the industry-universities cooperation, are size, age, R&D intensity (Laursen and Salter, 2004; Segarra-Ciprés *et al.*, 2012), openness strategies (Fontana *et al*., 2006), geographic proximity (Laursen *et al*., 2011), territorial characteristics, location in industrial clusters (D'Este *et al*., 2013; Mohnen *et al*., 2018). Finally, some studies have investigated absorptive capacity as a moderator in the relationship between industries-universities (Kobarg *et al*., 2018; Tsai, 2009).

9.4.1. R&D characteristics and openness strategies

Laursen and Salter (2004) examined the factors influencing manufacturing industries to draw from university in their innovation activities and found that companies that adopt ***'open' search strategies*** and ***invest in R&D*** are more likely than other firms to cooperate with universities and achieve satisfactory results.

Further, Fontana *et al.* (2006) explained two determinants of cooperation between manufacturing and service companies and public research organisations (PRO). First, the cooperation agreements firm/PRO depend on the industrial partner's 'absolute size'. Second, companies' openness to the external environment, measured by their willingness to 'search, filter and signaling' those agreements affect the establishment of R&D projects.

On the other hand, Segarra-Ciprés *et al.* (2012) found that the most R&D intensive firms and sectors explore external sources of knowledge to a greater extent than those which are less R&D intensive. Conversely, no substantial differences emerge concerning the exploitation of these sources.

9.4.2. Firm size

Studies about the innovation behaviour of companies use the firm's size as an explanatory variable (Becheikh *et al.*, 2006). The differences between large and small companies could explain the positive effect of size; the former have more resources to innovate and support risky activities than SMEs (W. Tsai, 2001). They can also benefit from economies of scale in R&D, production and marketing (Stock *et al.*, 2002).

According to these differences, the first adopters of OI practices were large high-tech companies (Chesbrough, 2003). However, van de Vrande *et al.* (2008) found that SMEs are also engaged in many OI practices, although SMEs pursue open innovation primarily for market-related motives such as meeting customer demands or keeping up with competitors. Moreover, Spithoven *et al.* (2013) argued that SMEs are more effective in using different OI practices simultaneously when introducing new products on the market, whereas this is less the case for large firms.

Notably, in cooperation with universities, Santoro and Chackrabarti (2002) found that large firms have higher intensity knowledge transfer and research support relationships for

strengthening skills, knowledge, and access to university facilities for ancillary, non-core technologies. However, the opposite is true for small firms that engage in relationships to strengthen skills, knowledge, and access to university facilities for essential, core technologies.

9.4.3. Location, territorial characteristics, and clusters

Some studies have examined firm's location, territorial characteristics, and clusters as determinants of cooperation with universities. For instance, Laursen *et al.* (2011) argued that firms' decision to collaborate with universities is dependable on the geographic proximity and quality of the university. The proximity of top research universities promotes firms' collaboration. Still, they observed that it does not work in general, and high-tech intensity firms prefer the university partner's research quality over geographical closeness.

Mohnen *et al.* (2018) found that the degree of internationalization of the firm is the primary determinant of cooperation with foreign universities. Differences in cooperation determinants appear between countries by cluster analysis on variables describing their institutional settings and national innovation systems.

9.4.4. The absorptive capacity

Absorptive capacity is the firm's ability to use its prior related knowledge to recognize, assimilate, and use external knowledge for its commercial ends (Cohen and Levinthal, 1990).

Based on this concept, some researchers have explored the effect of absorptive capacity on the relation between different types of partners, particularly universities-industries and innovation performance. For instance, (K.-H. H. Tsai, 2009) supported that absorptive capacity negatively affects the relationship between customer collaboration and the performance of marginally changed products. Conversely, it positively affects the relationships between competitor collaboration and the performance of new products with marginal changes. Tsai maintains that absorptive capacity negatively affects the relationship between collaboration with research organizations (universities and research institutes) and the performance of technologically new or improved products. While the opposite is true between research organizations collaboration and the performance of marginally changed products.

Kobarg *et al.* (2018) searched for the potential influence of the absorptive capacity on the relationship between universities-industries cooperation (UIC) and product innovation performance. They obtained the following results: (1) absorptive capacity in terms of internal R&D negatively moderates the relationship between UIC and incremental innovation performance; (2) absorptive capacity related to employee know-how positively moderates the relationship between UIC and radical innovation performance.

C h a p t e r I I I

"The methods section provides the essential information that allows the reader to judge the validity of the results and conclusions."
Azevedo et al., 2011

METHODOLOGY

We chose the quantitative and qualitative research methods in the thesis to achieve the research objectives and obtain valid and reliable results. This chapter describes the database used, the samples selected, and the data analysis techniques carried out in the two empirical studies. And also, explain the case study design: the unit of analysis, the rationale for a single case study, data collection, and their analysis.

1. Empirical studies' methodology

1.1. Database description

The empirical studies of the thesis used data from the Community Innovation Survey (CIS) for Spain. The first article used CIS 2012 and the second CIS 2014. The CIS survey-based innovation statistics are part of the EU science and technology statistics. Surveys are carried out on a two-year basis throughout the European Union and many SSE countries (Eurostat, 2020). The CIS data is normally released two and a half years after the survey is carried out.

The Commission Implementing Regulation (EU) No. 995/2012 on innovation statistics defines the variables to be

collected, the target population, the sectors to be covered and the breakdowns by size classes of the results for CIS.

1.1.1. Target population

According to the above regulation, the target population for the CIS survey are all enterprises with at least ten employees. They are organized into three size classes: a) Firms with 10-49 employees, b) Firms with 50-249 employees and c) Firms with 250 and more employees.

The enterprises have market activities included in Core NACE Rev. 2 sections B, C, D, E, H, J, K and divisions 46, 71, 72 and 73.

Table 3 describes this classification according to Eurostat.

Table 3. Firm's market activities according to NACE Rev.2

Sections	Title	Divisions
B	Mining and quarrying	05-09
C	Manufacturing	10-33
D	Electricity, gas steam and air conditioning supply	35
E	Water supply; sewerage, waste management and remediation activities	36-39
	Wholesale trade, except of motor vehicles and motorcycles	46
H	Transportation and storage	49-53
J	Information and communication	58-63
K	Financial and insurance activities	64-66
	Architectural and engineering activities; technical testing and analysis	71
	Scientific research and development	72
	Advertising and market research	73

Source: Eurostat-Detailed Structure of NACE Rev. 2.
Own elaboration

1.1.2. Data collection

The CIS survey (2012 and 2014 versions) apply the concepts and methodological guidelines for collecting and using data on innovation recommended in the Oslo Manual (3rd ed 2005) and Eurostat, the statistical office of the EU, develops harmonised definitions, classifications and methodologies for the production of European official statistics, in cooperation with national statistical authorities.

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 method was used for smaller enterprises.

The overall sample for CIS 2012 was 32,120 Spanish enterprises representing 42% of the target population. On the other hand, for CIS 2014 the overall sample accounted for 27,092, it corresponds to 39.4%.

Table 4 summarizes characteristics of Spanish CIS 2012 and CIS 2014 data collection and target population.

Table 4. Characteristics of the CIS 2012 and CIS 2014 for Spain

	CIS 2012	**CIS 2014**
Type of data collection	Mandatory	Mandatory
Data collection methods	Combination sample/census	Combination sample/census
Criterion to conduct a census	Size class (200+) and R&D performers	Size class (200+) and R&D performers
Target population	76,338 enterprises	68,683 enterprises
Sample	32,120 enterprises	27,092 enterprises
Overall Sample rate (%)	42.0%	39.4%

Source: Eurostat, CIS 2012 and CIS 2014 Synthesis of the Quality Reports.
Own elaboration.

1.2. The studies' population

Following the objective of the first study, we focused on firms that developed product innovations (new or significantly improved goods and services) in cooperation with partners, specifically with universities and research institutes. Thus, from the total number of enterprises surveyed in Spain during the study period 2010-2012, the firms that introduced product innovations were 6,638. From those, 45% 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, representing 2,989 firms which were considered as the study population of the first article.

Figure 5 shows the study population for the first article of the thesis.

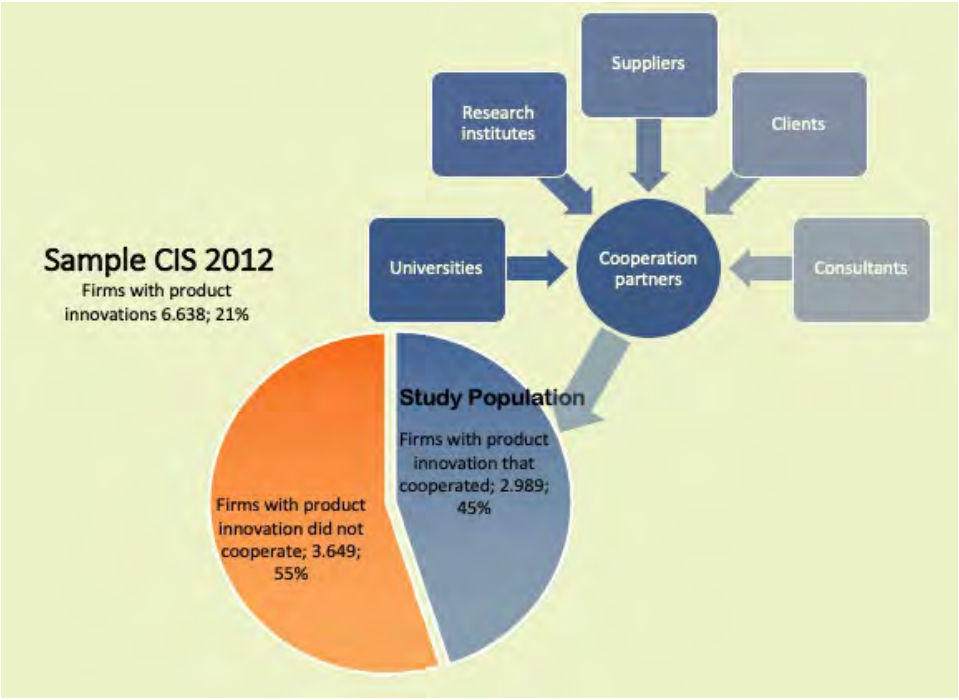

Figure 5. *Study population of the first article*
Own elaboration

In the second study, we aim to explain the cooperation propensity of manufacturing industries and services companies with universities and research institutes according to their technological or knowledge intensities. Therefore, from the total number of enterprises surveyed in Spain during the study period 2012-2014, the firms that introduced technological innovations (product or process) accounted for 9,157 (33.8%), while 2,546 firms (9.4%) abandoned the innovation activities for product and process innovations before

completion, and 5,991 firms (22.1%) were involved in ongoing innovation activities at the end of 2014.

Consequently, the study population of the second study included the firms that conducted innovation activities during the study period (whether they introduced product or process innovations, abandoned innovation activities, or were involved in ongoing innovation activities). They accounted for 11,262 (41.6%) of the total number of firms.

Figure 6 shows the study population of the second article of the thesis.

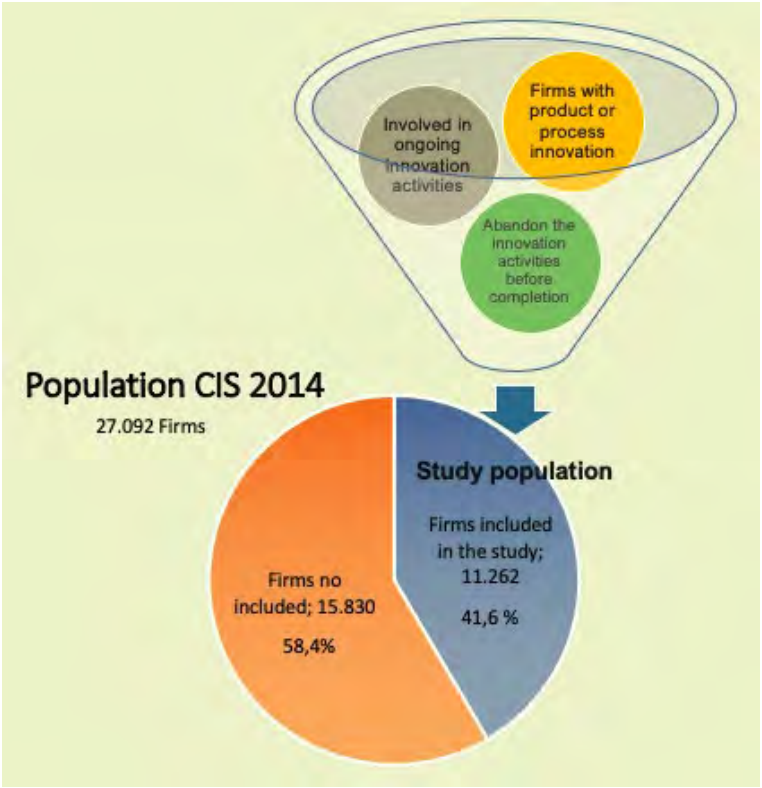

***Figure 6**. Study population for the second article*
Own elaboration

1.3. Harmonised Survey Questionnaire

CIS uses a harmonised questionnaire which provides information on different topics related to innovation in companies. It includes all types of innovation (product, process, organizational and marketing), and various aspects related to the development of an innovation, such as sources of information, cooperation, public funding, R&D expenses, among others.

The pertinent aspects of the questionnaire CIS 2012 used in first thesis study were taken from section 2 concerning to product

innovations and section 6 about the cooperation for product and process innovation.

CIS questionnaires follow the concepts of the Oslo Manual (3rd edition, 2005), where a product innovation is defined as *"the market introduction of a new or significantly improved good or service with respect to its capabilities, user-friendliness, components or subsystems"*. Moreover, product innovations (new or improved) must be new to the enterprise, but they do not need to be new to the market. These concepts guided us to operationalize innovation performance variable as we describe later.

In addition, the questionnaire explains that product innovations could have been originally developed by one's own enterprise or together with other enterprises or institutions. But it is also clear: *"Cooperation is active participation with other enterprises or institutions on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active cooperation"*.

According to this, the questions from the CIS 2012 questionnaire used for the analysis in the first study were:

> *(2.1) During the three years 2010 to 2012, did your enterprise introduce: Goods innovations / Services innovations*
>
> *(2.2) Who developed these product innovations?*

(2.3) Were any of your product innovations (goods or services) during the three years 2010 to 2012: New to your market / Only new to your firm?

This question also inquiries about the percent of total turnover from: innovations products introduced during the three years 2012 to 2014 that were new to the market, and innovation products that were only new to the enterprise.

(6.2) During the three years 2010 to 2012, did your enterprise cooperate on any of your innovation activities with other enterprises or institutions?

(6.3) Please indicate the type of innovation cooperation partner by location: a) other enterprises within your enterprise group, b) suppliers of equipment, materials, components, or software, c) clients or customers from the private sector, d) clients or customers from public sector, e) Competitors or other enterprises in the sector, f) consultants or commercial labs, g) universities or other higher education institutes, and g) government, public or private research institutes.

In addition to the pertinent issues about product innovations, the second study used the questions concerning process innovations (section 3) and ongoing and abandoned innovation activities (section 4) of the CIS 2014 questionnaire.

A process innovation is defined as *the implementation of a new or significantly improved production process, distribution method, or supporting activity*. They must be new to the firm, but they do not need to be new to your market and could have been originally developed only by the firm or in cooperation with partners.

Therefore, the second study also analysed data of the following questions:

> *(2.1) During the three years 2012 to 2014, did your enterprise introduce: New or significantly improved methods of manufacturing for producing goods or services; new or significantly improved logistics, delivery or distribution methods for your inputs, goods or services; new or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing.*
>
> *(2.2) Who developed these process innovations?*
>
> *(2.3) Were any of your process innovations introduced during the three years 2012 to 2014 new to your market?*

Appendix A shows the CIS 2012 harmonised survey questionnaire.

CIS 2014 questionnaire explains that innovation activities include "the acquisition of machinery, equipment, buildings, software, and licenses; engineering and development work, feasibility studies, design, training, R&D and marketing when they

are specifically undertaken to develop and/or implement a product or process innovation. This also includes all types of R&D consisting of research and development activities to create new knowledge or solve scientific or technical problems".

Considering this definition, we include the question (4.1) of the questionnaire because these innovation activities drive the cooperation with partners. This question is: *During the three years 2012 to 2014, did your enterprise have any innovation activities that did not result in a product or process innovation because the activities were: Abandoned or suspended before completion, still ongoing at the end of the 2014.*

The questions about cooperation partners (7.1 and 7.2) were maintained for this study.

Appendix B shows the CIS 2014 harmonised survey questionnaire.

1.4. Research Design

1.4.1. Cooperation groups

The population of the first study (2,989 companies) was organized into eight independent cooperative groups. Then, to investigate possible differences in innovation performance, we chose the six main cooperating groups and compared them in pairs. These groups were:

a. Firms that have cooperated only with universities (UNI_ONLY) and firms that have cooperated only with research institutes (RSI_ONLY)

b. Firms that have cooperated with universities and at least one other partner, which is not a research institute (TOTAL_UNI), and firms that have cooperated with research institutes and at least one other partner, which is not a university (TOTAL_RSI). This second comparison gives robustness to the analysis because it also compares universities with research institutes but adds other partners to each group.

c. Firms that have cooperated with both universities and research institutes (UNI-RSI) and firms cooperated with other partners (OTHR_ONLY), which are neither universities nor research institutes. This comparison allows us to measure the effect of universities and research institutes together against other types of partners.

Figure 7 shows graphically the cooperative groups used in the analysis.

Following the guidelines of the Oslo Manual applied to the CIS survey, 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.

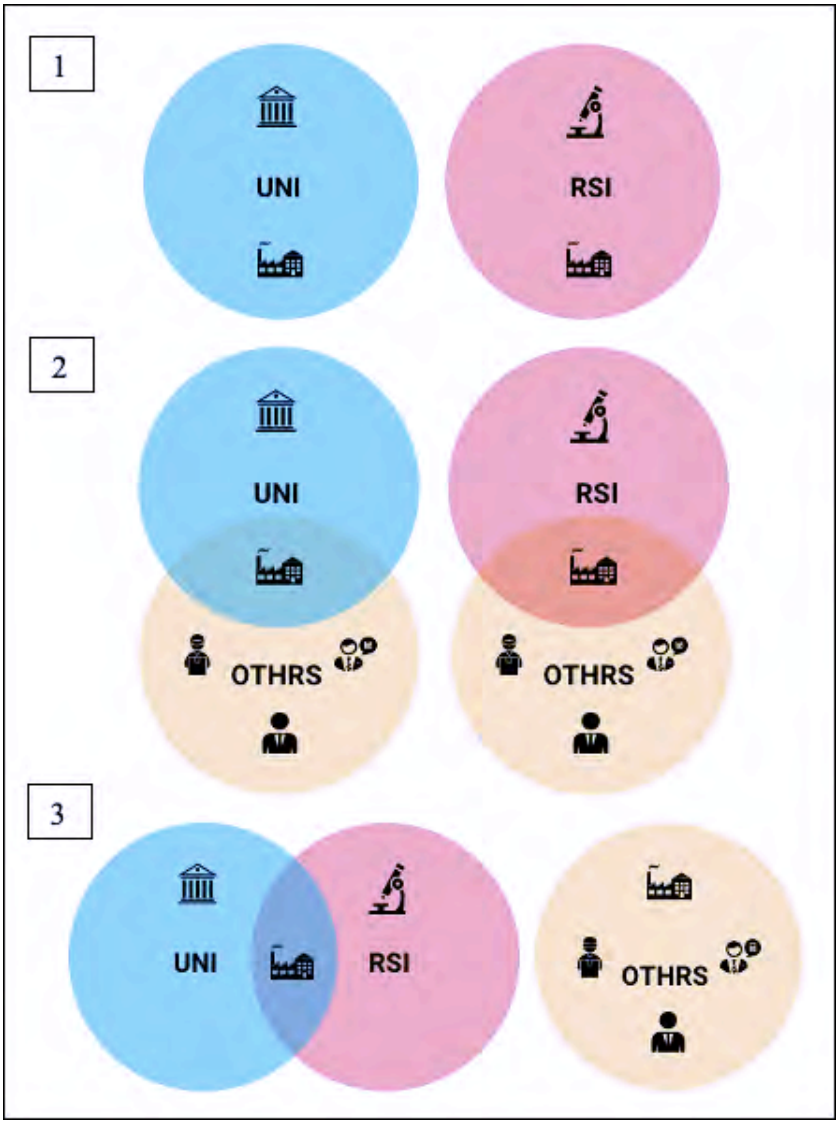

Figure 7. *Cooperation groups for the first study*
Own elaboration

The differences in the innovation performance by firms' size were also tested within the pairs of cooperation groups. To do so, the firms were grouped in two categories depending on the number of

employees: a) Firms with under 249 employees were considered as SMEs firms, and b) Firms with 250 and more employees were considered large firms.

The results obtained were controlled using sector as a control variable. To do so, the firms were grouped according to the economic activities established in the NACE classification. The categories of the firms by sector are a) the agricultural sector (code 1 to 14); b) the manufacturing sector (codes 15 to 37); and c) the services sector (code 38 and upwards). A special group of companies with two codes, (14-15) and (37-39), were included in the manufacturing sector.

1.4.2. Variables for logistic regression model

For the second study, we carried out a logistic regression model to explain the cooperation propensity of firms (manufacturing industries and services companies). The dependent and independent variables used for this statistical analysis were as follows.

a. Dependent variables: Cooperation and cooperation groups

For the first stage of the analysis, we were interested in explaining which type of firms are more likely to cooperate according to their technological characteristics or firm size. So, the categorical variable cooperation was used as the dependent variable. This binary variable corresponds to the CIS question whether the firm cooperated (yes/no). In the second stage, we took a subsample from the firms that cooperated to determine their likelihood to cooperate with universities and research institutes or with other partners according

to their size or technological intensity. The analysis allows us to investigate possible differences among these characteristics in the cooperation relationship with universities and research institutes between manufacturing and services companies. For this stage, we grouped the firms in cooperation with universities and research institutes following the same methodology of the first article.

b. Independent variables: Technological intensity, knowledge intensity, and firm size

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 main categories: low-technology and high-technology industries.

For the aggregation categories of the manufacturing industries, see **Table 5**.

In the same line of Eurostat's aggregation of firms in the services sector, based on the NACE Rev. 2 classification, the firms were grouped into less knowledge-intensive and knowledge-intensive.

Table 6 shows the aggregation categories of the knowledge-based services.

As in the first study, the firms were grouped into two categories according to the number of employees: a) firms with under 249 employees, which are small and medium-sized firms (SMEs), and b) firms with 250 and more employees, which are large firms. In this study, the variable size was also considered an independent variable.

Table 5. Eurostat' aggregation of the manufacturing industries based on NACE Rev. 2

Manufacturing Industries	**NACE Rev.2 codes – 2-digit level**	
High technology	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations;
	26	Manufacture of computer, electronic and optical products
Medium-high-technology	20	Manufacture of chemicals and chemical products;
	27 to	Manufacture of electrical equipment;
	30	Manufacture of machinery and equipment n.e.c.; Manufacture of motor vehicles, trailers and semi-trailers; Manufacture of other transport equipment
Medium-low-technology	19	Manufacture of coke and refined petroleum products;
	22 to	Manufacture of rubber and plastic products;
	25	Manufacture of other non-metallic mineral products; Manufacture of basic metals; Manufacture of fabricated metals products, excepts machinery and equipment;
	33	Repair and installation of machinery and equipment
Low technology	10 to	Manufacture of food products, beverages, tobacco
	18	products, textile, wearing apparel, leather and related products, wood and of products of wood, paper and paper products, printing and reproduction of recorded media;
	31to 32	Manufacture of furniture; Other manufacturing

Source: Eurostat (2016). Annex 3. High-tech aggregation by NACE Rev.2 in *High-tech industry and knowledge-intensive services (htec).* Own elaboration.

Table 6. Eurostat' aggregation of the services companies based on NACE Rev. 2

Knowledge based services	**NACE Rev.2 codes – 2-digit level**	
Knowledge intensive services (KIS)	50 to 51	Water transport; Air transport;
	58 to 63	Publishing activities; Motion picture, video and television programme production, sound recording and music publish activities; Programming and broadcasting activities; Telecommunications; computer programming, consultancy and related activities; Information service activities (section J);
	64 to 66	Financial and insurance activities (section K);
	69 to 75	Legal and accounting activities; Activities of head offices, management consultancy activities; Architectural and engineering activities, technical testing and analysis; Scientific research and development; Advertising and market research; Other professional, scientific and technical activities; Veterinary activities (section M);
	78	Employment activities;
	80	Security and investigation activities;
	84 to 93	Public administration and defence, compulsory social security (section O); Education (section P), Human health and social work activities (section Q); Arts, entertainment and recreation (section R).
Less Knowledge intensive services (LKIS)	45 to 47	Wholesale and retail trade; Repair of motor vehicles and motorcycles (section G);
	49	Land transport and transport via pipelines;
	52 to 53	Warehousing and support activities for transportation; Postal and courier activities;
	55 to 56	Accommodation and food service activities (section I);
	68	Real estate activities (section L);
	77	Rental and leasing activities;
	79	Travel agency, tour operator reservation service and related activities;
	81	Services to buildings and landscape activities;
	82	Office administrative, office support and other business support activities;
	94 to 96	Activities of membership organisation; Repair of computers and personal and household goods; Other personal service activities (section S);
	97 to 99	Activities of households as employers of domestic personnel; Undifferentiated goods- and services-producing activities of private households for own use (section T); Activities of extraterritorial organisations and bodies (section U).

Source: Eurostat (2016). Annex 3. High-tech aggregation by NACE Rev.2 in *High-tech industry and knowledge-intensive services (htec).*
Own elaboration.

1.5. Procedures

In the first study, we applied the Mann-Whitney U test. It is also known as the Wilcoxon rank-sum test, which tests for differences between two groups on a single, ordinal variable with no specific distribution (Mann and Whitney, 1947; Wilcoxon, 1947). We used this statistical test for 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 continuous numerical variables with no symmetric distributions.

McKnight and Najab (2010) pointed out that Mann-Whitney U is conceptually similar to the t-test for determining whether two sampled groups are from a single population. When data do not meet the parametric assumptions of the t-test, the Mann-Whitney U tends to be more appropriate.

In the second study, we carried out the statistical analysis in two stages and used appropriate statistical tests to achieve their objectives. In the first stage, we used the Chi-Square statistic for testing the relationships between cooperation and the manufacturing industries by technological intensity (LTCH/HTCH), cooperation and the services firms by knowledge intensity (LKIS/KIS), in addition to the firm size (SMEs/Large). Sirkin (2006) corroborated that empirical studies commonly use the Chi-Square statistic for testing the relationship between categorical variables in a contingency table.

In the second stage, we tested the hypotheses about these relationships by carrying out a logistic regression model for each sector. Hosmer *et al.* (2013) underlined 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.

Following Schreiber-Gregory and Bader (2018) recommendations to avoid future errors in results analysis, we verified the logistic regression key assumptions:

1. Binary logistic regression requires the dependent variable to be binary and ordinal logistic regression requires the dependent variable to be ordinal.
2. Logistic regression requires the observations to be independent of each other.
3. Logistic regression requires there to be little or no multicollinearity among the independent variables. This means that the independent variables should not be too highly correlated with each other.
4. This analysis requires that the independent variables are linearly related to the log odds.
5. Logistic regression typically requires a large sample size. A general guideline is that you need at least 10 cases with the least frequent outcome for each independent variable in the model.

In our logistic regression model, we use cooperation / non-cooperation, a binary outcome variable. The predictor variables used: technological intensity (LTCH / HTCH) or intensive knowledge (LKIS / KIS) and company size (SMEs / Large) are independent and non-correlated variables. Finally, the sample is large enough for each independent variable. In the second stage, the statistical analysis was replicated but this time using the cooperation groups Universities and research institutes (UNI-RSI) / Other partners (OTHRS) as a binary result variable. Therefore, all the above assumptions were met.

Figure 8 shows the variables used in the empirical studies 1 and 2.

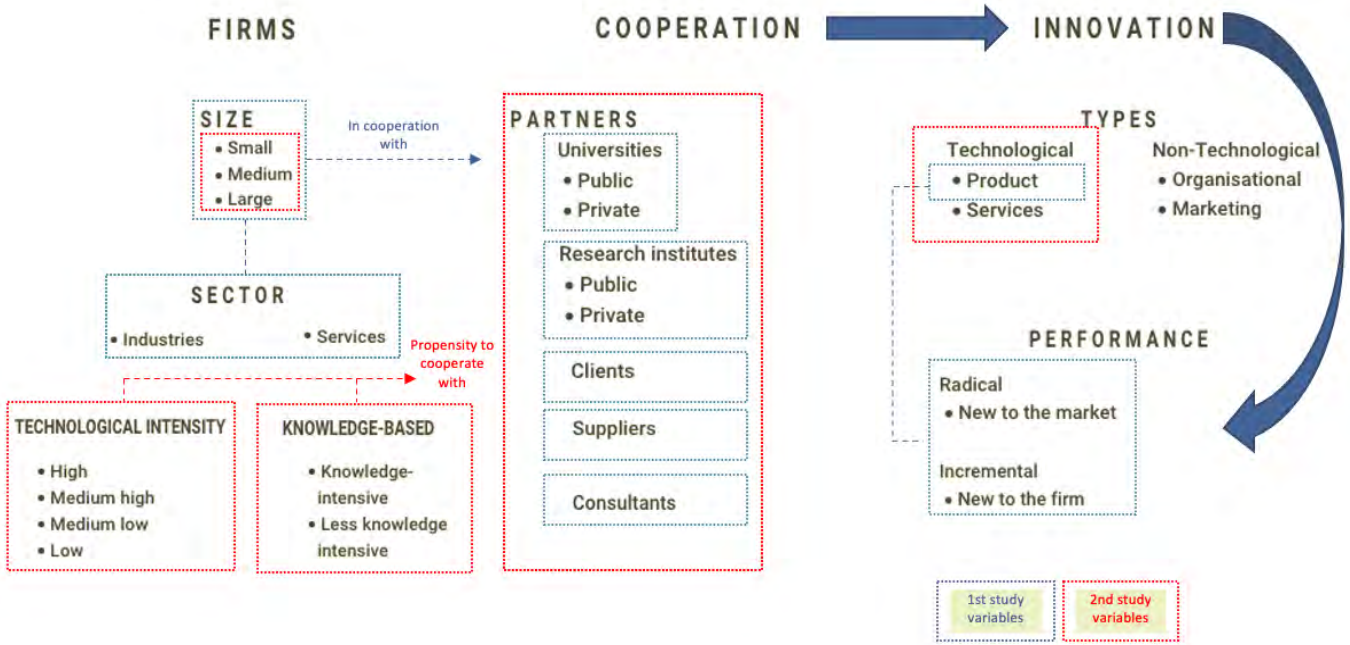

Figure 8. *Variables used in the studies 1 and 2*
Own elaboration

2. Case study's methodology

In the third article of the thesis, we used the case study as a research method. Yin (2009) defines a case study as *"an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between the phenomenon and the context are not clearly evident"*. The author recommends using case study as a research method when (a) how? or why? Questions are being posed, (b) the researcher has little or no control over the events and (c) the focus is a contemporary phenomenon within a real-life context.

As mentioned in the justification of the thesis, the Covid-19 pandemic generated a climate of openness and collaboration between companies worldwide to face the crisis through the development of many projects, applying different technologies and knowledge.

When we knew about the OxyGEN project, led by a Barcelona company that successfully designed and developed emergency ventilators for ICUs in hospitals collaboratively with different partners. We decided to investigate, document and analyze this project from the perspective of open innovation, considering the results obtained in our previous studies, but with the intention to better understand the phenomenon with a confirmed case in a unique context.

Initially, we asked ourselves several questions that would later be part of our research. What motivated the company to develop the project? How was the innovation designed and developed? How

was the technology transferred to other countries? How was the community created, and how was its participation in the project? Which organisational practices and strategies used by the company were critical to boost the innovation? How or why did other companies collaborate with the project? These types of questions, the fact of not having control over the variables and the unique context in which the project occurred, justified applying the case study method.

2.1. Case study design: Unit of analysis

A critical component of the case study design is identifying the unit of analysis. It is related to the initial research questions (Yin, 2009).

According to this, the case study design uses two units of analysis; for one hand, the company Protofy developed Project Oxygen. Also, the teams that participated in the innovation community were created around this project. To guide the investigation process and data collection, we design two research instruments: a semi-structured interview and surveys. The interviews were conducted to the company's co-founders with issues related to the company's characteristics, organizational practices, motivations to develop the project and the strategies used in the innovation process. On the other hand, the surveys were directed to the teams' members of the innovation community. They addressed questions about profiles of the teams' members, the adoption of the technology, the state of the product innovation and collaboration partners.

2.2. Rationale for a single-case study design

Yin (2009) pointed out that a single-case design is justifiable under certain conditions where the case represent (a) a critical test of existing theory, (b) a rare or unique circumstance, or (c) a representative or typical case, or where the case serves a (d) revelatory or (e) longitudinal purpose (Yin, 2009, p.52).

This case study meets some critical conditions that justified its design as a single case study:

1. The type of company that developed the innovation and the innovation community created around the project
2. The type of product that was innovated
3. The unique context in which this innovation occurred
4. The opportunity to test the results obtained in our previous studies and other essential taxonomies used in open innovation.

Protofy is a small knowledge-intensive services company whose main activity is prototyping different tech products from the idea to the industrialisation process, covering design, mechanical engineering, electronics, and software. The company designed and developed an innovative project, for which they sought collaboration with different partners (clients, suppliers, a university, and a research institute) and created an innovation community.

This condition allows us to illustrate with a practical and representative case the results obtained in our second study that the services firms' cooperation, particularly with universities and research institutes, was more explained by their knowledge intensity

than their size. On the other hand, this case lets us analyse other essential concepts in open innovation, such as the types of open innovation (e.g., Gassman and Enkel, 2007); the typologies of companies for taking advantage of the different knowledge sources (Brunswicker and Vanhaverbeke, 2015), and the concept of co-creation in innovation communities (by Von Hippel, 2005).

The company Protofy innovated an industrial-class emergency ventilator, this is type of medical device (class II). European directives and Royal National decrees regulate medical devices to ensure their functioning in conditions of security and quality. Accordingly, the prototype OxyGen was the first mechanical ventilator that obtained approval from the Spanish Ministry of Health (AEMPS) for use on patients.

This second condition of the case study is essential because products with high complexity and comprehensive architecture represent a more significant challenge for redistributing resources and having capabilities for cooperation (Elsahn and Siedlok, 2021).

The health crisis due to the Covid-19 pandemic created a unique context for open cooperation. Several teams of scientists, organisations, and companies worldwide decided to share their knowledge, data, or experiences to find quick local solutions to a global problem. The Oxygen Project was developed in Spain in these exceptional circumstances and impacted 32 countries, driven by an innovation community around it. This context also justified the case's

design to understand the company's main characteristics and strategies to obtain a successful result.

2.3. Data collection and analysis

The case study method uses multiple sources of evidence and can benefit from the prior development of theoretical propositions to guide data collection and analysis (Yin, 2009).

The primary data sources for this case study were interviews, surveys, and documental review. As mentioned above, interviews were conducted with the co-founders of Protofy to discuss their perspectives and experiences during the project. We used a semi-structured format for this interview. The interviews were recorded and transcribed to assist in the analysis.

The surveys were applied in the second half of April, during the confinement. The subjects selected for the sample were project team leaders or project members who filled out a self-administered questionnaire through the Google Forms application (online). These forms are flexible and suitable to adjust to the needs of the investigation for free and without limitations (Abundis, 2016).

The questionnaire consisted of 12 questions divided into three sections: general information about the project and team profile, degree of involvement in the OxyGEN project, and cooperation with partners in their respective countries.

We sent invitations with the questionnaire's link to all OxyGEN community members registered on Discord.com, the team

members' platform, to communicate and share relevant information for each project's development. As a result, the response level reached 62%, corresponding to 30 projects/teams worldwide.

Relevant company documents were also analysed. These included the blog, video journal, tutorials, publications in newspapers and magazines, the project's dedicated website, and participating partners' publications.

An active dialogue was maintained with Protofy to clarify inconsistencies and expand and develop the data. In the case of study research, by collecting and cross-examining data about the innovation process from multiple sources, data collection and interpretation are likely to be an accurate representation of reality (Yin, 2009).

In addition to information from the company and the innovation community built around the project, we collected data on the context of the Covid-19 outbreak in Spain.

Chapter IV

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

Preprint of the article published in [Journal of Innovation Management, Volume 24, Issue 06, 2020, 2050053] [https://doi.org/10.1142/S136391962050053X] © [copyright World Scientific Publishing Company] [https://www.worldscientific.com]

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

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

International Journal of Innovation Management
(2020) 2050053 (25 pages)

DOI: 10.1142/S136391962050053X

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

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

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

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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 partly depend 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 innovation 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. Customer cooperation, for instance, 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, 2018; de Faria *et al.*, 2010; Santamaria and Surroca, 2011). When firms cooperate with universities, on the other hand, they are seeking privileged access to new knowledge (Belderbos *et al.*, 2004; Monjon and Waelbroeck, 2003). Two main purposes of universities besides education are knowledge creation and transfer. Research institutes (both public and private) 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 sharing knowledge more widely, as envisaged in OI (Bogers *et al.*, 2018) makes the role of universities and research institutes in innovation systems even more relevant.

Studies involving large databases are required to learn how firms select parties with whom to collaborate (Huizingh, 2011). Most empirical studies about industry cooperation consider universities and research institutes as a joint category (Belderbos *et al.*, 2004, 2018; Guzzini and Iacobucci, 2017; Tsai, 2009); very few papers 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 have cooperated with other partners. The study includes large, medium, and small-sized firms (SMEs).

Specifically, the research questions are as follows: (a) Is there a difference in the innovation performance of firms with product innovations that have cooperated with universities and higher education institutions and the performance of firms with product innovations that have cooperated with public and private research institutions?; and (b) Is there a difference between the innovation performance of the firms with product innovations that have cooperated with both universities and/or public and private research institutes and that of firms with product innovations that have 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. Second section addresses the literature review; the methodologies are briefly described in third section; the results are presented in fourth section and discussed in fifth section; and the conclusions are drawn in sixth section.

Literature Review

The Inter-Organisational Relationships (IOR) approach focuses on the properties and general pattern of relationships between and among organisations that are pursuing a mutual interest while remaining independent and autonomous (Cropper *et al.*, 2008).

In this setting, collaboration between universities/research institutes and industries (UIC) is an IOR that focuses on two roles: interdependency and interaction. The interdependency approach refers to how to acquire and exchange the resources that one part lacks (Faems *et al.*, 2007), while an interaction process considers that new knowledge is not only created but also transferred given that neither of the partners previously possessed this knowledge (Galati and Bigliardi, 2019; Hardy *et al.*, 2003). In this approach, the innovation sources 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 by means of an ongoing social interaction between the actors during the collaboration lifetime. In this regard, Ortiz *et al.* (2018) highlights IOR 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) states that while universities and research centres focus on research projects that are unlikely to lead to immediate payoffs, cooperation

with these institutions can have positive effects on innovative performance in the long term.

This study aims to contribute to the understanding of the IOR between firms-universities-research institutes in Spain, focusing on the outcomes (firms' 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 that principally aims 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; creation of business opportunities; new or improved products/processes; and patents and prototypes. 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 improving innovation capacity, and access to new knowledge and leading-edge technologies and research infrastructure (Ankrah and AL-Tabbaa, 2015).

Nevertheless, other studies mention some potential negative effects of UIC. Galati and Bigliardi (2017) points out that differences between the organisational culture and goals of universities and research centres and those of firms may limit the effectiveness of collaborations. Lin (2017) affirms that the number of industry collaborations and academic innovations is curvilinear, meaning that at some point a large number of industry collaborations negatively affects academic innovation performance. Furthermore, 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.

There were 76 Universities in Spain in 2012 (MEC, 2012a). 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%) of this 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, 2012b). Of the total amount of funding from contracts with third parties, 30% came from collaborative research (university-company), representing 168 million euros in 2012 (CRUE RedOTRI, RedUGI, 2012).

Research institutes are also 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 awarded six research centres attached to various Ministerial Departments (MSI, 2011) the status of Public Research Organism (PRO). These nationwide bodies differ widely in terms of their scientific and technological capacity, size and structure. Together they comprise a network of 175 research centres with around 16,000 highly qualified, experienced staff involved in activities in approximately 29 different areas of research. They are mainly publicly funded from the General State Budget, the competitive public calls of the National Research Plan, 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 and handled as one or the same affiliate group in the literature when discussing cooperation relations with firms. For example, Guzzini and Iacobucci (2017) places them in a joint category when analysing the relationship between project failure and innovation performance in German firms that have collaborated with universities and research centres. Belderbos *et al.* (2004) analyses the impact of R&D cooperation on the innovation performance of Dutch firms, pointing out that cooperation with universities and research institutes (considered as a joint category) positively affects growth in sales per employee for products and services new to the market.

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

Interestingly, Chen *et al.* (2017) focuses on research institutes, exploring 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 a 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 unclear whether it is appropriate to consider universities and research institutions as a joint category in the absence of prior statistical tests. Hence, we put forward the following hypotheses:

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

Hypothesis 2: *There is a statistically significant difference between the innovation performance of the firms with product innovations that have cooperated with universities and other partners (but not with research institutes) and the innovation performance of firms that have 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, 2012, 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 a firm's propensity to introduce new products to the market. Patenting is positively influenced by cooperation with public institutions and cooperation with competitors occurs in high tech sectors to share R&D costs. Duysters and Lokshin (2011) warns that alliance complexity has an inverse U-shaped relationship with innovative performance; complexity facilitates learning and innovativeness, but each organisation has a certain management capacity to deal with complexity which sets limits on the number of alliances 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 collaborations 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 between the innovation performance of the firms with product innovations that have cooperated with both universities and research institutions and the performance of the firms that have cooperated with other partners.*

Firm size and innovation performance

Firm size has traditionally 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, 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 frequently studied firm characteristic (Huizingh, 2011). Whereas the first empirical studies suggested that most OI adopters were large firms (van de Vrande *et al.*, 2009; Bigliardi and Galati, 2016), later research has shown that SMEs are increasingly implementing OI activities (Lee *et al.*, 2010; van de Vrande *et al.*, 2009; Brunswicker and Vanhaverbeke, 2015; Martinez-Conesa *et al.*, 2017). Moreover, within the SMEs group, van de Vrande *et al.* (2009) finds that medium-sized firms are 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 are the group that implements the highest number of OI practices among SMEs. Start-ups have also been found to engage in OI activities (Usman and Vanhaverbeke, 2017).

However, the different sized firms face divergent challenges and expect different benefits from OI activities (Bigliardi and Galati, 2018). In this line, van de Vrande *et al.* (2009) shows that the OI activities of SMEs are mainly related to market-related targets, the main barriers to OI activities being organisational and cultural issues; and Spithoven *et al.* (2013) finds that SMEs that collaborate with partners are more likely to launch new products and services, while this is not 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 double or more the percentage 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. Regarding the challenges posed by collaboration such as diverting managers' time, knowledge leakages, and investments in absorptive capacity, the study finds that these may be more relevant in the case of SMEs.

Regarding cooperation with universities and research centres, Jang *et al.* (2017) finds that the percentage of large firms that cooperate with universities is almost triple 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 to technological partners like universities and research centres. Moreover, Tsai (2009) suggests that when the absorptive capacity of new technologies in SMEs is low, collaborations with research organisations (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 have cooperated only with universities and those that have cooperated only with research institutes.*

Hypothesis 5: *There is a statistically significant difference in the size of the firms that have cooperated with universities and other partners (but not with research institutes) and those that have 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 have cooperated with both universities and research institutions and those that have 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

The database of the Community Innovation Survey (CIS) for Spain for the period 2010–2012, conducted among enterprises of different sizes with at least 10 employees from a wide range of sectors based on Core NACE categories, was used in this study.

The concepts and methodology of the CIS2012 are based on the third edition of the Oslo Manual (2005). The harmonized survey provides an understanding of the

types of innovation performed by enterprises: product, process, organisational and marketing, among other important aspects in the development of an innovation such as the objectives, the strategies and obstacles, the information sources, 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 76 universities in Spain, of which 50 (66%) were public and 26 (44%) private. Research and knowledge transfer can be channelled through the 395 research units of these universities, 351 (88%) of which belong to public universities and the rest to private universities (MEC, 2012a). Regarding research institutes, in 2012 there was a network of 175 centres belonging to six PRO (MSI, 2011). Both the universities and the national research centres are important agents in the Spanish Science, Technology and Innovation System and they carry out most of their programmed activities 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. Of these, 45% 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, 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).

Throughout the study, six of the cooperation groups were organised into three pairs to test for differences within each pair: (1) firms that have cooperated only with universities (UNI_ONLY) and firms that have cooperated only with research institutes (RSI_ONLY); (2) firms that have cooperated with universities and at least one other partner, which is not a research institute (TOTAL_UNI), and firms that have cooperated with research institutes and at least one other partner, which is not a university (TOTAL_RSI) and (3) firms that have cooperated with both universities and research institutes (UNI-RSI) and firms that have cooperated with other partners (OTHR_ONLY), which are 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 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 describes the operationalisation of the variables used in the study.

Following the literature, differences in the innovation performance of firms by size was also tested within the pairs of cooperation groups. The firms were grouped into four categories depending on 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-sized 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: groups 1 and 2 corresponded to SMEs and groups 3 and 4 corresponded to large firms. The number of firms for each size category and cooperation group is described in Table 3.

Although most of the literature suggests a positive relationship between size and innovativeness, industry characteristics seem to play a role in the relative innovative advantage in favour of large or small firms (Acs and Audretsch, 1987; Veugelers and Cassiman, 1999; Bigliardi and Galati, 2016). Huizingh (2011) also considers industry as a most influential context characteristic in OI. To this effect, 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) the agricultural sector (code 1 to14); (b) the manufacturing sector (codes 15 to 37) and (c) the services sector (code 38 and upwards). A special group of companies with two codes, (14–15) and (37–39), were included in the manufacturing sector. The distribution of firms for each sector and cooperation group is described in Table 4.

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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 No cooperation	Categoric nominal
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 RSI_ ONLY	Categoric nominal
		TOTAL_UNI TOTAL_RSI	Categoric nominal
		UNI_RSI OTHR_ONLY	Categoric nominal
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
Manufacturing	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

A Mann–Whitney U-test was performed to contrast the previous hypotheses. Also known as 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 as 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 turnover from the new products introduced that were new to the firm between cooperation groups. These categories are numerical 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 have cooperated only with universities (UNI_ONLY) and the group of firms that have cooperated only with research institutes (RSI_ONLY). No statistically significant differences were observed between the group of firms that have cooperated with universities (TOTAL_UNI) and the group of firms that have cooperated with research institutions (TOTAL_RSI).

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

Innovation performance of the cooperation groups by firm size

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

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	

Note: *Level of significance = 0.5.

Most of the firms were small in the following two cooperation groups: the total number of firms that have cooperated with universities (TOTAL_UNI) and the total number of firms that have cooperated with research institutes (TOTAL_RSI). The distribution of the firms by size was 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.

The percentage of large firms (500 and more employees) for the last pair of cooperation groups was 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) was 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 the_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.

Regarding the comparison of the innovation performance within the cooperation groups by firm size, the results in Table 7 show that no differences were found within pairs 1 and 2. On the other hand, both SMEs and large firms that have cooperated with universities and research institutes obtained better innovation

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	

Note: *Level of significance = 0.5.

results with regards to turnover from products that were new to the market. The Mann–Whitney U-test applied with 95% significance yielded a p-value of < 0.001 for the TURNMAR category for both SMEs and large firms.

Innovation performance of the cooperation groups by sector

Despite most of the firms that have cooperated only with universities (UNI_ONLY) belonging to the service sector (53%), and most of the firms that have 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 innovation results for the companies that have cooperated with the total universities group (TOTAL_UNI) or for those that have cooperated with the total research institutes group (TOTAL_RSI) in all the sectors.

Last, there were statistically significant differences between the firms that have cooperated with UNI_RSI and the firms that have 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.

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	

Note: *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					
TURNMAR	N	21	34	51	90	62	120
	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					
TURNMAR	N	47	104	152	293	272	482
	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					
TURNMAR	N	76	62	262	197	363	535
	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	

Note: *Level of significance = 0.5.

Discussion

According to the results, the first hypothesis of this study is rejected: there are no statistically significant differences between the innovation performance of the firms with product innovations that have cooperated only with universities and the firms that have 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, 2018; Guzzini and Iacobucci, 2017; Tsai, 2009).

The second hypothesis of the study is also rejected: there are no statistically significant differences between the innovation performance of the firms that have achieved product innovations in cooperation with universities and other partners (but not with research institutes) and the firms that have done 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 not only adds robustness to the statistical analysis, but 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 result 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 noteworthy that a large number of links and a diversity of partners could negatively affect the performance of the organisations in the absence of appropriate managerial capacity (Belderbos *et al.*, 2006; Duysters and Lokshin, 2011). This is a major challenge for many small firms, as further discussed below.

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 have cooperated with both universities and research institutions and the firms that have 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).

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

The distribution of firms by size, however, did differ for the group of firms that have cooperated with both universities and research institutes and the group of firms that have cooperated with other partners: larger firms are more likely to cooperate with universities and research institutes than SMEs. Hypothesis 6 is thus supported. These results are in line with those in Jang *et al.* (2017), Narula (2004), Veugelers and Cassiman (2005) and Tsai (2009), among others.

Regarding the relationship between innovation performance and firm size, the results show that cooperation with universities and research institutes is more beneficial for both SMEs and large firms than cooperation with other agents in terms of reaching a higher turnover from products that are new to the market. The results of the tests of 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, which holds true in two of the three sectors analysed: the results for the manufacturing and services sectors show that there is a statistically significant difference in the first category (products new to the market) between the innovation performance of the group of firms that have cooperated with universities and research institutions and the performance of the group of firms that have cooperated with other partners. These results support the view that the industry plays a relevant role in explaining OI (Huizingh, 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, cutting-edge technologies and research infrastructure, which can be transformed into novel or improved products.

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

Universities and research institutes are important agents in the national innovation systems as they are responsible for a significant part of the science, technology and innovation activities 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, organisation and budgets to perform research. Despite these differences, there are many 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 like 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 innovation performance of the firms that have collaborated with universities and the innovation performance of the firms that have 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 like 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 a 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 maintained when tested for the groups of SMEs and large firms separately. Control by sector corroborates the decision to partially accept this hypothesis for the manufacturing and service sectors.

Regarding the role of size, there is no significant difference in size between the firms that have cooperated with universities and the firms that have 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).

Regarding the implications for firms, it is clear from this study that universities and research institutes together can comprise a broad network of potential cooperators in innovation for both SMEs and large firms, especially when introducing products that are new to the market. Furthermore, policy makers should consider 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 while they are doing their doctorate, is in line with this approach.

An important limitation of this study is that the data is not very recent. This limitation needs to be overcome with future research using more up-to-date data. Data limitations also hindered the use of parametric tests that would have enabled the effects of sector, size, and cooperation on the innovation performance of firms to be considered jointly. An analysis such as this would have shed new light on the view that industry characteristics play a role in the relative innovative advantage in favour of large and 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.

Acknowledgements

The first author is grateful for the financial support from the University of Armed Forces ESPE 019-2017-CCB. The second and third authors acknowledge the support from the Spanish Ministry of Economy and Competitiveness ECO2017-86054-C3-3-R and from the Autonomous Government of Catalonia 2017 SGR 0385.

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Chapter V

COOPERATION PROPENSITY WITH UNIVERSITIES AND RESEARCH INSTITUTES ACCORDING TO TECHNOLOGICAL AND KNOWLEDGE INTENSITY

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Abstract: This study explains the probability that an industry or services company to cooperate with universities and research institutes, according to its technological intensity, knowledge intensity or size. We apply multivariate logistic regression analysis to a sample of 11,262 Spanish companies' classified by the aggregated categories of these contextual characteristics. The results show that the propensity to cooperate with universities and research institutes is significant for manufacturing companies' size but not for their technological intensity. Conversely, services companies, independently firm size, are more likely to cooperate according to their knowledge intensity. Accordingly, they propose new cooperation models for this inter-organizational relationship.

Keywords: Cooperation; knowledge-intensity; open innovation; research institutes; technological intensity; universities

JEL: M13, O32, O36

Journal of Engineering and Technology Management

Cooperation propensity with universities and research institutes according to technological and knowledge intensity

--Manuscript Draft--

Manuscript Number:	
Article Type:	Full Length Article
Keywords:	Cooperation; knowledge intensity; open innovation; universities and research institutes; technological intensity
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Abstract:	This study explains the probability that an industry or services company cooperating with universities and research institutes, according to its technological intensity, knowledge intensity or size. We apply multivariate logistic regression analysis to a sample of 11,262 Spanish companies' classified by the aggregated categories of these contextual characteristics. The results show that the propensity to cooperate with universities and research institutes is significant for manufacturing companies' size but not for their technological intensity. Conversely, services companies, independently firm size, are more likely to cooperate according to their knowledge intensity. Accordingly, they propose new cooperation models for this inter-organizational relationship.
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1. Introduction

Since Chesbrough's seminal work in 2003, the most researched topics in the open innovation (hereafter 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 process, which treats two main aspects: collaboration partners and the stages of collaboration (Bigliardi *et al.*, 2020).

Regarding context-dependency, industry, as an external characteristic, was the first to be analysed. Chesbrough and Crowther (Chesbrough and Crowther, 2006) point out that early adopters of OI concepts were the high-tech industries (e.g., electronics, the automotive industry, biotechnology). However, they are nowadays in use in a wide range of industries and services (e.g., food, software, financial services). However, empirical studies show intra-sectoral and inter-sectoral differences. For instance, Poot *et al.* (2009) argue that the process of adoption of OI between industries does not occur continuously over time and that external innovation strategies are complementary to internal ones. Mina *et al.* (2014) point out that business services are more active open innovators than manufacturers; they are more engaged in informal than formal OI practices, and they attach more importance to scientific and technical knowledge than to market knowledge.

About the internal context, the most studied characteristic in the literature is company size (Huizingh, 2011). While early empirical studies suggest that most OI adopters are large companies (e.g., Keupp and Gassmann, 2009; Lichtenthaler and Ernst, 2009; Bianchi *et al.*, 2011), other studies show that SMEs have adopted many OI practices over the last fifteen years, while organizing and managing OI in an entirely different way from large companies (Usman *et al.*, 2018).

Therefore, it is not clear if cooperation is equally interesting for all companies depending on the contextual characteristics (industry or size). In the first part of this study, we use the two characteristics to determine which of them best explains the cooperation / non-cooperation of industries and service companies separately, according to their technological and knowledge intensity.

Regarding collaboration frameworks, some studies have shown that engaging in inter-organizational or collaborative networks with various partners is beneficial for firms' innovation (e.g., Ahuja, 2000; Faems *et al.*, 2005), emphasizing the importance of a portfolio approach to collaboration. Some studies find differences in the type of innovation results according to the type of collaborating partner. For instance, Belderbos *et al.* (2004) point out that cooperation with competitors and suppliers is on incremental innovations, while university cooperation is instrumental in generating radical innovations and improving companies' growth performance. Furthermore, they show that universities and research

institutes' incoming spillovers are a critical determinant of the firm's R&D cooperation. Additionally, Arranz *et al.* (2008) support that industries with limited knowledge and technological resources establish complementary agreements with universities and research institutions, motivated by financial incentives and seeking external technology sources.

Different results are also obtained for the relationship between universities, industries, and services according to contextual characteristics (industry or size). For example, Lee and Miozzo (2019) find that knowledge-intensive service companies and science-based manufacturing companies are active collaborators of universities for innovation. Trigo and Vence (2012) argue that the nature of the service activity affects both the choice of partner and the cooperation intensity. Furthermore, Lara *et al.* (2020) find that large firms cooperate more with universities and research institutes than SMEs. The firms that collaborated with universities and research institutes reached a higher average innovation performance than the firms collaborating with other partners. These differences held for manufacturing and services firms.

Consequently, within the collaborative framework, it is unclear which companies' contextual characteristics are most related to the propensity to cooperate with different partners, particularly with universities and research institutes. In the second part of this study, we are especially interested in explaining whether manufacturing industries' or service companies' propensity to

cooperate with universities, and research institutes or other partners is related to their technological or knowledge intensity and company size.

This study addresses the following research questions: a) Which contextual characteristics (technological / knowledge intensity, size) are statistically significant in the cooperation propensity of manufacturing industries and service companies? Moreover, b) Which contextual characteristics (technological / knowledge intensity, size) are statistically significant in the cooperation propensity with universities and research institutes or other partners?

Attempting to answer these questions, we classify the firms that cooperate in innovation activities according to their technological intensity (in the case of manufacturing firms) or knowledge intensity (in the case of service firms), and firm size to understand which characteristic best explains cooperation in general, and for specific groups of cooperation partners: universities, research institutes, and other partners.

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 discussed in the fifth section, and the sixth section concludes.

2. Literature Review

2.1. Cooperation with universities and research institutes

2.1.1. Manufacturing industries in cooperation with universities and research institutes

Pavitt's taxonomy (1984) classifies the innovative firms and sectors developing and using technology into four categories: (1) supplier-dominated; (2) production-intensive; (3) science-based: and (4) information-intensive. They are defined by the sources of technology, users' requirements, and the possibilities for appropriation. For the science-based firms, the primary sources of technology are the R&D activities of firms in the sectors, based on the rapid development of the universities' underlying sciences. Conversely, Bekkers and Bodas (2008) sustain that the firm's industrial sector do not significantly explain the differences in the importance of a wide variety of channels through which knowledge between universities and industry might be transferred.

In a study analysing manufacturing firms, Santoro and Chakrabarti (2002) point out that size matters concerning the types of relationships firms have with universities, and the types of technology-centred strategic initiatives firms pursue, i.e., core versus non-core technologies. The large firms have higher intensity knowledge transfer and stronger research support relationships to improve skills and knowledge and gain 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.

Jang *et al.* (2017) find that the percentage of large firms cooperating with universities is almost triple the percentage of SMEs. Lara *et al.* (2020) also 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. These differences remain between manufacturing and services firms.

Thus, in the first part of this study, we use technological intensity as an external contextual characteristic and firm size as an internal contextual characteristic to explain manufacturing industries' cooperation. Considering these results, in the second part, we use the same variables to explain the differences in the propensity to cooperate with universities and research institutes or other agents.

2.1.2. Services firms in cooperation with universities and research institutes

The literature on the relationship between universities and services companies has produced different results. Some researchers show that service firms are less likely than manufacturing firms to cooperate with universities for innovation but are more likely to do so with clients or suppliers (Tether, 2005). Moreover, the interaction between KIBS firms and universities does not improve their innovation performance (Love *et al.*, 2011).

Conversely, other studies show that KIBS firms are more likely than other firms to collaborate with universities for innovation (Segarra-Blasco and Arauzo-Carod, 2008), considering universities to be an essential knowledge source for new-to-market innovations (Rodriguez *et al.*, 2017). Moreover, they conclude that services firms are more active open innovators than manufacturers, they are more engaged in informal open innovation practices, and they attach more importance to scientific and technical knowledge than to market knowledge (Mina *et al.*, 2013).

Regarding KIBS characteristics for cooperation with universities, Lee and Miozzo (2019) determine that science-based KIBS firms (those engaged in a science, technology, and innovation [STI] mode of organizational learning), like science-based manufacturing firms, are active collaborators with universities for innovation.

Regarding the factors that influence service firms' collaboration with universities for innovation, Janeiro *et al.* (2013) point out that innovation success, radical innovations, and innovation intensity are crucial to developing links between innovative service firms and universities. They also support that large service firms tend to access universities more intensively than SMEs.

Taking these results into account and following our methodology, we use the knowledge intensity in services companies and their size to determine if these contextual characteristics can

explain differences in cooperating with universities and research institutes or other agents.

2.2. Cooperation and technological/knowledge intensity

There is an important debate within the innovation literature that concerns whether or not the innovation process in services differs from manufacturing (Gallouj and Windrum, 2009). For instance, Tether (2005) suggest that manufacturing firms are more likely to use "hard" sources of knowledge and technology (e.g., equipment and computer software). Contrarily, services tend to emphasize "softer" attributes (e.g., human skills and operating and cooperating practices), and their cooperation partners are mainly suppliers and customers. In a later analysis, Tether and Tajar (2008) identify three "modes of innovation": the product-research mode, the process-technologies mode, and the organizational-cooperation mode. These authors argue that firms of different sizes or different sectors have different propensities to engage in each mode. For example, high-tech industries are the most likely to participate in a product-research mode, low-tech industries are most likely to engage in the process-technology mode, and the organizational-cooperation mode is particularly prominent in services.

On the other hand, Hipp *et al.* (2015) explore the similarities and differences of innovation between KIBS in the country members of the European Union (EU), highlighting the relatively high innovative profile of them with respect to manufacturing industries, as well as its cooperative nature towards external partners in the

realization of its processes of innovation. However, it also suggests that there are significant differences among all KIBS categories.

2.2.1. Cooperation and manufacturing industries by technological intensity

Regarding technological cooperation, Hagedoorn (2002) finds that the main motives why companies engage in technological alliances are technology complementarity, reduction of the innovation time-span, and market access. He also shows a positive relationship between partnerships' research orientation and the research intensity of the sectors involved and a strongly market-oriented motivation in low-tech industries.

Other studies show differences in the cooperation of manufacturing industries in terms of technological intensity. For instance, Hirsch-Kreinsen (2008) finds that the innovation pattern of low- and medium-low-tech industries differs markedly from that of high and medium-high tech industries due to the lack of internal R&D capabilities, their specific knowledge base, and few structured innovation processes. Moreover, Segarra-Ciprés *et al.* (2012) show that R&D intensive industries explore external sources of knowledge more than less R&D intensive industries, but they do not find any differences in the exploitation of these sources.

2.2.2. Cooperation and services firms by knowledge intensity

Vence and Trigo (2010) perform an extended intra-sectoral analysis, finding notable differences in the innovation and cooperation patterns among services firms, pointing out that not all services are non-

innovative, as previously assumed. These authors identify three broad service types according to their innovation process attributes (1) Low-innovation-intensive sectors (LIIS); (2) Technology-intensive and moderately innovation-intensive sectors (TIMIIS); and (3) Knowledge and innovation-intensive sectors (KIIS). The last profile is also reported in the literature under the label KIBS (Knowledge-intensive business services). The latter is considered the leading service sector in terms of cooperation and innovation. The supplier is the main cooperation partner for each type studied, apart from the case of KIIS, where the client plays an important role throughout the innovation process. In a later study, Trigo and Vence (2012) argue that the nature of the service activity affects both the choice of partner and the cooperation intensity.

Other studies show different results. On comparing KIBS and Specialized Suppliers within Manufacturing (SSM), Cainelli *et al.* (2020) show that the impact of R&D is comparable in the two sectors. In contrast, cooperation with customers is more critical for SSM than for KIBS, which has a more extensive network of partners (especially knowledge providers). Amores *et al.* (2020) find differences in KIBS companies' behaviour and manufacturing industries regarding the R&D budget and the size of the company. The former ones show an inverse relationship; that is, the smaller KIBS companies make the most effort in R&D. On the other hand, they found some practices common to services and manufacturing are important to explain improvements in innovation and financial performance.

Additionally, universities and technology centres are the main providers for these companies.

2.3. Cooperation and firm size

Small and medium-sized enterprises (SMEs) have limited financial resources but are more flexible and less bureaucratic, more proactive, and market-oriented, characteristics that facilitate innovation (Acs and Audretsch, 1987; Brunswicker and Vanhaverbeke, 2015; Cohen and Klepper, 1996). On the other hand, large firms 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).

The first empirical studies suggest that the majority of OI adopters are large companies (Keupp and Gassmann, 2009; Lichtenthaler and Ernst, 2009; Bianchi *et al.*, 2011; Galati and Bigliardi, 2017), although several publications have shown that SMEs have been involved in many OI practices over the last fifteen years (Usman *et al.*, 2018). Some factors hinder the OI adoption process in SMEs, such as lack of knowledge, collaboration, organization, and financial and strategic barriers (Bigliardi and Galati, 2016).

The effect of size on Open Innovation shows different results. Van de Vrande *et al.* (2009) find that medium-sized firms are, on average, more heavily involved in OI than their smaller counterparts. Spithoven *et al.* (2013) find that the effects of OI practices 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, especially outbound open innovation, which involves the external exploitation of internal ideas in different markets. These authors also suggest that large firms collaborate with diverse partners in a percentage distribution compared to SMEs.

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

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

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

Hypothesis 3: Cooperation propensity with universities and research institutes or with other partners in the manufacturing industries differs according to their technological intensity and firm size.

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

3. Materials and methods

3.1. Data and Population

This study used data from the Community Innovation Survey (CIS) conducted in Spain from 2012 to 2014. The CIS 2014 applies the concepts and methodology of the Oslo Manual (3rd ed 2005). The harmonized survey provides a deep understanding of different issues concerning innovation in enterprises. This study uses data related to

product and process innovations, cooperation for innovation activities, cooperation partners, firm size, technological intensity, and knowledge intensity.

The number of enterprises surveyed in Spain CIS 2014 during the period was 27,092. The firms that introduced technological innovations (product or process) represented 34% of the total, while 2,546 firms (9.4%) abandoned the innovation activities for product and process innovations before completion, and 5,991 firms (22.1%) were involved in ongoing innovation activities at the end of 2014.

The study population includes 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). They accounted for 11,262 (41.6%) of the total number of firms.

3.2. Research design

3.2.1. Dependent variables: Cooperation and cooperation groups

The firms that cooperated in any of the innovation activities with other enterprises or organizations accounted for 4,293 (38.1%) of the total of the sample, and the remaining 61.9% did not cooperate.

We grouped the firms that cooperated with universities, research institutes, and other partners, following Lara *et al.* (2019) proposal.

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

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 of Eurostat's aggregation of firms in the services sector, based on the NACE Rev. 2 classification, the firms were grouped into less knowledge-intensive and knowledge-intensive.

The firms were grouped into two categories according to the number of employees: a) firms with under 449 employees, which are small and medium-sized firms (SMEs), and b) firms with more than 500 employees, which are large firms.

Table 1 describes the dependent and independent variables.

3.3. Procedure

In the first stage, the study uses the Chi-Square for testing the relationships between cooperation and the manufacturing industries by technological intensity (LTCH/HTCH) and cooperation, and the services firms by knowledge intensity (LKIS/KIS), in addition to firm size (SMEs/Large). Sirkin (2006) corroborates that the Chi-

Square statistic is commonly used for testing the relationship between categorical variables in a contingency table.

The study then tests the hypotheses about these relationships by carrying out a logistic regression model for each sector. 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 intensive (LKIS/KIS), and the firm size (SMEs/Large) represented by (0/1).

In the second stage, the analysis was replicated using cooperation groups as the outcome variable. These groups are a) Other partners (OTHRS) and b) Universities and research institutes (UNI-RSI), both represented with (0/1).

Table 1. Dependent and independent variables

Variables	*Description*	*Type of variable*	*Categories*	*N*	*%*
Cooperation	Firms that did NOT cooperate with other enterprises or organisations on innovation activities	Dependent variable	(0) N_COOP	6969	61.9
	Firms that cooperated with other enterprises 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 industries by technological intensity	Low + Medium-Low Technological intensity industries	Independent variable	(0) LTCH	4156	36.9
	Medium-High + High Technological intensity industries		(1) HTCH	1780	15.8
Services firms by knowledge intense	Less knowledge-intensive services	Independent variable	(0) LKIS	1726	15.3
	Knowledge-intensive services		(1) KIS	3600	32.0
Firm size	Firms with less than 250 employees	Independent variable	(0) SMEs	9806	87.1
	Firms with more than 250 employees		(1) Large	1456	12.9

4. Results

The next two subsections include (1) Results of the relationship between cooperation and technological / knowledge intensity and firm size, and (2) Results of the relationship between cooperation groups (Universities and research institutes | other partners) and technological / knowledge intensity and firm size. Each subsection shows the results of testing the hypothesis with the Chi-square test and the logistic regression model results for each sector.

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

4.1.1. Descriptive analysis and Chi-square test

The manufacturing industries accounted for 5,936 (52.7%) of the firms in the sample, of which around 70% are low-tech industries (LTCH), and the remaining 30% are high-tech industries (HTCH).

The number of industries that cooperated with other enterprises or organizations on innovation activities was 2,183 (36.8%). With 39.8%, high-tech companies were more engaged in cooperating than low-tech companies (35.5%). Specifically, the high-tech industries (HTCH) had a 1.2 times higher risk (odds ratio) of cooperating than the low-tech industries (LTCH).

Table 2(a) shows the cooperation of the manufacturing industries by technological intensity.

According to the chi-square test result, with a value of 9.83 and significance p-value=0.002, there is a statistically significant relationship between cooperation and the technological intensity of industries. This relationship is also moderately and directly proportional due to the Phi coefficient, with a value of 0.041 and p-value=0.002.

There were 5,326 services firms (47.3%) in the study population. Most of them (67.6%) were knowledge-intensive services (KIS), and the remaining 32.4% were less knowledge-intensive services (LKIS).

Regarding cooperation, about 44% of the knowledge-intensive services (KIS) cooperated with other enterprises or organizations, while 30.5% of the less knowledge-intensive services (LKIS) did so. Therefore, the knowledge-intensive services (KIS) had a 1.8 times higher risk (odds ratio) of cooperating than less the knowledge-intensive services (LKIS).

Table 2(b) shows the cooperation of the services firms by knowledge intensity.

According to the result of the Chi-square Test, with a value of 89.210 and a significance p-value<0.001, the variables cooperation and services sector by knowledge intensity are associated. Nevertheless, this relationship is low and directly proportional as per the result of the Phi coefficient, with a value of 0.129 and p-value<0.001.

Regarding firm size, small and medium-sized firms (SMEs) accounted for 87.1% of the study population (9,806 firms), while the remaining 12.9% were large firms. However, about 51.6% of the large firms cooperated with other enterprises or organizations in innovation activities instead of 36.1% of the SMEs. The large firms had a 1.89 times higher risk (odds ratio) of cooperating than the SMEs.

Table 2(c) shows the cooperation of the firms by their size.

Cooperation and the firm's size are associated variables as per the value of 128.43 obtained in the Chi-square Test with a significance p-value<0.001. This association is low but directly proportional, according to the result of the Phi coefficient, with a value of 0.107 and p-value<0.001

Table 2. Contingency table of cooperation by technological intensity, knowledge intensive and firm's size.

		(a) Technological Intensity			*(b) Knowledge Intensive*			*(c) 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
Did not cooperate (N_COOP)	N	2681	1072	3753	1200	2016	3216	6264	705	6969
	% within cooperation	71.4%	28.6%	100.0%	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%	100.0%	24.9%	75.1%	100%	82.5%	17.5%	100.0%
	% 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	11262
	% Total	70.0%	30.0%	100.0%	32.4%	67.6%	100.0%	87.1%	12.9%	100.0%
	% within intensity	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 3 above shows the Chi-Square Test and symmetric measures summary for cooperation among the manufacturing industries and services firms and the firms' size.

Table 3. Chi-square tests and symmetric measures summary of cooperation by technological intensity, knowledge intensive and firm's size.

	(a) Technological intensity	*(b) Knowledge-intensive*	*(c) Firm's Size*
N	5936	5326	11262
Pearson Chi-Square	9.839a	89.210b	128.439c
Degrees of freedom (df)	1	1	1
Phi	0.041	0.129	0.107
*p-value**	*0.002*	*<0.001*	*<0.001*

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 654.61
b. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 683.79
c. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 555.02

**Level of significance=0.05*

4.1.2. Logistic Regression Models

The logistic regression model of cooperation carried out with the manufacturing industries by the technological intensity and firm size categories showed the following results:

Predicted logit of (Cooperation) =

-0.705+1.126*(Size)+0.137*(Technological Intensity)

According to the model, the probability of a manufacturing firm cooperating is positively related to the firm size (p=<0.05) and positively related to the technological intensity (p=<0.05).

Nevertheless, the Wald statistic (160.645) of the firm size is higher than the Wald statistic (5.317) of the technological intensity. Thus, the firm's size contributes more to explaining the cooperation of manufacturing firms than their technological intensity.

Given the same technological intensity, the large firms were more likely to cooperate than the SMEs. Large firms have a 3.083 times higher risk (odds ratio) of cooperating than the SMEs.

Applying the model, the cooperation probability for a large company with high technological intensity was 0.634, while the cooperation probability for an SME with low technological intensity was 0.33.

Table 4(a) shows the logistic model of cooperation for the manufacturing industries.

The logistic regression model of cooperation applied to the services firms by knowledge intensity and firm size showed the following results:

Predicted logit of (Cooperation) =

-0.896+0.320*(Size)+0.611*(Knowledge-Intense)

According to the model, the cooperation probability for services firms was positively related to the firm size (p=<0.05) and positively related to the firm's knowledge intensity (p=<0.05). Furthermore, the Wald statistic (94.993) of knowledge intensity was higher than the Wald statistic (17.410) of the firm size. Thus,

knowledge intensity contributes more to explaining the cooperation of services firms than their size.

Given the same firm size, the knowledge-intensive firms (KIS) were more likely to cooperate than the less knowledge-intensive firms (LKIS). The odds ratio of KIS firms cooperating was 1.842 times higher than the odds ratio of LKIS doing so.

The cooperation probability of a large knowledge-intensive firm was 0.508, while the probability of a less knowledge-intensive SME was 0.289.

Table 4(b) shows the logistic model of cooperation for services firms.

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

The number of manufacturing industries that cooperated with universities and research institutes (UNI_RSI) or other partners (OTHRS) was 1,271. Of those, 66.4% are low-tech industries (LTCH), and the remaining 33.6% are high-tech industries (HTCH).

Table 4. Logistic regression model for the firm's cooperation*

(a) Manufacturing industries					
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
(b) 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-intensive (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*

The high-tech industries cooperated more with universities and research institutes (37%) than the low-tech industries (32.6%). The risk of HTCH cooperating was 1.2 times higher than for LTCH Conversely, LTCH cooperated more with other partners (67.4%) than HTCH (63%).

Table 5(a) shows the manufacturing industries by their technological intensity in cooperation with universities and research institutes or other partners.

Accordingly, the result of the Chi-square Test, with a value of 2.46 and significance p-value=0.116, showed that cooperation

groups and the technological intensity categories are independent variables.

The services firms that cooperated with universities and research institutes (UNI-RSI) or with other partners (OTHRS) accounted for 1,454 (69%) of the total cooperating firms. Most of the firms (73.2%) are knowledge-intensive services (KIS), and the remaining 26.8% are less knowledge-intensive (LKIS).

The knowledge-intensive firms 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).

Table 5(b) shows the services firms according to their knowledge-intensity in cooperation with universities and research institutes or other partners.

As a result, the Chi-square test, with a value of 57.359 and a significance p-value<0.001, showed an association between the cooperation groups and the knowledge intensity categories of the services firms. This relationship is low and directly proportional according to the Phi coefficient, with a value of 0.199 and p-value<0.001.

Regarding the firm size, the firms that cooperated with universities and research institutes (UNI_RSI) or other partners accounted for 2,725 (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 about 65.6% of the cases, and the percentage is similar in the case of the large firms, at 65.8%. Table 5(c) shows the firms' cooperation with universities and research institutes or other partners according to their size.

Cooperation with universities and research institutes (UNI_RSI) was also similar between the SMEs (34.4%) and the large firms (34.2%).

Consequently, the result of the Chi-square Test, with a value of 0.10 and significance p-value=0.921, showed that cooperation with universities or research institutes and firm size are independent variables.

Table 6 shows the results of the Chi-square test and the summary of the symmetric measure for the cooperation groups.

Table 5. Contingency table of the cooperation groups (**Universities and Research institutes | Other partners**) by technological intensity, knowledge intensive and firm's size.

		(a) Technological Intensity			*(b) Knowledge Intensive*			*(c) 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%	100.0%	14.7%	85.3%	100.0%	81.6%	18.4%	100.0%
	% 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%	100.0%	33.2%	66.8%	100.0%	81.5%	18.5%	100.0%
	% 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%	100.0%	26.8%	73.2%	100.0%	81.5%	18.5%	100.0%
	% within intensity	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 6. Chi-square tests and symmetric measures summary for the cooperation groups: Universities and Research institutes | Other partners.

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

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 145.47.

b. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 134.84.

c. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 172.96.

**Level of significance=0.05*

4.2.2. Logistic regression models

The logistic regression model carried out for cooperation with universities and research institutes (coded with 1) and other partners (coded with 0), and the variables technological intensity and size revealed the following results: Predicted logit of (Cooperation UNI_RSI) = -0.806+0.761*(Size)

According to the model, the probability of manufacturing industries cooperating with universities and research institutes (UNI-RSI) is positively related to the firm size (p=<0.05) and is not significant in terms of the technological intensity (0=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 is 0.488, and for SMEs, it is 0.308

Table 7(a) shows the logistic model of the cooperation groups (universities and research institutes | other partners) for the manufacturing industries.

The logistic regression model carried out for the cooperation groups, universities, and research institutes (coded with 1) and other partners (coded with 0), and the variables knowledge-intensity and firm size, reveal the following results: Predicted logit of (Cooperation UNI_RSI) = -1.299-0.637*(Size)+1.006*(Knowledge-intensive)

According to the model, the probability of the services firms cooperating with universities and research institutes is positively related to the firm size (p=<0.05) and the knowledge intensity (p=<0.05). Nevertheless, the Wald statistic (48.395) of knowledge intensity is higher than the Wald statistic (16.005) of firm size, meaning that the knowledge intensity variable contributes more to explaining cooperation with universities and research institutes.

Furthermore, given the same firm size, the knowledge-intensive services (KIS) were more likely to cooperate than the less knowledge-intensive services (LKIS). The odds ratio of KIS cooperating with universities and research institutes was 2.73 times greater than for LKIS.

The cooperation probability for large knowledge-intensive services firms is a 0.71 probability of cooperating with universities

and research institutes (UNI-RSI). Meanwhile, less knowledge-intensive SMEs have a 0.78 probability of cooperating with other partners (OTHRS).

Table 7(b) shows the logistic model of the cooperation groups (universities and research institutes | other partners) for the services firms.

Table 7. Logistic regression model for the cooperation group *: Universities and Research Institutes | Other partners

(a) Manufacturing industries					
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
(b) Services 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

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

5. Discussion

The results support accepting the first hypothesis, meaning that the cooperation propensity of manufacturing industries is related to both technological intensity and firm size. It was also 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, firm size better explains cooperation than technological intensity.

This finding is consistent with other studies comparing the OI practices of large companies and SMEs. For example, Spithoven *et al.* (2013) show that large companies use OI practices significantly more than SMEs, with differences in research collaboration and IP strategies. However, these authors also note that SMEs make more intensive use of OI practices than large companies and are more effective in reaping their benefits. Meanwhile, on considering the existing asymmetries between large and small companies, Jang *et al.* (2017) propose a model of complementary cooperation between the two types of companies in manufacturing industries.

We also found support for accepting the second hypothesis. The cooperation propensity of the services companies is related to their knowledge intensity and firm size. However, we also observed that 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, knowledge intensity contributes more to explaining the cooperation of services companies than their size.

This finding is consistent with other studies. For example, Miles (2005) points out that knowledge-intensive business services (KIBS) are among the fastest-growing European economy areas.

Their growth is associated with outsourcing, the internationalization of services, and the growth in demand for certain knowledge forms.

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 the firm size. Moreover, 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 for SMEs.

This finding is consistent with other studies highlighting the differences between SMEs and large firms in cooperation with different partners, particularly universities. For instance, Laursen and Salter (2004) find that a firm's capability to draw from university research increases with the organization's size. Moreover, the firms that adopt open strategies and invest in R&D are more likely to cooperate with universities.

Belderbos *et al.* (2006) find that the joint adoption of cooperation strategies could be either beneficial or detrimental to firm performance depending on firm size and specific combinations of strategies. They argue that SMEs benefit from combining customers with university or competitor cooperation. For large firms, there is a significant impact on a combination of supplier and university cooperation.

Santoro and Chakrabarti (2002) distinguish four main components in the industry and university relationship: research

support, cooperative research, knowledge transfer, and technology transfer. They show that larger firms use knowledge transfer and research support relationships to build non-core technological areas. In contrast, SMEs, particularly those in high-tech industrial sectors, focus on core technological areas through technology transfer and cooperative research relationships.

Regarding SMEs, Brunswicker and Vanhaverbeke (2015) argue that these firms 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 organizations.

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, 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. Thus, we find that knowledge intensity would better explain cooperation with universities and research institutes in services firms than firm size.

This finding is the opposite of the study by Wong and He (2005) because it shows a significantly lower incident collaboration involving universities and research institutes for KIBS firms than for manufacturing industries. On the other hand, it is consistent with

other studies. For instance, Freel (2006) shows that high innovativeness levels in SMEs (knowledge-intensive services and manufacturing firms) are related to cooperative relationships between KIBS and universities. Furthermore, Lee and Miozzo (2019) distinguish KIBS by knowledge bases and modes of organizational learning and find that science-based KIBS firms, those engaged in a science, technology, and innovation (STI) mode of organizational learning, and KIBS firms, engaged in a doing, using and interacting (DUI) mode of organizational learning, are active collaborators with universities for innovation, and benefit from this collaboration. It 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.

6. Conclusions

Regarding context-dependency in open innovation, it is not clear whether cooperation is equally interesting for all companies according to their contextual characteristics (industry or size). Similarly, in the cooperation framework, the results of the innovation performance of manufacturing industries and services companies differ depending on the type of cooperating partner (customers, suppliers, competitors, universities, and research institutes) and the internal and external characteristics of the firms, such as the capabilities and strategies they use to manage the cooperation.

The objective of this study was to explain if the propensity to collaborate in innovation activities with different partners, particularly with universities and research institutes, is related to the contextual characteristics of technological intensity in the case of manufacturing companies and knowledge intensity in the case of service companies, and the size of the companies.

In the first part of this study, we included both contextual characteristics in determining, in general, which of them best explains cooperation / non-cooperation. With these results, in the second part, we modelled the propensity to cooperate with universities and research institutes or other partners in the manufacturing industries and the services companies separately.

According to the results, there is support for accepting the first hypothesis and partially accepting the third hypothesis. That is, the manufacturing companies' propensity to cooperate is related to size and technological intensity. However, we observed that large companies have a greater probability of cooperating at the same technological intensity level as SMEs. Additionally, the technological intensity was not significant for the cooperation of industries with universities and research centres. Consequently, the industries' cooperation with universities and research institutes was more explained by their size than by their technological intensity.

We also found support for accepting the second and fourth hypotheses. The propensity of service companies is related to both their knowledge intensity and size. However, we observe that for

service companies of the same size, knowledge-intensive ones are more likely to cooperate than less knowledge-intensive ones. The same is true when it comes to the propensity to cooperate with universities and research institutes. Therefore, the services firms' cooperation was more explained by their knowledge intensity than by their size.

This study contributes to the literature on open innovation, particularly to the debate about internal and external context characteristics (size and technology/knowledge intensity) as determinants of manufacturing and service companies' cooperation. Significantly, this study contributes to a better understanding of the differences between industries' and services firms' inter-organizational relationships with universities and research institutes.

Knowing the cooperation model between universities and research centres and manufacturing companies due to their size, and service companies due to their knowledge intensity allows the same actors to understand the characteristics and needs of the parties involved, to find opportunities to improve knowledge creation and transfer processes, to obtain the expected results of innovation performance, and to strengthen their cooperation links.

Political decision-makers can develop strategies to promote the manufacturing industries and service companies' cooperative relationships, regardless of their technology level in the first case and their size in the second. Besides, they can support universities to

improve research and strengthen knowledge and technology transfer offices.

Despite the contributions, the limitation of this study, the use of a few explanatory variables, needs to be overcome when conducting future research. Other explanatory variables of the internal context, which may be related, such as organizational structures and strategies used for knowledge management, can be added to the cooperation model with universities and research centres. Last, it may be interesting to inquire more about the determinants and results of the services companies' cooperation, which constitute knowledge sources for their clients, including manufacturing companies themselves.

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Chapter VI

OPEN INNOVATION IN TIMES OF COVID-19: THE CASE OF PROJECT OXYGEN

Preprint of the article published in [European Accounting and Management Review Volume 7, Issue 1, 2020, 47-65] [https://doi.org/10.26595/eamr.2014.7.1.3] [copyright Catalan Association of Accounting and Management ACCID] [https://eamr-accid.eu]

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Abstract: In the face of the health crisis unleashed by Covid-19, experts worldwide took on the challenge of designing a low-cost emergency ventilator that could be assembled quickly. This study analyzes the successful case of the Project OxyGEN, led by the Barcelona-based design firm Protofy, which created an industrial-class emergency ventilator and obtained approval from the Spanish Ministry of Health (AEMPS) for use on patients. The project received scientific support from a local Research Hospital, and SEAT, a Volkswagen subsidiary, collaborated in the OxyGEN ventilators' mass-production. This open-hardware project sprung into action teams in more than 32 countries involved in the collaborative design process, adopted or made an iteration of the technology. These teams collaborated with suppliers, consultants, universities, and research institutes to drive this innovation forward. The case highlights the Open Innovation approach, inter-organisational relationships between firms of different sectors with research institutions, and innovation communities.

Keywords: Case study, Cooperation, Covid-19, Innovation communities, Inter-organisational relationships, Open Innovation, Open Hardware.

EAMR

EUROPEAN ACCOUNTING AND MANAGEMENT REVIEW

VOLUME 7, ISSUE 1, ARTICLE 3, 47-65, NOVEMBER 2020

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Received October 8, 2020; accepted December 9, 2020.

ABSTRACT

In the face of the health crisis unleashed by Covid-19, experts worldwide took on the challenge of designing a low-cost emergency ventilator that could be assembled quickly. This study analizes the successful case of the Project OxyGEN, led by the Barcelona-based design firm Protofy, which created an industrial-class emergency ventilator and obtained approval from the Spanish Ministry of Health (AEMPS) for use on patients. The project received scientific support from a local Research Hospital, and SEAT, a Volkswagen subsidiary, collaborated in the OxyGEN ventilators' mass-production. This open-hardware project sprung into action teams in more than 32 countries involved in the collaborative design process, adopted or made an iteration of the technology. These teams collaborated with suppliers, consultants, universities, and research institutes to drive this innovation forward. The case highlights the Open Innovation approach, inter-organisational relationships between firms of different sectors with research institutions, and innovation communities.

KEYWORDS

Case study, Cooperation, Covid-19, Innovation communities, Inter-organisational relationships, Open Innovation, Open Hardware.

ACKNOWLEDGMENT

A special thanks to Protofy and all the companies that participated in the OxyGEN project. To Kairos Cano for his valuable contribution to this study's improvement and the University of the Armed Forces ESPE for the financial support through grant No. 019-2017-CCB.

1. Introduction

In response to the Covid-19 pandemic, teams of experts worldwide took on the challenge of designing a low-cost emergency ventilator that could be assembled quickly. A particularly successful case is the OxyGEN Project, led by the Barcelona-based design firm Protofy. Building on MIT's production guidelines and scientific support from a local Research Hospital, Protofy created an industrial-grade emergency ventilator, which obtained approval from the Spanish Ministry of Health (AEMPS) for patients. SEAT, a Volkswagen subsidiary, collaborated with Protofy in the mass-production of OxyGEN ventilators.

The OxyGEN ventilator is an open hardware project which sprung into action teams in 32 countries. This community contributed to the design process, adopted, or made an iteration of the technology. These teams are also collaborating with suppliers, consultants, clients, universities, and research centers in their countries to drive this innovation forward.

This case study aims to describe and analyse the Project OxyGEN from the perspective of open innovation. We asked ourselves what characteristics and internal organisational practices of Protofy were remarkable to carry out this innovation during the Covid-19 pandemic and interact with the innovation community built around this open hardware project.

The paper is organized as follows: Section 2 addresses the literature review, section 3 briefly describes the methodology and data collection, section 4 presents the case, section 5 discusses the findings, and finally, section 6 draws conclusions, limitations, and future research.

2. Literature Review

2.1. Open Innovation

Open innovation holds that firms can and should use external and internal ideas and paths to market as they look to advance their technology (Chesbrough et al., 2006). As a result of firms adopting an Open innovation approach, Gassman and Enkel (2007) identify three

processes: a) The outside-in process (inbound), where the integration of suppliers, customers, and external knowledge sourcing increase a company's innovativeness, b) The inside-out process (outbound), occurs through external exploitation of internal ideas in different markets, selling IP and multiplying technology, and c) The linking outside-in and inside-out processes by working in alliances with complementary companies.

Although there are more studies focused on the inbound process (e.g., Bianchi et al., 2010; Chesbrough and Crowther 2006; van de Vrande et al., 2009, Parida et al., 2012) than those on the outbound process (e.g., Lichtentaler, 2009) both show positive effects on the performance of the firm. However, there is consensus that to benefit from open innovation successfully, a firm requires absorptive capacity and some higher-order management capabilities to align inbound knowledge flows with the firm's in-house innovation activities.

Besides, Brunswicker and Vanhaverbeke (2015a) argue that the nature of the external source of knowledge (e.g., customers, suppliers, universities, research institutions, competitors, consultants) for inbound processes are different, thus the organizations, according to their internal organizational practices, adopt different strategies to take advantages of each source purposely. These strategies are (1) minimal searcher, (2) supply-chain, (3) technology-oriented, (4) application-oriented, and (5) full scope sourcing.

The minimal searcher (Type 1) does not actively interact with external sources to combine internal and external potentials. Supply-chain (Type 2) has relatively intense interactions with direct customers and suppliers compared to other external sources. Technology-oriented firms (Type 3) have a relatively high degree of cooperation with universities, research organisations, and IPR experts. The application-oriented and demand-driven innovation are characteristic of the application-oriented Searcher (Type 4). Finally, the full scope-searcher (Type 5) is heavily involved in knowledge sourcing, shows a strong interest in external ideas from various innovation sources, and built an innovation ecosystem for new ideas.

It is worth noting that the authors also suggest that these strategy types map onto four internal organizational practices for innovation that help support and enable external knowledge sourcing and alignment at strategic and operational levels: They are (1) long-term investment activities, (2) innovation strategy processes, (3) innovation development processes, and (4) innovation project control.

The first practice involves innovation management directing a company's innovation efforts toward project-focused activities whose purpose is to build long-term knowledge rather than produce short-term results (Brunswicker and Vanhaverbeke, 2015b). The implementation of innovation strategy processes helps to identify and recognise the value of new external information and knowledge and direct internal innovation activities (Nelson and Winter, 1982). The third organisational practice: innovation development, which helps to assimilate and transform new knowledge (Tidd, 2001). Finally, innovation project control is related to the firm's actions to reconfigure activities (Benner, 2009; Goffin and Mitchell, 2005) and ensure that innovation measures are carried out within budget, schedule, and satisfactory level performance (Robertson et al., 2012).

Based on the typology mentioned above, this case study examines the firm Protofy to determine its external knowledge sourcing strategy and internal organisational practices to leverage inbound knowledge flows for the OxyGEN project.

2.2. Innovation Communities

The first studies on innovation communities were carried out in the context of open-source software projects, typically initiated by individuals or small groups, where they are more observable the interactions between users and the role of communities. However, innovation communities have also been part of the development of physical products in a very similar way (von Hippel, 2005). In 2011, inspired by the free software movement, open-source hardware appeared. Both share similar characteristics and benefits, such as a high level of transparency in the development process, a high level of continuous improvement, and, again, high community participation (Merkel et al., 2012a).

West and Lakhani (2008) point out that communities and their role in the innovation process fit within and offer an opportunity to extend the firm-centric concept of open innovation. Considering them to be a "voluntary association of actors, typically lacking in a priori common organisational affiliation (i.e., not working for the same firm) but united by a shared instrumental goal, creating, adapting, adopting, or disseminating innovations."

Regarding intra-community interactions, the peer-to-peer community support facilitates the adoption and use of innovation (Lakhani and von Hippel, 2003). Meanwhile, identification and interaction within a community mean that innovations fuel imitation and extension by other user innovators (von Hippel, 2001).

Fitcher K. (2009) highlights the role of innovation communities as networks of promoters, redefining innovation communities as "An informal network of like-minded individuals, acting as universal or specialised promoters, often from more than one company and different organisations that team up in a project, and commonly promote a specific innovation, either on one or across different levels of an innovation system."

Based on the framework mentioned above, the case study set out to analyse the community created around the OxyGEN project and its participation in developing and disseminating this innovation.

3. Methods

3.1. Case study methodology

This research used the case study methodology to document and analyse the OxyGEN emergency ventilator's development during the first wave of the Covid-19 pandemic. First, we describe Protofy, the firm that led, accelerated, and developed the project, followed by the context of the Covid-19 outbreak in Spain. Then, we recount the design and development of the Oxygen emergency ventilator itself and finally describe the innovation community built around the project, which played a crucial role in its manufacturing and global distribution.

The case study method was chosen for its suitability for showing how open hardware and the open innovation approach combined to drive innovation forward. As Yin (2009a) remarks, one of the strengths of the case study research methodology is that it provides a rich contextual analysis of the unit of study, at a qualitative detail that cannot be replicated using quantitative or experimental methods.

3.2. Data collection

The primary data sources for this case-study are interviews, surveys, and documental review. Interviews were conducted with the co-founders of Protofy to discuss their perspectives and experiences. We used a semi-structured format for this interview. The interviews were recorded and transcribed to assist in the analysis.

We applied the surveys in the second half of April, during the lockdown. The criterion for selecting the sample subjects (project/team leaders) was the completion of a self-administered questionnaire, through the Google Forms application (online), due to its flexibility and suitability to adjust to the needs of the research for free and without limitations (Abundis, 2016).

The questionnaire consists of 12 questions divided into three sections: general information about the project and team profile, degree of involvement in the OxyGEN project, and cooperation with partners in their respective countries.
Annex 1 shows the questionnaire applied to the OxyGEN community.

The questionnaire's link was sent to all OxyGEN community members registered on Discord.com, the team members' platform to communicate and share relevant information for each project's development. The response level reached 62%, which corresponds to 30 projects/teams worldwide.

Relevant company documents were also analysed. These included the blog, video journal, tutorials, publications in newspapers and magazines, the project's dedicated website, and participating partners' publications.

An active dialogue was maintained with Protofy to clarify inconsistencies and expand and develop the data. In the case of study research, by collecting and cross-examining data about the innovation process from multiple sources, data collection and interpretation are likely to be an accurate representation of reality (Yin, 2009b).

4. The OxyGEN Project

4.1. The company

Protofy is a company based in Barcelona, specialized in the design, engineering, and rapid prototyping of creative and innovative ideas. Protofy prides itself on its agility and its ability to work in close collaboration with its customers and stakeholders.

The company was created in February of 2016 by a multidisciplinary team of young engineers committed to quality, safety, and technology. The team currently consists of seven people, equipped with the knowledge, tools, and talent to design all kinds of electronic circuits incorporated and mechanical parts, Internet of Things (IoT) development, and software development for both desktop and mobile devices.
Protofy's service includes all development stages, from idea generation, testing, prototyping, and redesign of iterations. They aim to integrate hardware (mechanics, electronics, electricity) and software to provide high-quality technological solutions.

This small but knowledge-intensive company stands out for its speed to carry out the projects, between three and six weeks. According to Lluis Rovira, co-founder, this is due to the use of project tools such as lean and scrum, which let them plan and develop projects as design iterations validated by the clients and users. Protofy also has a distinctly developed capacity to create collaboration networks with suppliers and other market participants.

4.2. The problem

The first imported Covid-19 case in Spain was dated January 31, 2020, in the Spanish Canary Islands. One month later, on February 25, 2020, the first case was reported in the Spanish peninsula. However, Covid-19 cases were likely circulating in Catalonia before the official cases were reported (Coma et al., 2020). As Covid-19 confirmed cases grew

exponentially, on March 30, a national lockdown was declared, and all non-essential activities were suspended.

By April 4, Spain had become one of the worst-hit countries by the pandemic. The number of infected rose to 124,736 cases, 57,612 were hospitalized, and 11,700 deceased (Department of National Security DNS, 2020). The number of patients admitted to ICUs reached 3078 cases (Spanish Ministry of Health, 2020). According to the Spanish Scientific News Agency SINC (2020), between 10% and 15% of patients admitted to hospital with pneumonia caused by Covid-19 are admitted to the ICU, 90% of which require intubation and mechanical ventilation, generally for at least two or three weeks.

Thus, one of the most challenging problems to face during the pandemic was the sudden lack of ventilation equipment in intensive care units. With the international markets undersupplied and countries outbidding each other for equipment, locally developing and manufacturing ventilators became the most viable, if not the only option for Spain and many other countries.

4.3. The OxyGEN Ventilator

According to the interview with the founders of Protofy, what motivated them to carry out the OxyGEN Project was to contribute with their knowledge to solve the problem of the insufficient number of mechanical ventilators in the local hospitals to avoid loss of life, and to some extent also try to help alleviate the situation in remote small towns or less developed countries. Thus, their team of engineers set out to design a low-cost emergency ventilator that would be easy to build, with available materials that could be easy to find amid curfews and nation-wide lockdowns.

The team began looking for the technical requirements for the ventilator design and found valuable information shared by other experts who were also working around the world. In particular, MIT's emergency ventilator design toolkit proved useful to the team, and Protofy's design was eventually featured on MIT's website.

Very early, the team also adopted the Open-hardware strategy to carry out the project. They decided to create a dedicated website to document their journey, share information

about the project, and make their design available to download by interested builders worldwide. The decision to create a dedicated website and publish it both in English and Spanish proved to be pivotal, as search engines eventually indexed and gave their site great exposure, especially in Spanish-speaking countries.

The team had to overcome lockdown restrictions to procure the first set of pieces and materials, but they moved quickly with creativity and teamwork. They tapped into their network for expert advice when needed and created a community workspace, also known as "server" on Discord.com, where they could communicate, share information, and problem-solve about the project more effectively with people from their network, as well as visitors to the project's website. In a record time of three days, the team built the first version of the volume-controlled ventilator in wood with two innovative features: a) The use of a Bag Valve Mask Unit (BMV), also known as Ambu bag or manual resuscitator. A standard piece of medical equipment used for patient ventilation in ambulances and b) A retrofitted windshield wiper motor to provide compression.

After a series of iterations, the team decided to separate the design into two versions: a) OxyGEN-M, which can be made at makers' facilities using wood or methacrylate; and b) OxyGEN-IP, an industrial model in sheet metal, designed for mass-production.

Further into the design process, they sought scientific support from the Hospital and Research Institute Germans Trias and Pujol (IGTP) and the Faculty of Medicine and Health Sciences of the University of Barcelona. The hospital's involvement during ideation brought medical expertise and credibility into the project. It is worth noting the absorptive capacity of the hospital staff. Interviewees commented that one of the medical doctors happened to have an engineering degree, which created a natural affinity with their team.

Under the supervision of the medical personnel of the hospital, they carried out all the clinical trials. On March 30, 2020, they obtained a special authorization from the Spanish Ministry of Health (AEMPS) for the OxyGEN model-IP to be used in patients.

Finally, SEAT, a Volkswagen subsidiary, carried out the OxyGEN-IP model's mass-production at their Martorell factory. For this, they modified some of its vehicle assembly lines to assemble the electronic and mechanical components, among them the adapted motor of the windshield wiper, performing an exhaustive quality control with ultraviolet light sterilization. More than 150 employees participated in production to attend to the needs of health care centers. In total, 600 OxyGEN ventilators were produced. Equivalent to 20% of the projected demand in Spain for emergency respiratory equipment due to the Covid-19 outbreak. More than 15 enterprises among suppliers, hospitals, universities, research institutes, and authorities cooperated in carrying forward the OxyGEN project in Spain. Inspired by their success, other Volkswagen subsidiaries from Brazil and Eastern Europe followed suit and produced Oxygen ventilators for their countries.

4.4. The OxyGEN Community

The OxyGEN community is made up of 241 active members distributed in 47 teams in 32 countries. On average, there are five members in each group. Most of the teams (53%) belong to the Americas, 19% to Europe, 15% to Asia, and 13% to Africa. Table 1 shows the OxyGEN community members' distribution.

Continents	Countries		Teams		Members	
	N	%	N	%	N	%
America	13	41%	25	53%	150	62%
Europe	8	25%	9	19%	45	19%
Asia	7	22%	7	15%	28	12%
Africa	4	13%	6	13%	18	7%
Total	32	100%	47	100%	241	100%

Source: https://www.oxygen.protofy.xyz/community. Own elaboration.

Table 1. OxyGEN Community members.

The community teams are multidisciplinary. They are made up of engineers from different areas: industrial, mechanics, electronics, and computer science. About 26.32% of teams count with the support of doctors or health personnel; approximately 36.84% of teams count with designers, and another 36% are made up of professionals in other areas. Figure 1 shows the members' profiles of the teams.

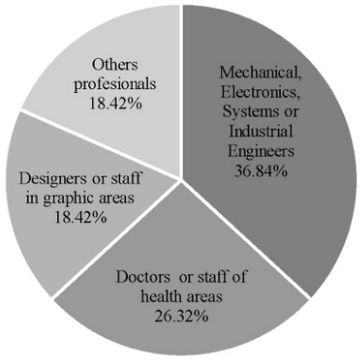

Figure 1. Profile of OxyGEN community members.

The OxyGEN community was formed very early in the project. Because of that, about 43% of teams collaborated directly in the design of the first OxyGEN prototype, but others joined quickly and learned from the experience gained to apply it to their projects. Once Protofy company released the manual for ventilator design and construction, 36% of community member teams directly adopted the design. The remaining 64% iterated on the design to develop their own derived version of the ventilator. Figure 2 shows the technology adoption.

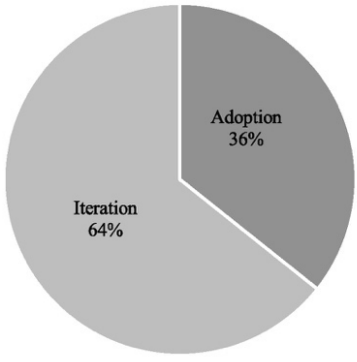

Figure 2. Technology adoption among members of the OxyGEN community

At the time of this study, 43% of the projects are in the prototyping phase, 38% are waiting for authorization from other entities or institutions, and 21% have reached the manufacturing stage. Figure 3 shows the status of the projects.

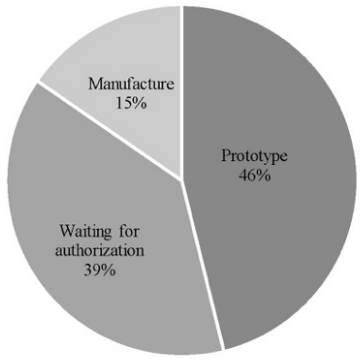

Figure 3. Status of projects in the OxyGEN community.

Most of the teams collaborated with suppliers of equipment, materials, components, and software inside the community (31%), consultants and laboratories outside of the community (27,6%), other teams in the OxyGEN community (17%), and the remaining 30% with universities or research institutes. Figure 4 shows the collaboration of the teams with different partners.

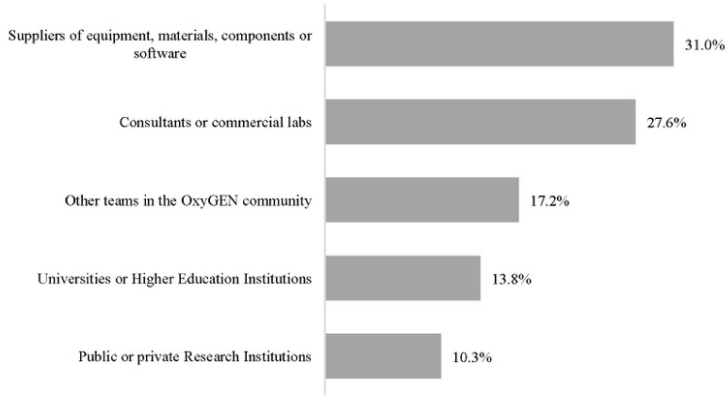

Figure 4. Collaboration partners

5. Discussion

According to the results, the characteristics and internal organisational practices of Protofy and the Project Oxygen community which enabled them to develop and carry out this innovation during the Covid-19 pandemic correspond to the three processes of open innovation: the inbound process, the outbound process, and the linking of inbound and outbound processes (Gassman and Enkel (2007).

5.1. Inbound Process

At the beginning of the process, Protofy had to find useful ideas and external information to develop their project. Nevertheless, the firm had well developed internal organizational practices for open inbound innovation already, which allow us to characterize it as a "full-scope searcher." Brunswicker and Vanhaverbeke (2015) point out that firms in this typology are heavily involved in knowledge sourcing, show a keen interest in external ideas from various sources, and have built an innovation ecosystem for new ideas. The number and diversity of Protofy's sources (researchers in universities, companies, or teams in the world who also had taken on the challenge of creating an emergency ventilator) are a straightforward exhibit of this profile.

The internal organizational practices observed implementing/supporting this innovation sourcing profile are:

1. Innovation strategy processes. Protofy used the open hardware strategy for the development of a low cost and quickly-to-assemble emergency ventilator. Precisely, some benefits of the open-source hardware are a significant source of good ideas, high participation of the community and a high level of transparency in the development process, a high development speed, often high modularity in their solutions, extraordinary development potential for free and a high level of continuous improvement (Merkel et al., 2012b). Niezen et al. (2016) point out that such advantages are particularly well suited for medical equipment production.

2. Innovation development processes. Protofy created an ecosystem to share ideas and solutions to develop the OxyGEN project collaboratively. The practice to document and make everything publicly available in different media formats and platforms, with

a particular preoccupation on how others can make use of their design or how they can be engaged in co-designing the prototype, was critical in building a community of co-innovators and promoters of the innovation.

3. Innovation project control. Protofy used agile project management methodologies to enable rapid prototyping. Well suited to the crisis, which demanded a fast response. Furthermore, workflows built around close and constant communication with customers translated well to dealing with Hospital staff to co-design the ventilator and work with stakeholders in a clinical trial and industrial settings.

4. Long-term investment activities. Protofy carried out the OxyGEN project motivated solely by its spirit of collaboration in the face of the health crisis. However, the activities carried out for the construction of a medical device successfully in such a short-time contributed to developing new knowledge and skills in the project's team. The company could exploit this investment of time and resources in new healthcare industry projects or others.

5.2. Outbound process

The inside-out (outbound) process occurred through the release of OxyGEN ventilator design so that other individuals, teams, manufacturers, or companies could take it and develop their projects. These individuals or firms became part of the community either by adopting or interacting with the technology.

This community of co-innovators and promoters of innovation played a fundamental role in developing and expanding this innovation to other countries. The community interactions with Protofy helped overcome the challenges intrinsic to developing medical technology, while support among the community members facilitated its adoption and use. The leadership of promoters and managerial skills aforementioned allowed Protofy to find complex solutions in a collaborative environment. Based on the results obtained of the survey to the OxyGEN community, below we point out the characteristics beyond the firm level that facilitated the adoption/iteration of the technology:

1. Multidisciplinary teams. This characteristic allows them to find rapid solutions to complex problems or situations.

2. Collaborative technologies support effective communication. They enabled real-time communication, mutual support and allowed massive exposure.

3. Open access to knowledge and information. The pandemic created the conditions for the practice of open innovation to become widespread. This climate of willingness to cooperate in response to the pandemic was further facilitated by using the Creative Commons Licence, which removed legal barriers to involving enterprises such as car manufacturers. In Canada, for instance, car manufacturing companies willing to collaborate with medical technology firms also emerged in response to the pandemic. However, the collaboration did not occur to the same degree due to legal concerns (Globe and Mail, 2020).

4. No language barrier. The community quickly became populated by members from different nationalities, who, in turn, facilitated access to the technology by people from non-English speaking countries.

5. Low level of competition. Developing countries found themselves unable to compete in international markets to acquire the necessary medical equipment during the pandemic, nor did they have local companies to manufacture such equipment. This issue could explain the predominance of teams from developing countries and the absence of teams from advanced economies.

6. Network effects. The initial collaboration with all types of local partners: suppliers, consultants, or commercial laboratories, universities, and research institutions, in turn, fostered the involvement of similar institutions in other countries.

5.3. Linking of inbound and outbound processes

Protofy moved to established alliances with relevant and complementary companies to advance the development and adoption of the OxyGEN Ventilator. The GTP Research Hospital and SEAT, most notably, were the partners whose involvement in the project

had the most transformative effect. Partnership with the Research Hospital resulted from Protofy's initiative; however, SEAT's participation came about due to the prior relationship with that company, which had hired Protofy in the past. Acquiring knowledge through the partnership with the Research hospital, while recasting SEAT to make use of one of their designs once again, demonstrates this firm's ability to link inbound and outbound processes to advance their purpose.

6. Conclusions

This case study set out to describe and analyse the OxyGEN Project from the perspective of Open Innovation. In response to the health crisis caused by the Covid-19 outbreak, Protofy, a Barcelona-based design company, led this project, which prototyped, developed, mass-produced, and distributed an industrial-class emergency ventilator to hospitals worldwide by creating an innovation community around the project. Protofy pursued this project with non-profit motivations, yet it provides a useful example of how open innovation strategies and building innovation communities can reduce time to market and increase technology adoption rates.

For this innovation project's design and development, the company directed its efforts to search for external sources of knowledge through cooperation with clients, suppliers, universities, and research centers. In other words, adopted an inbound open innovation process. Also, it deployed its ability to create an innovation community, combining an outbound open innovation process with an open hardware strategy, following the trend of companies adopting practices and values of the open-source movement to advance technological development and project goals.

The organizational practices observed and the strategies adopted by the company also allowed us to characterize Protofy as a "full-scope searcher." Brunswicker and Vanhaverbeke (2015) define firms in this typology as those which are: heavily involved in knowledge sourcing, show a keen interest in external ideas from various sources, and have built an innovation ecosystem for new ideas. Protofy's example, in particular, shows how firms who adopt a full-scope searcher innovation strategy can respond quickly to dramatic change.

The Oxygen community played a dual role in the project's development, as co-creators and promoters of this innovation. As Von Hippel (2006) points out: "Democratization of the opportunity to create is important beyond giving more users the ability to make exactly the right product for themselves. The joy and the learning associated with creativity and membership in creative communities are also important". It was this sense of community the main factor which channeled international enthusiasm into action. This factor, which combined others mainly: the teams' multidisciplinarity, collaborative tools to support remote work and effective communication, and a climate of openness for inter-organizational partnerships, resulted in a remarkable response to the Covid-19 pandemic.

For academics, this case study provides an example of open innovation in the crisis and inter-organizational collaboration between firms of different sectors (industries and services) with universities and research institutes. In particular, evidencing how knowledge-intensive business services (KIBS) cooperate with research institutions to receive scientific support and apply knowledge transfer for innovation. (Lee and Miozzo, 2019).

For companies, this case highlights the importance of community-building and developing internal capabilities to co-create with innovation communities. As a way to adopt external knowledge sourcing strategies and take advantage of open innovation.

Policymakers may use this case study to support the streamlining of approval processes for medical equipment and policies to promote public-private research projects.

The main limitation of a case study is that it cannot be generalised but allows digging into how and why questions. In that sense, further empirical research could analyze a sample of industries and services that used open-source values and strategies to innovate during the pandemic. Furthermore, future research could be performed regarding firms that reinvented themselves, innovated their products or services using collaborative tools during the pandemic. Also, to investigate the effects of the new forms of work enabled by these technologies on their organizational structure.

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Chapter VII

"When we decide to conduct research and contribute to the body of knowledge, we are joining a "dialogue" that is already in progress."
J. R. Latham

DISCUSSION

In this chapter, we answer and discuss the research questions of the thesis according to the results obtained in the studies performed.

Research question 1.1

> *Is there a difference in the innovation performance of firms with product innovations that have cooperated with universities and higher education institutions and the performance of firms with product innovations that have cooperated with public and private research institutions?*

According to the results obtained in the first study, there were no statistically significant differences between the innovation performance of the firms with product innovations that have cooperated only with universities and the performance of the firms that have cooperated only with research institutes. The first hypothesis of this study was rejected for both categories of innovation: (1) turnover from the new products that were new to the market and (2) turnover from the new products 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 using data as CIS data (as, for example, Belderbos *et al*., 2004; Belderbos *et al*., 2018; Guzzini and Iacobucci, 2017; Tsai, 2009).

This study also compared universities and research institutes, including other types of cooperation partners in the analysis. However, the results remained unchanged, then the second hypothesis of this study was also rejected. This double comparison adds robustness to the statistical analysis and confirms that firms engage in inter-organizational collaboration with different types of partners looking for benefits on their innovation performance (Ahuja, 2000; Faems *et al*., 2005).

Research question 1.2

> *Is there a difference between the innovation performance of the firms with product innovations that have cooperated with both universities and public and private research institutes and that of firms with product innovations that have cooperated with other partners?*

There were statistically significant differences in the innovation performance category 'new to the market'. These results partially supported the third hypothesis of the first study. This result corroborates 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; Un *et al*., 2010).

Following the literature, the first study also carried out the analysis to search possible differences between the innovation performance of the firms, according to their size. The results showed no statistically significant differences between the firms that have cooperated only with universities and the performance of the firms that have cooperated only with research institutes. The results remained when these cooperation groups included other partners. Consequently, the hypotheses 4 and 5 were rejected. Thus, these findings validate considering universities and research institutes as a joint category in empirical studies when using samples of SMEs or large firms separately.

Interestingly, the results obtained by the firm size supported hypothesis 6 of this study, the innovation performance of the group of firms that have cooperated with both universities and research institutes differed from the performance of the group of firms that have cooperated with other partners. It means that larger firms are more likely to cooperate with universities and research institutes than SMEs. These results are in line with those in Jang *et al.* (2017), Narula (2004), Veugelers and Cassiman (2005), and Tsai (2009), among others.

In this study, the sector which firms belong to was used as a control variable. The main results showed significant differences for the innovation category 'new to the market' in both the manufacturing and the services sectors. Therefore, these results support the view that the industry plays a relevant role in explaining open innovation

(Huizingh, 2011). Additionally, to take advantage of this cooperative relationship, companies will need to develop their absorption capacity (Kobarg *et al*., 2018) and open strategies to reach agreements (Fontana *et al*., 2006).

Research question 2.1

> *Which contextual characteristics (technological / knowledge intensity, size) are statistically significant in the cooperation propensity of manufacturing and service companies?*

According to the results obtained in the second study, the cooperation propensity of manufacturing industries is related to both technological intensity and firm size. However, it was observed that large manufacturing firms are three times more likely to cooperate than SMEs. Thus, firm size better explains cooperation than technological intensity. These findings are consistent with other studies comparing the OI practices of large companies and SMEs (Santoro and Chakrabarti, 2002; Spithoven *et al*., 2013).

On the other hand, the cooperation propensity of the services companies is related to their knowledge intensity and firm size. However, it was observed that knowledge-intensive services firms (KIS) are twice as likely to cooperate than less knowledge-intensive services companies (LKIS). Thus, knowledge intensity contributes more to explaining the cooperation of services companies than their size. These findings are consistent with the idea that KIBS differs from manufacturing firms but also vary substantially in their

knowledge bases, drivers and propensities to innovate (Janeiro *et al.*, 2013; Pina and Tether, 2016).

Research question 2.2

> *Which contextual characteristics (technological / knowledge intensity, size) are statistically significant in the cooperation propensity with universities and research institutes or other partners?*

Interestingly, the results showed that cooperation propensity with universities and research institutes in manufacturing industries was not significant in terms of technological intensity, but it is in terms of the firm size. These results support the view of other studies that size is a determinant in the industries-universities cooperation (Larsen and Salter, 2004; Belderbos *et al.*, 2006; Fontana *et al.*, 2006), particularly for manufacturing industries. The explanation is that SMEs typically have fewer resources and specialized personnel than large companies, which limits them to "absorb or exploit" scientific knowledge and technologies that are developed in universities.

On the other hand, cooperation propensity with universities and research institutes in services firms was significant for both knowledge intensity and firm size. However, the analysis also showed that given the same firm size, the knowledge-intensive services firms (KIS) were more likely to cooperate with universities and research institutes than the less knowledge-intensive services companies (LKIS). Thus, knowledge intensity would better explain cooperation with universities and research institutes in services firms

than firm size. This finding is consistent with the idea that high innovativeness levels in knowledge-intensive services and manufacturing firms are related to cooperation with universities (Freel, 2006; Lee and Miozzo, 2019). On the other hand, this result differs from other studies that showed that KIBS companies collaborated less than manufacturing industries with universities and research institutes (e.g., Wong and He, 2005).

Research question 3.1

> *Which characteristics, organisational practices and strategies applied by Protofy were remarkable in carrying out the product innovation (low-cost emergency ventilator) during the Covid-19 pandemic and interacting with the innovation community built around this project?*

Protofy is a company established in 2016, based in Barcelona, Spain. It is a small, knowledge-intensive services company specialising in designing, engineering, and prototyping creative ideas and technological solutions.

The primary characteristics, organisational practices and strategies used by this firm during the development of the project OxyGEN, were as follows:

1. The company stands out for the speed to carry out their projects. To do so, they use agile project management methodologies (e.g., lean, scrum) to enable rapid prototyping validated by their clients and users.

2. They have a well-integrated multidisciplinary team with a distinctly developed capacity to create collaboration networks with suppliers and other market participants.
3. They applied an open hardware strategy for designing the product innovation (low-cost emergency ventilator) collaboratively. Creating an innovation community to share ideas and solutions boosts the OxyGEN project and the adoption of technology in other countries.
4. The outside-in (inbound innovation) process occurred when the firm sourced from different knowledge sources, such as the MIT team, a research hospital, a university, automotive manufacturer and suppliers to develop their project.
5. The inside-out (outbound innovation) process occurred through the release of OxyGEN ventilator design so that other individuals, teams, manufacturers, or companies could take it and develop their projects.

These organisational practices let us characterise this firm as a *"full-scope searcher"* company. Brunswicker and Vanhaverbeke (2015) define firms in this typology as those which are: heavily involved in knowledge sourcing, show a keen interest in external ideas from various sources, and have built an innovation ecosystem for new ideas. Protofy's example, in particular, shows how firms who adopt a full-scope searcher innovation strategy can respond quickly to critical changes.

Although the Protofy company did not seek an economic benefit with this project, the case is consistent with the idea of Li and Seering, (2019) that an open-source strategy can make economic sense for hardware startups. These companies can naturally establish a community that is part of their success. The community can increase customer perceived value, decrease product development and sales cost, and shorten product go-to-market time.

The case of the company Protofy is also consistent with the results obtained in the second study of the thesis, in the idea that the probability of cooperating with universities and research institutes in the service companies is more related to their intensity of knowledge than to their size. In addition, the absorptive capacity of the firm in terms of previous collaboration experiences could have influenced the relationship positively.

Research question 3.2

> *Which characteristics and practices used by members of the OxyGEN project community facilitated the co-creation and promotion of this innovation?*

The innovation community created around the project OxyGEN was created very early and played a dual role in the project's development, as co-creators and promoters of this innovation. The teams of innovators voluntarily joined with the idea of driving innovation and "benefiting" from valuable information to develop their own projects in the context of their country. As Von Hippel (2006) points out: *“Democratization of the opportunity to create is important beyond*

giving more users the ability to make exactly the right product for themselves".

The community members collaborated closely and informally, and the use of the following practices facilitated the process of co-creating and promoting this innovation:

1. Multidisciplinary teams
2. Collaborative technologies supporting effective communication
3. Open access to knowledge and information
4. No language barrier between members of the community
5. Low level of competition
6. Network effects
7. Capability to establish alliances with different partners: universities, research institutes, suppliers, customers.

These practices are consistent with Fichter's definition (2009); innovation communities are promotor networks or informal personal networks of innovators. They are different from other forms of social networks (e.g., scientific communities, professional communities) by three key criteria:

a. The community is always related to a specific innovation idea or project.
b. All community members play a promotor role in this process.
c. The community members collaborate closely and informally, and they perceive themselves as a 'team', a 'group' or a similar entity, with a feeling of group identity.

Chapter VIII

The final step in the research process is
to put all the "pieces" together in a cogent conclusion.
J. R. Latham

CONCLUSIONS

In a global and competitive environment, collaboration has shown to have a positive impact on innovation performance. However, studies have observed that there are differences in performance according to the type of cooperator. These findings suggest that establishing alliances with different types of collaborators could be favourable, depending on the number of sources of knowledge (breadth) and the intensity of their use (depth) (Laursen and Salter, 2006).

The main objective of this thesis was to explore the cooperation between manufacturing industries and service companies, with universities and research institutes, their propensity to cooperate with them in innovation activities and the impact on innovation performance. Additionally, it analyzed a practical example of cooperation for innovation in a crisis context.

Universities and research institutes are recognized vehicles of innovation through the transfer of knowledge. Thus, the companies seek to draw relations with them to access new knowledge, cutting-edge technologies and research infrastructure to enhance their internal research capabilities, improve learning skills, and create new or significantly improved products and services to access new

markets. Both are essential actors in the national innovation systems, they have different characteristics, roles and functions. Thus, they are complementary but not substitutes (Arnold *et al.*, 2010).

Despite their differences, most studies about firms' cooperation with universities and research institutes have analysed them in a joint category obtaining different results. In the first study, we filled this research gap by comparing the firms' innovation performance that succeeded in developing product innovations in cooperation with universities with companies' innovation performance cooperating with research institutes. Additionally, the study compared these two groups' performances with the companies that cooperated with other types of partners.

The context-dependency frames a critical aspect of open innovation; companies' internal and external characteristics could affect the propensity of companies to cooperate, the choice of partner and the intensity of their cooperation. Taking this into account, the second study aimed to explain if the propensity to collaborate in innovation activities with different partners, particularly with universities and research institutes, is related to the contextual characteristics of technological intensity in the case of manufacturing companies and knowledge intensity in the case of service companies, and the firm's size.

The Covid-19 pandemic unleashed an unprecedented social and economic crisis and generated a unique climate of openness

among companies and institutions to find viable solutions to a global problem.

In this crisis context, a services company based in Barcelona carried out a project called OxyGEN for designing and developing low-cost emergency ventilators for use in ICUs. For the design and development of this innovation, the firm searched for collaboration of different partners such as a research hospital, a university, suppliers, and an automotive company to produce the industrial model of the ventilator. The project sprung an innovation community in 32 countries, which boosted this innovation in their countries.

We documented and analysed this case study from the open innovation perspective to understand which organisational practices and strategies were relevant to drive this innovation in a context of crisis.

1. Contributions for academics, practitioners, and policy makers

The analysis carried out in the first study of the thesis reveals no significant differences when companies collaborated with universities and research institutes separately. This result makes an academic contribution because support considering universities and research institutes as a joint category in empirical studies in Spain using data like the CIS data. Despite these results, there could be differences in the future and other contexts. We maintain that it would be advisable to analyse universities and research institutes

independently, as they seem to continuing to evolve into social institutions of different character.

Interestingly, the results supported that firms that cooperated with universities and research institutes together outperformed the group of firms that cooperated with other partners, for the innovation performance category 'new to the market'. The analysis by firm size and sector confirmed these results. Thus, it is clear that universities and research institutes can form a vast network of potential innovation cooperators for SMEs and large companies in the manufacturing and services sectors when they want to introduce product innovations new to the market.

The logistic regression models performed in the second study showed interesting results. The likelihood to cooperate with universities and research institutes for manufacturing industries was not significant in terms of technological intensity, but it was in terms of the firm size. On the other hand, the cooperation propensity of the services firms was significant in terms of both knowledge intensity and firm size. However, at the same size, the knowledge-intensive firms are more likely to cooperate with universities and research institutes than less knowledge-intensive companies.

These results contribute to the literature on open innovation, particularly to the debate about the contextual characteristics, firm size and technology/knowledge intensity as determinants of manufacturing and service companies' cooperation. Moreover, this knowledge contributes to universities and research institutes in

designing a cooperation model adequate to the characteristics of manufacturing firms and services firms. The parties involved could find opportunities to improve knowledge creation and transfer processes, obtain the expected results of innovation performance, and strengthen their cooperation links.

As a result of the case study analysis, organisational practices and strategies that facilitated inbound and outbound innovation processes were identified and the company was classified as a "full-scope searcher", following the typology of Brunswicker and Vanhaverbeke (2015). On the other hand, the study identified practices used by members of the innovation community that facilitated their role in the co-creation and promotion of this innovation.

For academics, this case study provides an example of open innovation in times of crisis and inter-organisational collaboration between firms of different sectors (industries and services) with universities and research institutes. It contributes to the literature about this collaborative relationship.

For practitioners, it highlights the importance of community-building and developing internal capabilities to co-create and communicate with innovation communities using collaborative platforms. Also, to adopt external knowledge sourcing strategies for taking advantage of open innovation.

In general, we consider that these studies contribute to academics and practitioners to better understand the cooperation

between industries, services firms, universities, and research institutions. In addition, policymakers should consider the distinctive role that universities and research institutes play when cooperating with firms, particularly developing product innovations to be introduced in new markets.

They should develop strategies to promote the manufacturing industries and service companies' cooperative relationships, regardless of their technology level in the first case and their size in the second. Besides, they can support universities to improve research and strengthen knowledge and technology transfer offices.

Finally, policy-makers may use the case study to support the streamlining of approval processes for innovation and policies aimed to promote public-private research projects.

2. Limitations and future research

In addition to contributions, the thesis' studies have some limitations which should be overcome with future research, for instance:

The limitation of the first study is that the data is not very recent. This could be overcome using more up-to-date data. Data limitations also hindered the use of parametric tests that would have enabled the effects of cooperation, size, and sector on the innovation performance of firms to be considered jointly. These newer databases should ideally be from different countries and cover an extended period of time.

The second study has a limited number of explanatory variables. This limitation could be overcome by adding other explanatory variables in the analysis. Future studies could explore other internal characteristics, such as organizational structures and strategies used for knowledge management, which can be added to the cooperation model with universities and research institutes.

The main limitation of a case study is that it cannot be generalised but allows digging into how and why questions. To overcome this limitation, future research could design a multi-case study about industries and services companies that used open-source values and strategies to innovate during the pandemic or resourced products in this context.

In the research line of cooperation with universities and research institutes still there are still new avenues to explore, future research could focus on:

a. Measure the effect of cooperation with universities and research institutes on the innovation performance of knowledge-intensive small and medium service companies.
b. Inquire more about the determinants of services companies' cooperation, for example organizational structure and practices.
c. More research will be needed to understand the behaviour of firms that reinvented themselves, innovated their products or services using collaborative tools during the pandemic of Covid-19.

d. Investigate the effects of the new forms of work enabled by collaborative technologies on the organizational structure.

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APPENDIXES

Appendix A. CIS 2012 The Harmonised Survey Questionnaire

The Community Innovation Survey 2012

THE HARMONISED SURVEY QUESTIONNAIRE, JULY 23, 2012

The Community Innovation Survey 2012 **FINAL VERSION July 23, 2012 (v15)**

This survey collects information on your enterprise's innovations and innovation activities during the three years 2010 to 2012 inclusive.

An innovation is the introduction of a new or significantly improved product, process, organisational method, or marketing method by your enterprise.

An innovation must have characteristics or intended uses that are new or which provide a significant improvement over what was previously used or sold by your enterprise. However, an innovation can fail or take time to prove itself.

An innovation need only be new or significantly improved for your enterprise. It could have been originally developed or used by other enterprises.

Sections 2 to 7 only refer to product and process innovations. Organisational and marketing innovations are covered in sections 8 and 9.

Please complete **all** questions, unless otherwise instructed.

Person we should contact if there are any queries regarding the form:

Name: _____
Job title: _____
Organisation: _____
Phone: _____
Fax: _____
E-mail: _____

1. General information about the enterprise

Name of enterprise _____ *ID*
Address[1] _____ *NUTS*
Postal code _____ **Main activity**[2] _____ *NACE*

1.1 In 2012, was your enterprise part of an enterprise group? (A group consists of two or more legally defined enterprises under common ownership. Each enterprise in the group can serve different markets, as with national or regional subsidiaries, or serve different product markets. The head office is also part of an enterprise group.) *GP*

Yes ☐ In which country is the head office of your group located?[3] _____ *HO*
No ☐

If your enterprise is part of an enterprise group: Please answer all further questions about your enterprise only for the enterprise for which you are responsible in [your country]. Exclude all subsidiaries or parent enterprises.

1.2 During the three years 2010 to 2012 did your enterprise:

	Yes	No	
	1	*0*	
Merge with or take over another enterprise	☐	☐	*ENMRG*
Sell, close or outsource some of the tasks or functions of your enterprise	☐	☐	*ENOUT*
Establish new subsidiaries in [your country] or in other European countries*	☐	☐	*ENNWEUR*
Establish new subsidiaries outside Europe	☐	☐	*ENNWOTH*

1.3 In which geographic markets did your enterprise sell goods and/or services during the three years 2010 to 2012?

	Yes	No	
	1	*0*	
A. Local / regional within [your country]	☐	☐	*MARLOC*
B. National (other regions of [your country])	☐	☐	*MARNAT*
C. Other European Union or associated countries*[4]	☐	☐	*MAREUR*
D. All other countries	☐	☐	*MAROTH*

Which of these geographic areas was your largest market in terms of turnover during the three years 2010 to 2012? (Give corresponding letter) _____ *LARMAR*

*: Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

[1] NUTS 2 code
[2] NACE 4 digit code
[3] Country code according to ISO standard
[4] Each NSO needs to remove their own country from the list of European countries.

2. Product (good or service) innovation

A product innovation is the market introduction of a **new** or **significantly** improved **good or service** with respect to its capabilities, user friendliness, components or sub-systems.

- Product innovations (new or improved) **must be new to your enterprise**, but they **do not need to be new to your market**.
- Product innovations could have been originally developed by your enterprise or by other enterprises or institutions.

A **good** is usually a tangible object such as a smartphone, furniture, or packaged software, but downloadable software, music and film are also goods. A **service** is usually intangible, such as retailing, insurance, educational courses, air travel, consulting, etc.

2.1 During the three years 2010 to 2012, did your enterprise introduce:

	Yes *1*	No *0*	
Goods innovations: New or significantly improved goods (exclude the simple resale of new goods and changes of a solely aesthetic nature)	☐	☐	*INPDGD*
Service innovations: New or significantly improved services	☐	☐	*INPDSV*

If no to all options, go to section 3
Otherwise go to question 2.2

2.2 Who developed these product innovations?

	Tick all that apply **Goods innovations**		**Service innovations**	
Your enterprise by itself	☐	*INITGD*	☐	*INITSV*
Your enterprise together with other enterprises or institutions*	☐	*INTOGD*	☐	*INTOSV*
Your enterprise by adapting or modifying goods or services originally developed by other enterprises or institutions*	☐	*INADGD*	☐	*INADSV*
Other enterprises or institutions*	☐	*INOTHGD*	☐	*INOTHSV*

* *Include independent enterprises plus other parts of your enterprise group (subsidiaries, sister enterprises, head office, etc.). Institutions include universities, research institutes, non-profits, etc.*

2.3 Were any of your product innovations (goods or services) during the three years 2010 to 2012:

		Yes	No	
		1	*0*	
New to your market?	Your enterprise introduced a new or significantly improved product onto your market before your competitors (it may have already been available in other markets)	☐	☐	*NEWMKT*
Only new to your firm?	Your enterprise introduced a new or significantly improved product that was already available from your competitors in your market	☐	☐	*NEWFRM*

Using the definitions above, please give the percentage of your total turnover[5] in 2012 from:

New or significantly improved products introduced during the three years 2010 to 2012 that were **new to your market**	*TURNMAR*	☐☐☐ %
New or significantly improved products introduced during the three years 2010 to 2012 that were **only new to your firm**	*TURNIN*	☐☐☐ %
Products that were **unchanged or only marginally modified** during the three years 2010 to 2012 (include the resale of new products purchased from other enterprises)	*TURNUNG*	☐☐☐ %
Total turnover in 2012		1 0 0 %

2.4 To the best of your knowledge, were <u>any</u> of your product innovations during the three years 2010 to 2012:

	Yes	No	Don't know	
	1	*0*	*2*	
A first in [your country]	☐	☐	☐	*INPDFC*
A first in Europe*	☐	☐	☐	*INPDFE*
A world first	☐	☐	☐	*INPDFW*

*: Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.[6]

If no world-first product innovations go to Section 3, otherwise go to question 2.5

2.5 What percent of your total turnover in 2012 was from world first product innovations introduced between 2010 and 2012? *(This should be a subset of your new-to-market turnover share in question 2.3 above)*

	FWTURN	
0% to less than 1%	☐	*1*
1% to less than 5%	☐	*2*
5% to less than 10%	☐	*3*
10% to less than 25%	☐	*4*
25% or more	☐	*5*
Don't know	☐	*0*

[5] For Credit institutions: Interests receivable and similar income, for insurance services: Gross premiums written
[6] Each NSO needs to remove their own country from the list of European countries.

3. Process innovation

A process innovation is the implementation of a **new** or **significantly** improved production process, distribution method, or supporting activity.

- Process innovations **must be new to your enterprise**, but they **do not need to be new to your market**.
- The innovation could have been originally developed by your enterprise or by other enterprises or institutions.
- Exclude purely organisational innovations – these are covered in section 8.

3.1 During the three years 2010 to 2012, did your enterprise introduce?

	Yes *1*	No *0*	
New or significantly improved methods of manufacturing or producing goods or services	☐	☐	*INPSPD*
New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services	☐	☐	*INPSLG*
New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing	☐	☐	*INPSSU*

If no to all options, go to section 4

Otherwise go to question 3.2

3.2 Who developed these process innovations?

	Tick all that apply	
Your enterprise by itself	☐	*INITPS*
Your enterprise together with other enterprises or institutions*	☐	*INTOPS*
Your enterprise by adapting or modifying processes originally developed by other enterprises or institutions*	☐	*INADPS*
Other enterprises or institutions*	☐	*INOTHPS*

**: Include independent enterprises plus other parts of your enterprise group (subsidiaries, sister enterprises, head office, etc). Institutions include universities, research institutes, non-profits, etc.*

3.3 Were any of your process innovations introduced during the three years 2010 to 2012 new to your market?

	INPSNM
Yes	☐ *1*
No	☐ *0*
Do not know	☐ *2*

4. Ongoing or abandoned innovation activities for product and process innovations

Innovation activities include the acquisition of machinery, equipment, buildings, software, and licenses; engineering and development work, design, training, and marketing when they are specifically undertaken to develop and/or implement a product or process innovation. Also include all types of R&D activities.

4.1 During the three years 2010 to 2012, did your enterprise have any innovation activities that did not result in a product or process innovation because the activities were:

	Yes	No	
	1	*0*	
Abandoned or suspended before completion	☐	☐	*INABA*
Still on-going at the end of the 2012	☐	☐	*INONG*

If your enterprise had no product or process innovations or innovation activity during the three years 2010 to 2012 (no to all options in questions 2.1, 3.1, and 4.1), go to section 8

Otherwise, go to section 5

5. Activities and expenditures for product and process innovations

5.1 During the three years 2010 to 2012, did your enterprise engage in the following innovation activities:

		Yes *1*	No *0*	
In-house R&D	Research and development activities undertaken by your enterprise to create new knowledge or to solve scientific or technical problems (include software development in-house that meets this requirement)	☐	☐	*RRDIN*
	If yes, did your enterprise perform R&D during the three years 2010 to 2012:			*RDENG*
	Continuously (your enterprise has permanent R&D staff in-house) ☐ *1*			
	Occasionally (as needed only) ☐ *2*			
External R&D	R&D that your enterprise has contracted out to other enterprises (including other enterprises in your group) or to public or private research organisations	☐	☐	*RRDEX*
Acquisition of machinery, equipment, software & buildings	Acquisition of advanced machinery, equipment, software and buildings to be used for new or significantly improved products or processes	☐	☐	*RMAC*
Acquisition of existing knowledge from other enterprises or organisations	Acquisition of existing know-how, copyrighted works, patented and non-patented inventions, etc. from other enterprises or organisations for the development of new or significantly improved products and processes	☐	☐	*ROEK*
Training for innovative activities	In-house or contracted out training for your personnel specifically for the development and/or introduction of new or significantly improved products and processes	☐	☐	*RTR*
Market introduction of innovations	In-house or contracted out activities for the market introduction of your new or significantly improved goods or services, including market research and launch advertising	☐	☐	*RMAR*
Design	In-house or contracted out activities to design or alter the shape or appearance of goods or services	☐	☐	*RDSG*
Other	Other in-house or contracted out activities to implement new or significantly improved products and processes such as feasibility studies, testing, tooling up, industrial engineering, etc.	☐	☐	*RPRE*

5.2 How much did your enterprise spend on each of the following innovation activities in 2012 only? Innovation activities are defined in question 5.1 above. Include current expenditures (including labour costs, contracted-out activities, and other related costs) as well as capital expenditures on buildings and equipment.[7]

Please fill in '0' if your enterprise had no expenditures for an activity in 2012

With a lack of precise accounting data please use estimates

In-house R&D (Include current expenditures including labour costs and capital expenditures on buildings and equipment specifically for R&D)		RRDINX
External R&D		RRDEXX
Acquisition of machinery, equipment, software & buildings (Exclude expenditures on these items that are for R&D)		RMACX
Acquisition of existing knowledge from other enterprises or organisations		ROEKX
All other innovation activities including design, training, marketing, and other relevant activities		ROTRX
Total expenditures on innovation activities (Sum of expenditures for all types of innovation activities)		RALLX

5.3 During the three years 2010 to 2012, did your enterprise receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude research and other innovation activities conducted entirely for the public sector* under contract.

	Yes	No	
	1	0	
Local or regional authorities	☐	☐	FUNLOC
Central government (including central government agencies or ministries)	☐	☐	FUNGMT
The European Union (EU)	☐	☐	FUNEU
If yes, did your enterprise participate in the EU 7th Framework Programme for Research and Technical Development?	☐	☐	FUNRTD

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

[7] Give expenditure data in 000's of national currency units to eight digits.

6. Sources of information and co-operation for product and process innovation

6.1 During the three years 2010 to 2012, how important to your enterprise's innovation activities were each of the following information sources? Include information sources that provided information for new innovation projects or contributed to the completion of existing projects.

	Information source	Degree of importance *Tick 'not used' if no information was obtained from a source.* High 3	Medium 2	Low 1	Not used 0	
Internal	Within your enterprise or enterprise group	☐	☐	☐	☐	*SENTG*
Market sources	Suppliers of equipment, materials, components, or software	☐	☐	☐	☐	*SSUP*
	Clients or customers from the private sector	☐	☐	☐	☐	*SCLPR*
	Clients or customers from the public sector*	☐	☐	☐	☐	*SCLPU*
	Competitors or other enterprises in your industry	☐	☐	☐	☐	*SCOM*
	Consultants and commercial labs	☐	☐	☐	☐	*SINS*
Education & research institutes	Universities or other higher education institutions	☐	☐	☐	☐	*SUNI*
	Government, public or private research institutes	☐	☐	☐	☐	*SGMT*
Other sources	Conferences, trade fairs, exhibitions	☐	☐	☐	☐	*SCON*
	Scientific journals and trade/technical publications	☐	☐	☐	☐	*SJOU*
	Professional and industry associations	☐	☐	☐	☐	*SPRO*

6.2 During the three years 2010 to 2012, did your enterprise co-operate on any of your innovation activities with other enterprises or institutions? Innovation co-operation is active participation with other enterprises or institutions on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active co-operation.

Yes ☐
No ☐ **(Please go to question 7.1)** *CO*

6.3 Please indicate the type of innovation co-operation partner by location

(Tick all that apply)

Type of co-operation partner	[Your country]	Other Europe**	United States	China or India	All other countries
A. Other enterprises within your enterprise group	☐ *Co11*	☐ *Co12*	☐ *Co13*	☐ *Co14*	☐ *Co15*
B. Suppliers of equipment, materials, components, or software	☐ *Co21*	☐ *Co22*	☐ *Co23*	☐ *Co24*	☐ *Co25*
C. Clients or customers from the private sector	☐ *Co311*	☐ *Co312*	☐ *Co313*	☐ *Co314*	☐ *Co315*
D. Clients or customers from the public sector*	☐ *Co321*	☐ *Co322*	☐ *Co323*	☐ *Co324*	☐ *Co325*
E. Competitors or other enterprises in your sector	☐ *Co41*	☐ *Co42*	☐ *Co43*	☐ *Co44*	☐ *Co45*
F. Consultants and commercial labs	☐ *Co51*	☐ *Co52*	☐ *Co53*	☐ *Co54*	☐ *Co55*
G. Universities or other higher education institutions	☐ *Co61*	☐ *Co62*	☐ *Co63*	☐ *Co64*	☐ *Co65*
H. Government, public or private research institutes	☐ *Co71*	☐ *Co72*	☐ *Co73*	☐ *Co74*	☐ *Co75*

6.4 Which type of co-operation partner did you find the most valuable for your enterprise's innovation activities? (Give corresponding letter) _____ *PMOS*

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

**: Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

7. Competitiveness of your enterprise's product and process innovations

7.1 How effective were the following methods for maintaining or increasing the competitiveness of product and process innovations introduced during 2010 to 2012?

	Degree of effectiveness				
	High	Medium	Low	Not used	
	3	*2*	*1*	*0*	
Patents	☐	☐	☐	☐	*CMPAT*
Design registration	☐	☐	☐	☐	*CMRCD*
Copyright	☐	☐	☐	☐	*CMCO*
Trademarks	☐	☐	☐	☐	*CMCTM*
Lead time advantages	☐	☐	☐	☐	*CMLTAD*
Complexity of goods or services	☐	☐	☐	☐	*CMCPX*
Secrecy (include non-disclosure agreements)	☐	☐	☐	☐	*CMSEC*

Note: Countries that provide utility patents should include this as a sub-question after patents.

8. Organisational Innovation

An organisational innovation is a new organisational method in your enterprise's business practices (including knowledge management), workplace organisation or external relations that has not been previously used by your enterprise.

- It must be the result of strategic decisions taken by management.
- Exclude mergers or acquisitions, even if for the first time.

8.1 During the three years 2010 to 2012, did your enterprise introduce:

	Yes *1*	No *0*	
New **business practices** for organising procedures (i.e. supply chain management, business re-engineering, knowledge management, lean production, quality management, etc.)	☐	☐	*ORGBUP*
New methods of **organising work responsibilities and decision making** (i.e. first use of a new system of employee responsibilities, team work, decentralisation, integration or de-integration of departments, education/training systems, etc.)	☐	☐	*ORGWKP*
New methods of **organising external relations** with other firms or public institutions (i.e. first use of alliances, partnerships, outsourcing or sub-contracting, etc.)	☐	☐	*ORGEXR*

9. Marketing innovation

A marketing innovation is the implementation of a new marketing concept or strategy that differs significantly from your enterprise's existing marketing methods and which has not been used before.

- It requires significant changes in product design or packaging, product placement, product promotion or pricing.
- Exclude seasonal, regular and other routine changes in marketing methods.

9.1 During the three years 2010 to 2012, did your enterprise introduce:

	Yes *1*	No *0*	
Significant changes to the aesthetic **design** or **packaging** of a good or service (*exclude changes that alter the product's functional or user characteristics – these are product innovations*)	☐	☐	*MKTDGP*
New media or techniques for **product promotion** (*i.e. the first time use of a new advertising media, a new brand image, introduction of loyalty cards, etc.*)	☐	☐	*MKTPDP*
New methods for **product placement** or sales channels (*i.e. first time use of franchising or distribution licenses, direct selling, exclusive retailing, new concepts for product presentation, etc.*)	☐	☐	*MKTPDL*
New methods of **pricing** goods or services (*i.e. first time use of variable pricing by demand, discount systems, etc.*)	☐	☐	*MKTPRI*

10. Public sector procurement and innovation

10.1 During the three years 2010 to 2012, did your enterprise have any procurement contracts to provide goods or services for:

	Yes *1*	No *0*	
Domestic public sector organisations*	☐	☐	*PUBDOM*
Foreign public sector organisations*	☐	☐	*PUBFOR*

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

If no to both options go to section 11

Otherwise go to question 10.2

10.2 Did your enterprise undertake any innovation activities as part of a procurement contract to provide goods or services to a public sector organisation? *(Include activities for product, process, organisational and marketing innovations)*

(If your enterprise had several procurement contracts, tick all that apply)

Yes and innovation required as part of the contract	☐	*PBINCT*
Yes but innovation *not* required as part of the contract	☐	*PBNOCT*
No	☐	*PBNOINN*

11. Strategies and obstacles for reaching your enterprise's goals

11.1 During the three years 2010 to 2012, how important were each of the following goals for your enterprise? (It does not matter if your enterprise was able to attain these goals)

	Degree of Importance				
	High	Medium	Low	Not relevant	
	3	2	1	0	
Increase turnover	☐	☐	☐	☐	GOTURN
Increase market share	☐	☐	☐	☐	GOMKT
Decrease costs	☐	☐	☐	☐	GOCOS
Increase profit margins	☐	☐	☐	☐	GOPRF

11.2 During 2010 to 2012, how important were each of the following strategies for reaching your enterprise's goals?

	Degree of Importance				
	High	Medium	Low	Not relevant	
	3	2	1	0	
Developing new markets within Europe*	☐	☐	☐	☐	STMKEUR
Developing new markets outside Europe*	☐	☐	☐	☐	STMKOTH
Reducing in-house costs of operation	☐	☐	☐	☐	STIHCOS
Reducing costs of purchased materials, components or services	☐	☐	☐	☐	STEXCOS
Introducing new or significantly improved goods or services	☐	☐	☐	☐	STINNPD
Intensifying or improving the marketing of goods or services	☐	☐	☐	☐	STMKT
Increasing flexibility / responsiveness of your organisation	☐	☐	☐	☐	STFLEX
Building alliances with other enterprises or institutions	☐	☐	☐	☐	STALL

11.3 During 2010 to 2012, how important were the following factors as obstacles to meeting your enterprise's goals?

	Degree of Importance				
	High	Medium	Low	Not relevant	
	3	2	1	0	
Strong price competition	☐	☐	☐	☐	OBSPR
Strong competition on product quality, reputation or brand	☐	☐	☐	☐	OBSQL
Lack of demand	☐	☐	☐	☐	OBSLDE
Innovations by competitors	☐	☐	☐	☐	OBSCP
Dominant market share held by competitors	☐	☐	☐	☐	OBSDMK
Lack of qualified personnel	☐	☐	☐	☐	OBSPRS
Lack of adequate finance	☐	☐	☐	☐	OBSFIN
High cost of access to new markets	☐	☐	☐	☐	OBSAMK
High cost of meeting government regulations or legal requirements	☐	☐	☐	☐	OBSREG

*: Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

12. Basic economic information on your enterprise

12.1 What was your enterprise's total turnover for 2010 and 2012?[8] Turnover is defined as the market sales of goods and services (Include all taxes except VAT[9])

2010	2012
TURN10	TURN12

12.2 What was your enterprise's average number of employees in 2010 and 2012?[10]

2010	2012
EMP10	EMP12

12.3 Approximately what percent of your enterprise's employees in 2012 had a tertiary degree?[11]

	EMPUD
0%	☐ 0
1% to 4%	☐ 1
5% to 9%	☐ 2
10% to 24%	☐ 3
25% to 49%	☐ 4
50% to 74%	☐ 5
75% to 100%	☐ 6

[8] Give turnover in '000 of national currency units. *Leave space for up to nine digits.*
[9] For Credit institutions: Interests receivable and similar income; for Insurance services give gross premiums written.
[10] If administrative data are used and the annual average is not available, give results for the end of each year. Leave space for up to six digits for question 12.2.
[11] ISCED 2011 levels 5 to 8.

Appendix B. CIS 2014 The Harmonised Survey Questionnaire

The Community Innovation Survey 2014

THE HARMONISED SURVEY QUESTIONNAIRE, 23 July 2014

The Community Innovation Survey 2014 **Version 13 of 23 July 2014**

This survey collects information on your enterprise's **innovations and innovation activities** during the three years 2012 to 2014 inclusive.

An **innovation** is the introduction of a new or significantly improved product, process, organisational method, or marketing method by your enterprise.

An innovation must have characteristics or intended uses that are new or which provide a significant improvement over what was previously used or sold by your enterprise. However, an innovation can fail or take time to prove itself.

An innovation need only be new or significantly improved for your enterprise. It could have been originally developed or used by other enterprises or organisations.

Innovation activities include the acquisition of machinery, equipment, buildings, software, and licenses; engineering and development work, feasibility studies, design, training, R&D and marketing when they are specifically undertaken to develop and/or implement a product or process innovation. This includes also all types of R&D consisting of research and development activities to create new knowledge or solve scientific or technical problems.

Sections 2 to 7 cover product and process innovations. Organisational and marketing innovations are covered in sections 8 and 9.

Please complete **all** questions, unless otherwise instructed.

Person we should contact if there are any queries regarding the form:

Name: _____
Job title: _____
Organisation: _____
Phone: _____
E-mail: _____

1. General information about the enterprise

Name of enterprise _____ *ID*
Address[1] _____ *NUTS*
Postal code _____ **Main activity**[2] _____ *NACE*

1.1 In 2014, was your enterprise part of an enterprise group? (A group consists of two or more legally defined enterprises under common ownership. Each enterprise in the group can serve different markets, as with national or regional subsidiaries, or serve different product markets. The head office is also part of an enterprise group.) *GP*

Yes ☐ In which country is the head office of your group located?[3] _____ *HO*
No ☐

If your enterprise is part of an enterprise group: Please answer all further questions about your enterprise only for its own activities in [your country]. Exclude all subsidiaries or parent enterprises.

1.2 During the three years 2012 to 2014, did your enterprise:

	Yes *1*	**No** *0*	
Merge with or take over another enterprise or a part of another enterprise	☐	☐	*ENMRG*
Sell, close or contract out some of the tasks or functions of your enterprise	☐	☐	*ENOUT*

1.3 In which geographic markets did your enterprise sell goods and/or services during the three years 2012 to 2014?

	Yes *1*	**No** *0*	
A. Local / regional within [your country]	☐	☐	*MARLOC*
B. National (other regions of [your country])	☐	☐	*MARNAT*
C. Other European Union or associated countries*[4]	☐	☐	*MAREUR*
D. All other countries	☐	☐	*MAROTH*

Which of these geographic areas was your largest market in terms of turnover during the three years 2012 to 2014? (Give corresponding letter) _____ *LARMAR*

*: Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, FYR Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

[1] NUTS 2 code
[2] NACE 4 digit code
[3] Country code according to ISO standard
[4] Each NSO needs to remove their own country from the list of European countries.

2. Product innovation (good or service)

A product innovation is the market introduction of a **new** or **significantly** improved **good or service** with respect to its capabilities, user friendliness, components or sub-systems.

- Product innovations (new or improved) **must be new to your enterprise**, but they **do not need to be new to your market**.
- Product innovations could have been originally developed by your enterprise or by other enterprises or organisations.

A **good** is usually a tangible object such as a smartphone, furniture, or packaged software, but downloadable software, music and film are also goods. A **service** is usually intangible, such as retailing, insurance, educational courses, air travel, consulting, etc.

2.1 During the three years 2012 to 2014, did your enterprise introduce:

	Yes *1*	No *0*	
Goods innovations: New or significantly improved goods (exclude the simple resale of new goods and changes of a solely aesthetic nature)	☐	☐	*INPDGD*
Service innovations: New or significantly improved services	☐	☐	*INPDSV*

If no to all options, go to section 3
Otherwise, go to question 2.2

2.2 Who developed these product innovations?

Tick all that apply

	Goods innovations		Service innovations	
Your enterprise by itself	☐	*INITGD*	☐	*INITSV*
Your enterprise together with other enterprises or organisations*	☐	*INTOGD*	☐	*INTOSV*
Your enterprise by adapting or modifying goods or services originally developed by other enterprises or organisations*	☐	*INADGD*	☐	*INADSV*
Other enterprises or organisations	☐	*INOTHGD*	☐	*INOTHSV*

**: Include independent enterprises plus other parts of your enterprise group (subsidiaries, sister enterprises, head office, etc.). Organisations include universities, research institutes, non-profits, etc.*

2.3 Were any of your product innovations (goods or services) during the three years 2012 to 2014:

		Yes	No	
		1	*0*	
New to your market?	Your enterprise introduced a new or significantly improved product onto your market before your competitors (it may have already been available in other markets)	☐	☐	*NEWMKT*
Only new to your enterprise?	Your enterprise introduced a new or significantly improved product that was already available from your competitors in your market	☐	☐	*NEWFRM*

Using the definitions above, please give the percent of your total turnover[5] in 2014 from:

New or significantly improved products introduced during the three years 2012 to 2014 that were **new to your market**	*TURNMAR*	☐☐☐ %
New or significantly improved products introduced during the three years 2012 to 2014 that were **only new to your enterprise**	*TURNIN*	☐☐☐ %
Products that were **unchanged or only marginally modified** during the three years 2012 to 2014 (include the resale of new products purchased from other enterprises)	*TURNUNG*	☐☐☐ %
Total turnover in 2014		**1 0 0** %

2.4 To the best of your knowledge, were <u>any</u> of your product innovations during the three years 2012 to 2014:

(Please tick one option in every row)

	Yes	No	Don't know	
	1	*0*	*2*	
A first in [your country]	☐	☐	☐	*INPDFC*
A first in Europe*	☐	☐	☐	*INPDFE*
A world first	☐	☐	☐	*INPDFW*

*: Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, FYR Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.[6]

If no world-first innovation, go to Section 3,
Otherwise, go to question 2.5

2.5 What percent of your total turnover in 2014 was from world first product innovations introduced between 2012 and 2014? *(This should be a subset of your new-to-market turnover share in question 2.3 above)*

	FWTURN	
0% to less than 1%	☐	*1*
1% to less than 5%	☐	*2*
5% to less than 10%	☐	*3*
10% to less than 25%	☐	*4*
25% or more	☐	*5*
Don't know	☐	*6*

[5] For Credit institutions: Interests receivable and similar income, for insurance services: Gross premiums written

[6] Each NSO needs to remove their own country from the list of European countries.

3. Process innovation

A process innovation is the implementation of a **new** or **significantly** improved production process, distribution method, or supporting activity.

- Process innovations **must be new to your enterprise**, but they **do not need to be new to your market**.
- The innovation could have been originally developed by your enterprise or by other enterprises or organisations.
- Exclude purely organisational innovations – these are covered in section 8.

3.1 During the three years 2012 to 2014, did your enterprise introduce:

	Yes	No	
	1	*0*	
New or significantly improved methods of manufacturing for producing goods or services	☐	☐	*INPSPD*
New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services	☐	☐	*INPSLG*
New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing	☐	☐	*INPSSU*

If no to all options, go to section 4

Otherwise, go to question 3.2

3.2 Who developed these process innovations?

	Tick all that apply	
Your enterprise by itself	☐	*INITPS*
Your enterprise together with other enterprises or organisations*	☐	*INTOPS*
Your enterprise by adapting or modifying processes originally developed by other enterprises or organisations*	☐	*INADPS*
Other enterprises or organisations*	☐	*INOTHPS*

**: Include independent enterprises plus other parts of your enterprise group (subsidiaries, sister enterprises, head office, etc). Organisations include universities, research institutes, non-profits, etc.*

3.3 Were any of your process innovations introduced during the three years 2012 to 2014 new to your market?

	INPSNM
Yes	☐ *1*
No	☐ *0*
Don't know	☐ *2*

4. Ongoing or abandoned innovation activities for product or process innovations

Innovation activities include the acquisition of machinery, equipment, buildings, software, and licenses; engineering and development work, feasibility studies, design, training, R&D and marketing when they are specifically undertaken to develop and/or implement a product or process innovation. This includes also all types of R&D consisting of research and development activities to create new knowledge or solve scientific or technical problems. .

4.1 During the three years 2012 to 2014, did your enterprise have any innovation activities that did not result in a product or process innovation because the activities were:

	Yes	No	
	1	*0*	
Abandoned or suspended before completion	☐	☐	*INABA*
Still ongoing at the end of the 2014	☐	☐	*INONG*

If no to all options in questions 2.1, 3.1 and 4.1 go to section 8

Otherwise, go to section 5

5. Activities and expenditures for product and process innovations

5.1 During the three years 2012 to 2014, did your enterprise engage in the following innovation activities:

		Yes *1*	No *0*	
In-house R&D	Research and development activities undertaken by your enterprise to create new knowledge or to solve scientific or technical problems (include software development in-house that meets this requirement) If yes, did your enterprise perform R&D during the three years 2012 to 2014: Continuously (your enterprise had permanent R&D staff in-house) ☐ *1* Occasionally (as needed only) ☐ *2*	☐	☐	*RRDIN* *RDENG*
External R&D	Your enterprise contracted-out R&D to other enterprises (include enterprises in your own group) or to public or private research organisations	☐	☐	*RRDEX*
Acquisition of machinery, equipment, software & buildings	Acquisition of advanced machinery, equipment, software and buildings to be used for new or significantly improved products or processes	☐	☐	*RMAC*
Acquisition of existing knowledge from other enterprises or organisations	Acquisition of existing know-how, copyrighted works, patented and non-patented inventions, etc. from other enterprises or organisations for the development of new or significantly improved products and processes	☐	☐	*ROEK*
Training for innovative activities	In-house or contracted out training for your personnel specifically for the development and/or introduction of new or significantly improved products and processes	☐	☐	*RTR*
Market introduction of innovations	In-house or contracted out activities for the market introduction of your new or significantly improved goods or services, including market research and launch advertising	☐	☐	*RMAR*
Design	In-house or contracted out activities to alter the shape, appearance or usability of goods or services	☐	☐	*RDSG*
Other	Other in-house or contracted out activities to implement new or significantly improved products and processes such as feasibility studies, testing, tooling up, industrial engineering, etc.	☐	☐	*RPRE*

5.2 How much did your enterprise spend on each of the following innovation activities in <u>2014</u> only? Innovation activities are defined in question 5.1 above. Include current expenditures (including labour costs, contracted-out activities, and other related costs) as well as capital expenditures on buildings and equipment.[7]

Please fill in '0' if your enterprise had no expenditures for an activity in 2014

Please estimate if you lack precise accounting data

In-house R&D (Include current expenditures including labour costs and capital expenditures on buildings and equipment specifically for R&D)	☐☐☐☐☐☐☐☐	*RRDINX*
External R&D	☐☐☐☐☐☐☐☐	*RRDEXX*
Acquisition of machinery, equipment, software & buildings (Exclude expenditures on these items that are for R&D)	☐☐☐☐☐☐☐☐	*RMACX*
Acquisition of existing knowledge from other enterprises or organisations	☐☐☐☐☐☐☐☐	*ROEKX*
All other innovation activities including design, training, marketing, and other relevant activities	☐☐☐☐☐☐☐☐	*ROTRX*
Total of the above innovation activities	☐☐☐☐☐☐☐☐	*RALLX*

6. Public financial support for innovation activities

6.1 During the three years 2012 to 2014, did your enterprise receive any public financial support for innovation activities from the following levels of government? Include financial support via tax credits or deductions, grants, subsidised loans, and loan guarantees. Exclude R&D and other innovation activities conducted entirely for the public sector* under contract.

	Yes	No	
	1	*0*	
Local or regional authorities	☐	☐	*FUNLOC*
Central government (including central government agencies or ministries)	☐	☐	*FUNGMT*
The European Union (EU)	☐	☐	*FUNEU*
If yes, did your enterprise participate in the EU 7th Framework Programme for Research and Technical Development or in the Horizon 2020 Programme for Research and Innovation?	☐	☐	*FUNRTD*

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

[7] Give expenditure data in 000's of national currency units to eight digits.

7. Co-operation for product and process innovation activities

7.1 During the three years 2012 to 2014, **did your enterprise co-operate on any of your innovation activities with other enterprises or organisations?** Innovation co-operation is active participation with other enterprises or organisations on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active co-operation.

No ☐ ***(Go to section 8)*** *CO*
Yes ☐ *(Go to question 7.2)*

7.2 Please indicate the type of innovation co-operation partner by location

(Tick all that apply)

Type of co-operation partner	[Your country]	Other Europe**	United States	China or India	All other countries
A. Other enterprises within your enterprise group	☐ *Co11*	☐ *Co12*	☐ *Co13*	☐ *Co14*	☐ *Co15*
B. Suppliers of equipment, materials, components, or software	☐ *Co21*	☐ *Co22*	☐ *Co23*	☐ *Co24*	☐ *Co25*
C. Clients or customers from the private sector	☐ *Co311*	☐ *Co312*	☐ *Co313*	☐ *Co314*	☐ *Co315*
D. Clients or customers from the public sector*	☐ *Co321*	☐ *Co322*	☐ *Co323*	☐ *Co324*	☐ *Co325*
E. Competitors or other enterprises in your sector	☐ *Co41*	☐ *Co42*	☐ *Co43*	☐ *Co44*	☐ *Co45*
F. Consultants or commercial labs	☐ *Co51*	☐ *Co52*	☐ *Co53*	☐ *Co54*	☐ *Co55*
G. Universities or other higher education institutes	☐ *Co61*	☐ *Co62*	☐ *Co63*	☐ *Co64*	☐ *Co65*
H. Government, public or private research institutes	☐ *Co71*	☐ *Co72*	☐ *Co73*	☐ *Co74*	☐ *Co75*

7.3 Which type of co-operation partner was the most valuable for your enterprise's innovation activities? (Give corresponding letter) _____ *PMOS*

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

**: Include the following European Union (EU) and associated countries: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Italy, Ireland, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, FYR Macedonia, Malta, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Switzerland, Turkey, Spain, Sweden and the United Kingdom.

8. Organisational Innovation

An organisational innovation is a new organisational method in your enterprise's business practices (including knowledge management), workplace organisation or external relations that has not been previously used by your enterprise.

- It must be the result of strategic decisions taken by management.
- Exclude mergers or acquisitions, even if for the first time.

8.1 During the three years 2012 to 2014, did your enterprise introduce:

	Yes *1*	No *0*	
New **business practices** for organising procedures (i.e. first time use of supply chain management, business re-engineering, knowledge management, lean production, quality management, etc.)	☐	☐	*ORGBUP*
New methods of **organising work responsibilities and decision making** (i.e. first time use of a new system of employee responsibilities, team work, decentralisation, integration or de-integration of departments, education/training systems, etc.)	☐	☐	*ORGWKP*
New methods of **organising external relations** with other enterprises or public organisations (i.e. first time use of alliances, partnerships, outsourcing or sub-contracting, etc.)	☐	☐	*ORGEXR*

9. Marketing innovation

A marketing innovation is the implementation of a new marketing concept or strategy that differs significantly from your enterprise's existing marketing methods and which has not been used before.

- It requires significant changes in product design or packaging, product placement, product promotion or pricing.
- Exclude seasonal, regular and other routine changes in marketing methods.

9.1 During the three years 2012 to 2014, did your enterprise introduce:

	Yes *1*	No *0*	
Significant changes to the aesthetic **design** or **packaging** of a good or service (*exclude changes that alter the product's functional or user characteristics – these are product innovations*)	☐	☐	*MKTDGP*
New media or techniques for **product promotion** *(i.e. first time use of a new advertising media, a new brand image, introduction of loyalty cards, etc.*)	☐	☐	*MKTPDP*
New methods for **product placement** or sales channels *(i.e. first time use of franchising or distribution licenses, direct selling, exclusive retailing, new concepts for product presentation, etc.)*	☐	☐	*MKTPDL*
New methods of **pricing** goods or services *(i.e. first time use of variable pricing by demand, discount systems, etc.)*	☐	☐	*MKTPRI*

10. Public sector contracts and innovation

10.1 During the three years 2012 to 2014, did your enterprise have any contracts to provide goods or services for:

	Yes *1*	No *0*	
Domestic public sector organisations*	☐	☐	*PUBDOM*
Foreign public sector organisations*	☐	☐	*PUBFOR*

*The public sector includes government owned organisations such as local, regional and national administrations and agencies, schools, hospitals, and government providers of services such as security, transport, housing, energy, etc.

If no to both options, go to section 11

Otherwise go to question 10.2

10.2 Did your enterprise undertake any innovation activities as part of a contract to provide goods or services to a public sector organisation? ***(Include activities for product, process, organisational and marketing innovations)***

No	☐ (***Go to section 11)***	*0*	*PBINN*
Yes	☐	*1*	

If yes, did one or more of your public sector contracts:

	(If your enterprise had several contracts, tick all that apply)	
Specifically require innovation as part of the contract	☐	*PBINCT*
Not require innovation as part of the contract	☐	*PBNOCT*

11. Intellectual property rights and licensing

11.1 During the three years 2012 to 2014, did your enterprise:

	Yes	No	
	1	*0*	
Apply for a patent	☐	☐	*PROPAT*
Apply for a European utility model	☐	☐	*PROEUM*
Register an industrial design right	☐	☐	*PRODSG*
Register a trademark	☐	☐	*PROTM*

11.2 During the three years 2012 to 2014, did your enterprise:

	Yes	No	
	1	*0*	
License out or sell a patent, industrial design right, copyright or trademark to another enterprise, university or research institute	☐	☐	*PROLEX*
License in* or buy a patent, industrial design right, copyright or trademark owned by another enterprise, university or research institute	☐	☐	*PROLIN*

*Exclude the acquisition of licenses for common software for desktop and laptop computers such as operating systems, word processing, spreadsheets, etc.)

Only answer section 12 if your enterprise did <u>not</u> introduce an innovation and did not have ongoing/abandoned innovation activities during the three years 2012 to 2014 ('no' to all options in questions 2.1, 3.1, 4.1, 8.1 and 9.1).
Otherwise go to section 13.

12. Non-innovators

12.1 Which of the following best describes why your enterprise had no innovation activities during the three years from 2012 to 2014:

	Tick one only		
No compelling reason to innovate	☐	***Go to 12.2***	*HCOMPR*
Considered innovating, but barriers to innovation too large	☐	***Go to 12.3***	*HBARIN*

12.2 How important were the following reasons for your enterprise not to conduct innovation activities during 2012 to 2014?

	Degree of importance				
	High	**Medium**	**Low**	**Not important**	
	3	*2*	*1*	*0*	
Low demand for innovations in your market	☐	☐	☐	☐	*HLDEM*
No need to innovate due to previous innovations	☐	☐	☐	☐	*HPRIOR*
No need to innovate due to very little competition in your enterprise's market	☐	☐	☐	☐	*HCOMPL*
Lack of good ideas for innovations	☐	☐	☐	☐	*HIDIN*

Go to question 13.4

12.3 How important to your enterprise were the following barriers to innovation during 2012 to 2014?

	Degree of importance				
	High	**Medium**	**Low**	**Not important**	
	3	*2*	*1*	*0*	
Lack of internal finance for innovation	☐	☐	☐	☐	*HFENT*
Lack of credit or private equity	☐	☐	☐	☐	*HCRE*
Lack of skilled employees within your enterprise	☐	☐	☐	☐	*HPER*
Difficulties in obtaining government grants or subsidies for innovation	☐	☐	☐	☐	*HSUBS*
Lack of collaboration partners	☐	☐	☐	☐	*HPAR*
Uncertain market demand for your ideas for innovations	☐	☐	☐	☐	*HDEM*
Too much competition in your market	☐	☐	☐	☐	*HCOMPH*

Go to question 13.4

13. Innovations with environmental benefits

An innovation with environmental benefits is a new or significantly improved product (good or service), process, organisational method or marketing method that creates environmental benefits compared to alternatives.

- The environmental benefits can be the primary objective of the innovation or a by-product of other objectives.
- The environmental benefits of an innovation can occur during the production of a good or service, or during its consumption or use by the end user of a product. The end user can be an individual, another enterprise, the Government, etc.

13.1 During the three years 2012 to 2014, did your enterprise introduce a product (good or service), process, organisational or marketing innovation with any of the following environmental benefits?

	Yes	No	
Environmental benefits obtained within your enterprise	*1*	*0*	
Reduced material or water use per unit of output	☐	☐	*ECOMAT*
Reduced energy use or CO_2 'footprint' (reduce total CO_2 production)	☐	☐	*ECOENO*
Reduced air, water, noise or soil pollution	☐	☐	*ECOPOL*
Replaced a share of materials with less polluting or hazardous substitutes	☐	☐	*ECOSUB*
Replaced a share of fossil energy with renewable energy sources	☐	☐	*ECOREP*
Recycled waste, water, or materials for own use or sale	☐	☐	*ECOREC*
Environmental benefits obtained during the consumption or use of a good or service by the end user			
Reduced energy use or CO_2 'footprint'	☐	☐	*ECOENU*
Reduced air, water, noise or soil pollution	☐	☐	*ECOPOS*
Facilitated recycling of product after use	☐	☐	*ECOREA*
Extended product life through longer-lasting, more durable products	☐	☐	*ECOEXT*

If no to all options, go to question 13.4
Otherwise go to question 13.2

13.2 Were any of these environmental benefits due to the following types of your enterprise's innovations?

	Yes	No	
	1	*0*	
Product (goods or services) innovations	☐	☐	*ECOPRD*
Process innovations	☐	☐	*ECOPRC*
Organisational innovations	☐	☐	*ECORG*
Marketing innovations	☐	☐	*ECOMKT*

13.3 During 2012 to 2014, how important were the following factors in driving your enterprise's decisions to introduce innovations with environmental benefits?

	Degree of importance				
	High	**Medium**	**Low**	**Not relevant**	
	3	*2*	*1*	*0*	
Existing environmental regulations	☐	☐	☐	☐	*ENEREG*
Existing environmental taxes, charges or fees	☐	☐	☐	☐	*ENETX*
Environmental regulations or taxes expected in the future	☐	☐	☐	☐	*ENREGF*
Government grants, subsidies or other financial incentives for environmental innovations	☐	☐	☐	☐	*ENGRA*
Current or expected market demand for environmental innovations	☐	☐	☐	☐	*ENDEM*
Improving your enterprise's reputation	☐	☐	☐	☐	*ENREP*
Voluntary actions or initiatives for environmental good practice within your sector	☐	☐	☐	☐	*ENAGR*
High cost of energy, water or materials	☐	☐	☐	☐	*ENCOST*
Need to meet requirements for public procurement contracts	☐	☐	☐	☐	*ENREQU*

13.4 Does your enterprise have procedures in place to regularly identify and reduce your enterprise's environmental impacts? (For example preparing environmental audits, setting environmental performance goals, ISO 14001 certification, ISO 50001 certification, etc).

No	☐ (***Go to section 14***)	*0*	*ENVID*
Yes	☐	*1*	

If your enterprise had any procedures in place, when were they implemented?

(Tick all that apply)

Some procedures were implemented before 2012	☐	*ENVBF*
Some procedures were implemented or significantly changed between 2012 and 2014	☐	*ENVBT*

14. Basic economic information on your enterprise

14.1 What was your enterprise's total turnover for 2012 and 2014?[8] Turnover is defined as the market sales of goods and services (Include all taxes except VAT[9])

2012	2014
☐☐☐☐☐☐☐☐☐	☐☐☐☐☐☐☐☐☐
TURN12	*TURN14*

14.2 What was the percent of your total turnover from sales to clients outside your country?

Please insert '0' if your enterprise had no sales outside your country

2012	2014
☐☐☐ %	☐☐☐ %
SLO12	*SLO14*

14.3 14.3 What was your enterprise's average number of employees in 2012 and 2014?[10]

2012	2014
☐☐☐☐☐☐	☐☐☐☐☐☐
EMP12	*EMP14*

14.4 Approximately what percent of your enterprise's employees in 2014 had a tertiary degree?[11]

	EMPUD	
0%	☐	*0*
1% to less than 5%	☐	*1*
5% to less than 10%	☐	*2*
10% to less than 25%	☐	*3*
25% to less than 50%	☐	*4*
50% to less than 75%	☐	*5*
75% or more	☐	*6*

[8] Give turnover in '000 of national currency units. *Leave space for up to nine digits.*
[9] For Credit institutions: Interests receivable and similar income; for Insurance services give gross premiums written.
[10] If administrative data are used and the annual average is not available, give results for the end of each year. Leave space for up to six digits for question 14.3
[11] ISCED 2011 levels 5 to 8