DRIVERS AND EFFECTS OF FIRMS' EXTERNAL KNOWLEDGE SOURCING STRATEGIES IN A GLOBAL CONTEXT: THE ROLE OF FIRM AGE AND SIZE

Anna Izotova

Department of Business

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by

Anna Izotova

under the supervision of

María Teresa Bolívar Ramos, Ph.D.

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ABSTRACT

Innovation is essential for firms' competitiveness and success. To be able to develop new innovative outcomes, companies need to rely on diverse internal and external knowledge resources. In a global context, and drawing on the insights of the Knowledge-Based View (KBV) of the firm and the open-innovation literature, the main objective of this doctoral dissertation is to analyze the drivers and the effects of external knowledge-sourcing strategies on the performance of innovative firms, while simultaneously addressing how these effects are influenced by two key organizational characteristics: firm's age and size.

This dissertation is organized around three articles to analyze more concrete objectives within this field. The empirical analyses carried out in the first two articles are based on panel data extracted from PITEC (*Panel de Innovación Tecnológica*), while the third article relies on data from the Community Innovation Survey (CIS). The first paper analyzes the main drivers of international R&D outsourcing and the role of firms' age. In particular, the research shows that the firm's technological resources and engagement in international trade positively affect the propensity to outsource R&D internationally. Along with it, the research confirms that firm age is as a factor that negatively moderates these relationships. The second paper of the research provides empirical evidence on how the functional breadth and the geographical diversity of the cooperation portfolio affects the firm's radical innovation performance, proving the existence of U-inverted relationships. In addition, the results confirm the negative moderating role of firm size in the relation between the functional breadth of collaborations and the firms' radical innovation performance. As for the third paper of this thesis, the study focuses on the effects of international exploitative and explorative collaborations on eco-innovation in SMEs and large firms. The results show that small and medium-sized enterprises (SMEs)'s international exploitative collaborations are the most valuable to improve eco-innovation. For large firms, despite they benefit from both international explorative and exploitative collaborations, international explorative collaborations are the ones with the greatest positive effect on eco-innovation.

All these findings present relevant implications for theory, practice, and policy that are discussed at the end of this dissertation, along with suggestions for future research.

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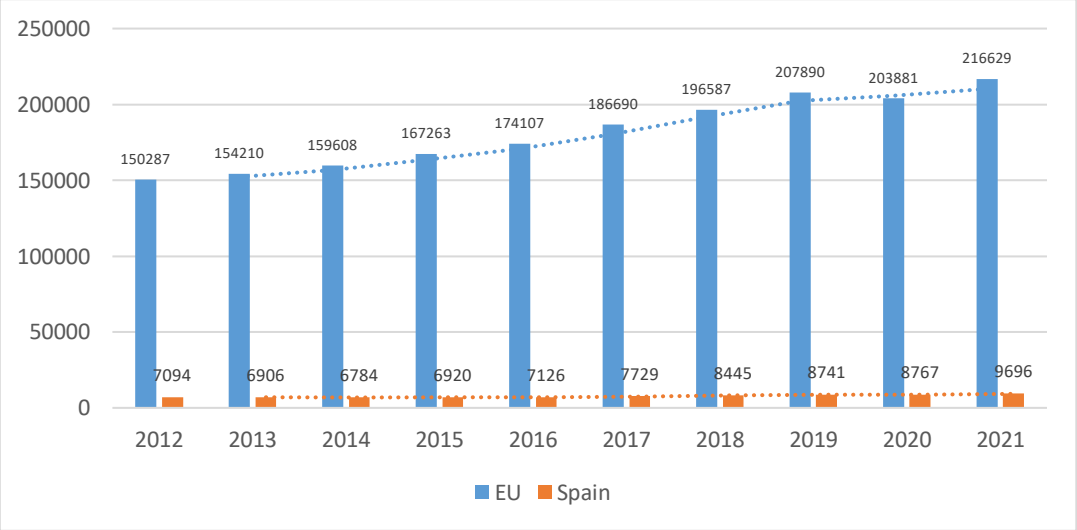
CHAPTER 1

INTRODUCTION

1.1. Problem statement and motivation

The innovation literature has consistently shown that knowledge is one of the most important resources for a firm in order to get competitive advantage (Berchicci, 2013; Geldres-Weiss et al., 2016; Lin & Wu, 2010). As a result, companies are developing strategies to increase their knowledge inputs. To illustrate, there has been an increasing trend in business expenditure in R&D activities in European Union (EU) countries (Eurostat, 2023). In 2012, the total business R&D expenditure was 150287 million euros, and by the end of 2021 the total sum increased up to 216629 million euros. More concretely, in Spain, business R&D expenditure increased up to 9696 million euros in 2021, in comparison with 7094 million euros in 2012. Figure 1.1. illustrates these trends.

Figure 1.1. Business enterprise R&D expenditure in Spain and total in EU countries (mln. euros), 2012-2021.



Source: Own elaboration, based on Eurostat (2023)

In today's fast changing and dynamic business environment, firms need to innovate constantly to stay ahead of the competition. Innovation is a complex process that requires firms to rely on both internal (e.g. R&D) and external knowledge sources. By leveraging both internal and external sources, firms can access a wider range of technologies, knowledge, expertise, and resources to create innovative products, services, or processes, while also filling internal gaps (Santoro et al., 2018; Vega-Jurado et al., 2009). In other words, firms can diversify their pool of ideas, reduce costs, and access new talent, all of

which can help to drive success and competitiveness. For example, Apple's iPod was a breakthrough innovation at the time that combined existing knowledge and technologies (MP3 players and hard drives) with new and novel ideas.

In multiple occasions firms do not possess all the knowledge inputs required to develop innovative outcomes, which boosts their engagement in knowledge sourcing strategies. Also, innovation success relies on the firms' ability to effectively assimilate external knowledge and integrate it with their own internal knowledge (Ho et al., 2019; Zahra & George, 2002), in order to develop new-to-market products and services (Haus-Reve et al., 2019; Hervas-Oliver et al., 2021). Thus, as this topic has become crucial nowadays, this dissertation falls in the thematic field of external knowledge search and innovation management, with an emphasis on sourcing strategies that cross national frontiers.

In today's globalized economy, international knowledge is especially important as firms must compete not only with domestic rivals, but also with international competitors. Moreover, firms that operate in multiple countries or regions must be able to integrate diverse perspectives and approaches to problem-solving to succeed in different cultural, economic, and regulatory environments. Firms that fail to adapt to these global pressures risk being left behind or even becoming irrelevant in their markets. Therefore, firms' acquisition, absorption and integration of international knowledge is critical to remain competitive, innovate faster and more efficiently, and access new markets and customers (Ruiz et al., 2020).

As mentioned before, globalization and fast changing technologies have increased the importance of external knowledge sourcing strategies, which refer to the ability to search and apply new ideas, knowledge and technologies that extend beyond firm boundaries (Monteiro & Birkinshaw, 2017). In this dissertation, the specific focus lies on two of the most important strategies in this context: international R&D outsourcing and inter-organizational collaborations. International R&D outsourcing involves firm's strategic decisions to contract out R&D activities or acquire knowledge from external providers located in foreign countries in order to complement internal resources, reduce production costs, and increase innovation performance (Martínez-Noya & García-Canal, 2018; Sommer & Bhandari, 2022). While inter-organizational collaborations are often defined as a firms' strategy that involves a partnership to achieve common goals, such as enhancing knowledge transfer for innovation improving (Radziwon & Bogers, 2019).

To provide a holistic framework, initially this thesis addresses the factors that drive the decision to engage in international R&D outsourcing, while considering the differences in this innovative behavior between young and mature firms. Later, the dissertation focuses on inter-organizational collaborations and innovative outcomes; more concretely radical innovations and eco-innovations, in order to explore how different types of collaboration partners and compositions of the network portfolio trigger distinct innovative outcomes, accounting for the differences between SMEs and large firms. To clarify these aspects, the dissertation is organized around three main research articles.

Chapter 2 focuses on the strategy of international R&D outsourcing, also known as R&D offshoring, as a way for firms to acquire external knowledge (Martínez-Noya et al., 2012). Previous research has shown that external knowledge acquisition can enhance firms' innovation performance, reduce costs, risks, and the time needed for innovation activities (Díaz-Mora, 2008; Tojeiro-Rivero & Moreno, 2019). Moreover, it allows to explore new research areas with lower commitment of resources and risks in case of failure, and with comparatively lower capital investments (Narula, 2001). However, some studies suggest that outsourcing knowledge and technologies can have a negative effect on firms' innovation performance after a certain point (Grimpe & Kaiser, 2010; Weigelt, 2009), so it is not exempt from risks.

Although R&D outsourcing is an important topic, there have been relatively few studies that specifically examine the factors that drive international R&D outsourcing (García-Vega & Huergo, 2011; Hijzen, 2007; Naldi & Davidsson, 2014). Given the global nature of the business environment, firms can play a key role in facilitating international technology transfer and driving technological change, which can in turn enhance their innovativeness (García-Vega & Huergo, 2019). International R&D outsourcing can have significant benefits for firms, enabling them to gain efficiency by accessing a greater diversity of knowledge, new technologies, and highly skilled personnel, while also opening new foreign markets (Contractor et al., 2010; García-Vega & Huergo, 2011; Garrigos et al., 2011; Un, 2017). By acquiring foreign R&D, firms are able to tap into specific knowledge and technologies that may not be available within their domestic market, thus helping to overcome resource constraints and facilitate growth in foreign markets (Nieto & Rodríguez, 2011; Naldi & Davidsson, 2014). Thus, Chapter 2 addresses the impact of internal technological resources and international experience on international R&D outsourcing. In particular, it shows that a firm's internal technological

resources have an impact on the capacity to identify and absorb external knowledge from international sources, which is crucial for firms' innovation performance and its competitiveness. Additionally, international experience plays a significant role in gaining and disseminating technological knowledge and information across markets, allowing firms to access specialized knowledge.

Further, in order to address recent calls that point out the need to consider organizational differences between young and mature firms in terms of their international R&D outsourcing strategies (Asimakopoulos et al., 2023), Chapter 2 considers firms' age as a moderator. In this sense, one of the main purposes of this study is to identify the differences that might exist between mature and younger firms in relation to their tendency to engage in international R&D outsourcing. This is because firm age is a critical variable in organization studies (Naldi & Davidsson, 2014), and different characteristics and behavior based on the level of maturity of firms can exist. Young firms can achieve a high level of innovation output by leveraging their flexibility, agility, and ability to adapt rapidly to fast changing environments. They may be more willing to outsource knowledge from external partners as a way to access knowledge and resources that are not available in-house. Yet, mature firms may have a better market position and resources to adapt faster to the external knowledge acquired (Un, 2017).

Later in this thesis (Chapter 3 and 4), inter-organizational collaborations as a second sourcing strategy are explored. The second paper of this dissertation explores the impact of the geographical and functional breadth of collaborations on a firm's radical innovation performance - i.e radical innovation characterized as completely new products and services or revolutionary changes in technology from existing practices (Flor et al., 2018; Ritala & Hurmelinna-Laukkanen, 2013). Given the significance of radical innovations in enabling firms to differentiate themselves in the market and improve their overall performance (Ritala et al., 2018), their analysis has become a critical topic in resent research.

Previous studies indicate that a firm's innovation performance can be influenced by the diversity in the innovation collaboration portfolio, in terms of types of partners and location diversity (Carree et al., 2019; Sarpong & Teirlinck, 2018; Trąpczyński et al., 2018; van Beers & Zand, 2014). However, there is still a need to explore in greater detail how this diversity of partners may be related to the firm's radical innovation performance. In this context, Chapter 3 examines the importance of the functional breadth and the

geographical scope of the collaboration portfolio in accelerating the propensity to innovate (Haus-Reve et al., 2019), more concretely in terms of radical innovation.

On the functional side, firms can access richer information and knowledge combinations from different types of partners, including suppliers, customers, competitors, universities, and research centers (D'Agostino & Moreno, 2018). On the geographic scope, knowledge from partners located in different countries helps firms to introduce brand new innovations and adapt to local needs and regulations, while simultaneously getting access to highly skilled employees and specialized external knowledge, which are essential for facilitating radical innovation (Duysters & Lokshin, 2011). In spite of these widely acknowledged benefits of engaging in various types of collaborations, research suggests that there is a point beyond which the marginal costs of diversity exceed the expected advantages due to increased complexity (Duysters & Lokshin, 2011). Previous studies on the effects of R&D collaboration have found a curvilinear (inverted U-shape) relationship between the breadth of the collaboration and radical innovation performance (Bayona Sáez et al., 2017; Delgado-Márquez et al., 2018), however they did not make a distinction between the functional and geographical breadth of the collaboration portfolio; a topic addressed in the third Chapter of this dissertation.

Further, considering that engaging in collaborations to obtain information and knowledge in SMEs and large firms may differ (Verhees et al., 2010), Chapter 3 also explores firm's size as a moderator in the relationships proposed, as contradictory arguments exist. On the one hand, large firms may take greater advantage of a more solid reputation and experience in cooperation networks with different partners (Shinkle & Kriauciunas, 2010), and benefit more for radical innovation purposes. However, SMEs may have a greater gap in human, financial, and other resources, and this is why it may increase their enrolment in different types and locations of cooperations to a greater extent.

Finally, Chapter 4 addresses eco-innovation in response to the growing political and social awareness of environmental issues (Díaz-García et al., 2015). The concept of eco-innovation relates to organizational sustainability and circular economies (Pereira et al., 2020). As introduced in the 90's last century, eco-innovation can be defined as a novel product or process that generates value for the business or customer, while also resulting in a substantial decrease in environmental effects (Fussler & James, 1996). Despite its relevance, firms may encounter resource and organizational challenges in the process of environmental innovations development, as well as a lack of knowledge and technologies

(Lee et al., 2018), particularly in countries with weaker innovation strategies (Guridi et al., 2020). To overcome these obstacles, firms can collaborate with international partners to gain new knowledge and facilitate eco-innovation adoption. Moreover, depending on their main strategy, firms should proactively seek out different international networks for exploration -i.e. collaborating with universities or research centers- or exploitation -cooperating with customers or suppliers (Bolivar-Ramos et al., 2020), in their attempts to increase eco-innovation activities. This research addresses this topic, by accounting for the differences between small and medium-sized enterprises (SMEs) and large firms.

Previous studies have shown that SMEs tend to seek partners for developmental stages, while large firms tend to collaborate with partners for explorative stages and search for new technologies (Jang et al., 2017). SMEs typically opt for exploitative collaborations with other companies to compensate for their limited resources and capabilities, leading to improved eco-innovation performance and a competitive advantage. Conversely, large firms with ample resources and a solid reputation tend to focus on explorative collaborations, often internationally. Large firms have unique opportunities to exploit existing technologies and explore new knowledge due to the uncertainty and novelty of eco-innovations and the need to expand beyond their core competencies (Jové-Llopis & Segarra-Blasco, 2018). Yet, both international explorative and exploitative collaborations can play a critical role in nurturing eco-innovations in SMEs and large firms; a topic Chapter 4 explores in detail.

To conclude, based on the previous discussion, several general questions remain without a clear answer in the literature, such as: what are the main drivers that induce the engagement in different international external knowledge sourcing strategies? Do external knowledge inputs always bring innovative benefits for a company? How do firm age and size affect the process of external knowledge search and the firm innovation performance, including eco-innovation? This dissertation aims to clarify some of these topics as explained next.

1.2. Purpose and research objectives

The general purpose of this dissertation is to analyze the drivers and effects of international external knowledge-sourcing strategies on the development and performance of innovative firms, while simultaneously addressing how these effects may be influenced by the firm's age and size (Carree et al., 2019; Naldi & Davidsson, 2014;

Un, 2017). As this is a broad theme, being more concrete, this thesis addresses the following specific objectives:

I. To analyze what factors trigger international R&D outsourcing, in relation to technological resources and the firm's international experience, and how these relationships may vary depending on the firm age.
II. To explore how the functional breadth and the geographical scope of the firm's collaboration network affect its radical innovation performance. Further, the aim is to understand how firm size moderates these relationships.
III. To examine how international exploitative collaborations (with suppliers and customers) and international explorative collaborations (with universities, research institutions and laboratories) affect eco-innovative performance in SMEs and large firms.

All in one, this dissertation aims to analyze the main drivers and effects of firms' external knowledge sourcing strategies (R&D outsourcing and different collaboration portfolios) on the firm's innovative performance (radical innovation and eco-innovation, concretely), considering key contingencies such as firm age and size. To achieve the specific aforementioned objectives, the thesis is articulated in three research papers that address the following research questions:

In relation to the drivers of international R&D outsourcing:

- How do the firm's internal technological resources and international experience affect the firms' propensity to engage in international R&D outsourcing?
- How do the effects of internal technological resources and international experience on international R&D outsourcing may vary depending on the firm's age?

Regarding the inter-organizational collaborations – radical innovation relationship:

- How does the functional breadth of the collaboration portfolio affect the firms' radical innovation performance?
- How does the geographical scope of the collaboration portfolio affect the firms' radical innovation performance?

- How does firm size moderate the relationships between the functional/geographical scope of collaborations and the firm's radical innovation performance?

In terms of the international collaborations – eco-innovation relationship:

- How does international exploitative and explorative collaboration affect eco-innovation?
- Do exploitative and explorative collaboration effects on eco-innovation differ in SMEs and large firms?

These questions will be examined thoroughly in the rest of the Chapters of this dissertation.

1.3. Theoretical background

As previously discussed, in today's globalized economy, firms are increasingly engaging in international knowledge sourcing to gain a competitive advantage (Berchicci, 2013). This involves accessing knowledge, expertise, and resources from outside their organization and often from other countries. International knowledge sourcing can accelerate innovation by providing access to new ideas, technologies, and resources (Deng et al., 2021). By collaborating with other firms, firms can speed up the innovation process and bring new products and services to market more quickly. It also can provide firms with access to new markets and customers. By collaborating with partners in other countries, firms can gain a better understanding of local customer needs and preferences, and tailor their products and services to meet those needs. Research on international knowledge sourcing is important because it can provide insights into how firms can stay competitive in a globalized economy, and how countries can promote innovation and economic development.

In line of the above, in the next section the main theoretical frameworks that inspire this dissertation, as well as how this thesis contributes to them, will be discussed.

1.3.1. Knowledge-Based View of the firm

Penrose's (1959) work provided the foundational concepts for the Resource-Based View (RBV) of the firm, which identified the firm as an administrative organization with

productive resources, including both physical and human resources. These resources can provide the firm with various value-adding capabilities and competitive advantage. However, as some authors later pointed out, over the last decades the most developed economies shifted from manufacturing to services, where the manipulation of information and intangible resources became a key, rather than solely physical products (Fulk & DeSanctis, 1995). The RBV has since been expanded by the introduction of the Knowledge-Based View (KBV) of the firm (Drucker, 1993; Grant, 1996), which emphasizes the role of knowledge as the most important driver of a firm's competitive advantage, as highlighted by several scholars (De Carolis, 2002; Hoskisson et al., 1999; Kogut & Zander, 1992).

In the KBV literature, knowledge management refers to a range of activities, including acquiring, sharing, and employing knowledge, that firms deploy to gain competitive advantage (Kogut & Zander, 1992). By effectively managing their knowledge resources, firms can enhance their ability to innovate, improve their products and services, and remain adaptable to changing market conditions. In other words, knowledge management can be a key driver of business success in today's rapidly evolving business landscape.

As highlighted in the strategic management literature, competitive advantage is frequently linked to intangible resources that are believed to account for differences in firm performance (Rouse & Daellenbach, 2002). It is thus clear that becoming a knowledge-based organization is crucial for organizational success in today's economy. The KBV of the firm recognizes that organizations are diverse entities that possess a wealth of knowledge, as noted by Hoskisson et al. (1999). Thus, the KBV suggests that firms can enhance their innovative performance by obtaining, assimilating, and implementing diverse knowledge inputs. This includes not only knowledge that is generated internally, but also knowledge that is sourced from external partners through collaborations. The more diverse the knowledge inputs a firm can acquire, the greater its ability to innovate and differentiate itself from competitors.

In recent years, the process of crossing national frontiers for international trade, information technology growth and globalization has been simplified and facilitated. That is why international knowledge sourcing has become critical for firms to get access to specific benefits of other countries and sources of international knowledge and resources (Naldi & Davidsson, 2014). By acquiring new external knowledge inputs and

technologies, firms can increase their growth and competitiveness by introducing new products and services or expanding into new markets.

Under the lens of the KBV of the firm, this dissertation provides a theoretical and empirical analysis focused on two of the most important international external knowledge sourcing strategies: international R&D outsourcing and international collaborations, analysing their repercussion on firm's innovative outcomes, as a means to achieve competitive advantage.

1.3.2. Open innovation literature

After the publication of Chesbrough's book in 2003, the idea of open innovation has garnered significant interest among researchers. According to Chesbrough (2003), open innovation is an approach to innovation management that involves intentionally leveraging external sources of knowledge, ideas, and technology to accelerate internal innovation and to create new opportunities for the external use of innovation. In other words, it is a purposeful use of both internal and external resources to foster innovation and growth. Many studies have adopted the term to refer to the trend where organizations increasingly rely on external sources of innovation, resulting in the exchange of ideas, resources, and personnel between organizations (Chiaroni et al., 2011).

Open innovation has affected business practice, with daily industry press releases and middle managers adopting the term (West et al., 2014). To succeed in an environment of diverse knowledge sources, firms must be able to collaborate effectively with other players. This requires building trust and developing strong relationships with key partners. It also requires a willingness to share knowledge and resources, and to be open to new ideas and perspectives (Wang et al., 2012). Managers recognize the importance of specific skills but sometimes may face challenges aligning open innovation with strategic objectives. According to a recent research of Chesbrough (2019), initially, the concept of open innovation used external knowledge to complement internal R&D, accelerating and enhancing current business innovation, while also allowing others to utilize internal R&D. However, this author also found that after the financial crisis in 2008, some organizations have used open innovation terminology to reduce or eliminate internal R&D and rely on outsourcing, which goes against the original intention of open innovation and may lead to short-term gains but long-term decline.

Open Innovation still offers promising prospects for novel and fundamental revelations, encompassing theoretical and empirical advancements and corporate experiments in openness. Considering the intellectual advancements of the last decades, there is reason to be positive that the innovative outlook of open innovation will be increasingly acknowledged for the diverse, rich, and even unforeseen perspectives it can provide for understanding the innovation process in the forthcoming decade.

Based on the two theoretical frameworks described above, as a general overview, further developed later in the thesis, the first paper contributes to the KBV of the firm (Grant, 1996), by examining R&D offshoring and its drivers as one of the most relevant strategies to gain external knowledge sources from international locations, that can help firms promote strategic renewal, innovation, and competitive advantage. The second paper, also framed within the KBV of the firm and the open innovation literature (Chesbrough, 2003), tackles how the functional breadth and geographical scope of a firm's collaborations affects its radical innovation performance. Specifically, the study looks at how firms can benefit from the valuable and diverse knowledge inputs obtained from collaborations that are varied in their functional breadth and geographically dispersed. Finally, also from the lens of the KBV and the open innovation literature, Chapter 3 explores the role of international exploitative and explorative collaborations, as mechanisms that offer distinct knowledge inputs, and how they affect eco-innovation (De Marchi, 2012; Pereira et al., 2020). Nevertheless, in exploring the previous topics, the dissertation also examines two key contingencies that affect these relationships: firm age and size, as discussed next.

1.3.3. The role of organizational contingencies in innovation studies: firm size and age

The contingency theory, in an innovative context (Burns & Stalker, 1961), suggests the most effective management approach can be affected by factors such as firm's age, size, technology, or market conditions in the environment (Betts, 2003). This dissertation focuses on firm's age and size, in particular.

According to recent research in the field of organizational innovation, the impact of firm size on innovation is significant and multifaceted (Nieto & Santamaría, 2010; Spithoven et al., 2013; Wang et al., 2015). Larger firms tend to possess greater resources and better access to capital compared to SMEs, providing them with the ability to invest more in research and development, and facilitate faster introduction of new products and

technologies into the market (Jang et al., 2017). Conversely, SMEs can leverage their size advantage to be more flexible, enabling them to adapt more promptly to dynamic market conditions (O'Connor & DeMartino, 2006). Moreover, given the distinct market orientations of small and large firms, it is appropriate to examine them as distinct entities (O'Dwyer & Ledwith, 2010). Further, the innovation process itself may differ significantly for SMEs and large firms. SMEs are more likely to rely on informal networks and collaborate with other firms and organizations to access knowledge and resources to drive innovation and overcome the liability of newness, financial and knowledge constraints required to innovate (Bolívar–Ramos, 2019). On the other hand, larger firms may utilize more structured processes for research and development activities.

In addition to firm size, many studies have highlighted the difference in innovative behavior between young and mature firms, depending on the firm's age. Studying young and mature firms separately in the context of innovation is important because age affects a firm's innovation capabilities, strategies and propensity to engage in R&D activities (García-Quevedo et al., 2014; Naldi & Davidsson, 2014). Young firms are often more innovative due to less structure constraints, their flexibility and greater incentives to look for new opportunities externally in order to avoid the intense competition (Lee et al., 2015). In contrast, mature firms may have established routines and structures that limit innovation but have greater advantage of more solid reputations and existing resource base (Shinkle & Kriauciunas, 2010). Moreover, age matters because firms go through different stages of development, with innovation critical to early success. Understanding age's impact on innovation can provide insights into supporting innovation in different types of firms at different stages of development. For these reasons, the effects of both firm age and size will be analyzed in the next Chapters of this thesis, providing contributions to both young and mature firms, and SMEs and large firms.

1.4. Structure and main contents of the dissertation

Finally, this section presents the main contents of this doctoral thesis. Apart from the Chapters on introduction and conclusions (Chapter 1, and Chapter 5, respectively), this dissertation is organized around three research articles (Chapters 2, 3 and 4), in order to tackle the three main objectives presented before.

The first paper is focused on exploring the main drivers of international R&D outsourcing and the role of firms' age. In this context, Chapter 2 examines how the firm's internal technological resources and international experiences, in terms of exporting and international collaborations, affect the decision to engage in international R&D outsourcing. In addition to that, the first paper also addresses how the previous relationships are affected by firm age. Thus, exploring the moderating role of firm age allows to provide a more fine-grained analysis of international R&D outsourcing, as a key factor for innovation and strategic renewal, while simultaneously tackling organizational differences based on the level of maturity of firms.

This research is based on a sample of 3720 Spanish manufacturing firms over the years 2009 to 2016, provided by PITEC ("*Panel de Innovación Tecnológica*") database. To discard multicollinearity issues, Variance Inflation Factors (VIFs) were computed. Then, probit models were used, due to the binary nature of the dependent variable that identifies whether the company has engaged in international R&D outsourcing during the period of the analysis. The independent and control variables were lagged for one year in order to avoid endogeneity issues and because the variables proposed may affect the dependent variable with some delay, in the next period (Un, 2017).

The findings from the first paper indicate that a firm's technological resources have an impact on its ability to identify and obtain external knowledge from international sources, which can be crucial in converting this knowledge into subsequent innovations that enhance competitiveness in the marketplace (Appio et al., 2019; Un, 2017). In addition, international trade is an important mechanism that facilitates the dissemination of technological knowledge and information across markets, enabling firms to acquire knowledge that is not available internally (García-Vega & Huergo, 2011; Tojeiro-Rivero & Moreno, 2019). Furthermore, the research also highlights that firm age has a negative moderating effect on the aforementioned relationships. This fact confirms that in young ventures, the relationship between exporting and international R&D outsourcing is stronger, which consequently leads to increasing their propensity to acquire knowledge from abroad. In addition, the results confirm that younger firms are more flexible and more efficient in using their international networks to acquire knowledge from abroad in comparison to mature firms.

The paper that resulted from this investigation, entitled "Understanding the Drivers of International R&D Outsourcing and the Role of Firm Age" was presented at the Academy of Management Meeting (2022) and the ACEDE (2022) conferences.

The second paper of this dissertation examines different collaboration portfolios and their impact on the firm's radical innovation. In particular, this research focuses on the type of functional partners involved in the network, as well as their geographic locations. This paper also addresses the moderating role of firm size as previous studies have shown that firm size is a factor that plays a crucial role in innovation activities (Nieto & Santamaría, 2010; Spithoven et al., 2013; Wang et al., 2015).

The second paper uses a longitudinal database also extracted from PITEC. The analysis is restricted to the sample of firms that present innovation expenditures over the period 2012 to 2016. In the empirical analysis, after applying the Hausman test, fixed effect models were run for the analysis of panel data. In order to avoid simultaneity problems, the dependent variable was introduced with a *t+1* year lag in relation to the independent and control variables (Cinyabuguma et al., 2005).

The results of Chapter 3 show that there is a curvilinear (inverted U-shape) relation between the functional breadth of collaborations/ geographical scope of the collaboration portfolio and the firms' radical innovation performance. Further, this study explores the role of firm size as a moderator. In this sense, the study reveals that SMEs can benefit more from engaging in more varied functional R&D collaboration portfolios, although after a certain point, the benefits tend to reduce with increasing diversity in the cooperation network.

An initial version of this paper, entitled "Partners' diversity in collaboration networks and radical innovation: understanding the differences between SMEs and large firms", was presented at the EURAM (2022) conference.

Finally, as there is an increasing political and social awareness of the importance and significance of environmental innovations development (Díaz-García et al., 2015), the third paper of the dissertation focuses on eco-innovation promotion through international collaborations. In order to provide a deeper explanation on how international collaborations affect eco-innovation, this article also distinguishes between different cooperation types according to their purpose, depending on exploitation and exploration distinct models (March, 1991; Calantone & Rubera, 2012). Further, the study also

contributes to the literature by analyzing the differences between SMEs and large firms, and how they use their collaboration strategies to improve eco-innovative performance.

In the third paper, the empirical analysis relies on the Community Innovation Survey (CIS) for the period 2012-2014, based on data of SMEs and large firms from eleven European Union countries. In this case, the Tobit regression model (Hendrickx, 2002; McDonald & Moffitt, 1980) was used, due to its effectiveness in estimating eco-innovation because the dependent variable, eco-innovation, is censored (García-Sánchez et al., 2021). The methodology adopted in this study is thus determined by the nature of the dependent variable, eco-innovation (EI). To address the research objectives in line with the study's hypotheses, the regression model was applied to SMEs and large firms separately. Thus, Chapter 4 focuses on comparing SMEs with large firms, rather than examining how the size of the organizations either strengthens or weakens the main hypotheses proposed in the study, as opposed to the previous chapters, where moderating effects were introduced.

The findings of Chapter 4 reveal that there are positive relations between international exploitative collaborations and eco-innovation in SMEs and large firms. Moreover, international explorative collaboration is more relevant than international exploitative collaboration in the context of large firms, while international exploitative collaboration is more important in the context of SMEs.

The following Table 1.1. presents a summary of the structure and key contents of this dissertation, highlighting how the objectives, theoretical foundations, methodology, and results of the various papers that form the core of this dissertation are interconnected, as a logical outcome of the preceding section.

Table 1.1. Structure and main contents of the dissertation

Paper Number	Objective	Main theoretical background	Sample	Methodology	Main results
Paper 1	International R&D outsourcing: drivers and moderating role of firm age	• KBV • International entrepreneurship • R&D outsourcing literature	PITEC database, 3720 Spanish manufacturing firms over the period 2009-2016	Panel data, Probit Random Effects (RE) regression models. Firm ages as moderator	1. Firm's technological resources have a positive impact on R&D offshoring. 2. International experience enhances the propensity to engage in international R&D outsourcing. 3. Firm age has a negative moderating effect on the aforementioned relationships.
Paper 2	Functional and geographical scope of collaborations - radical innovation. Moderating role of firm size	• Open innovation • KBV • Geography of networks	PITEC database, 4677 Spanish innovative firms over the period 2012 -2016	Panel data, Fixed-effects (FE) models (Inverted U-shape). Size as moderator	1. There is a curvilinear (inverted U-shape) relation between the functional breadth of collaborations and the firms' radical innovation performance. 2. There is a curvilinear (inverted U-shape) relation between the geographical scope of the collaboration portfolio and the firms' radical innovation performance. 3. SMEs can benefit more from engaging in more varied functional R&D collaboration portfolios, although after a certain point, the benefits tend to reduce with increasing diversity in the cooperation network.
Paper 3	International exploitative and explorative collaboration – eco-innovation in SMEs and large firms	• KBV • International alliances • Exploration /exploitation • Eco-innovation literature	Community Innovation Survey (CIS), sample of SMEs and large firms over the period 2012-2014, based on data from eleven European Union countries	Tobit regression model	1. There is a positive relationship between international exploitative collaborations and eco-innovation in SMEs. 2. There is a positive relationship between international exploitative collaborations and eco-innovation in large firms. 3. There is a positive relation between international explorative collaborations and eco-innovation in large firms. 4. To promote eco-innovation, international exploitative collaborations are more important in the context of SMEs, while international explorative collaborations are more relevant in the case of large firms.

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CHAPTER 2

WHAT TRIGGERS INTERNATIONAL R&D OUTSOURCING? UNDERSTANDING THE INFLUENCE OF FIRM AGE

Abstract

Due to increased globalization, fast information technology growth, and trade liberalization, the tendency to outsource knowledge is becoming more important as a strategy to nurture innovative activities. This paper contributes to the literature by studying the main drivers of international R&D outsourcing, in terms of technological resources and international experience. In addition, the research discusses how this innovation behavior differs between young and more mature firms. To achieve this goal, an empirical study using PITEC database was conducted, based on a sample of 3720 Spanish manufacturing firms over the years 2009 to 2016. The results show that technological resources and international experience positively affect the propensity to outsource international R&D. Further, the strength of these relationships varies depending on the level of maturity of a firm. In this sense, the younger firms are, the stronger the positive relationship between international experience and international R&D outsourcing.

Keywords

International R&D outsourcing, technological resources, exports, cooperation, firm age

1. Introduction

Nowadays, innovation plays a crucial role in the productivity and competitiveness of companies and, consequently, the economic growth of countries (Risso & Carrera, 2019). As innovation emerges from interactions between market participants, R&D outsourcing has become a key factor in innovation management (Howells et al., 2008; Mol et al., 2004). To cope with fast-changing and highly competitive markets, firms are more likely to blur their organizational boundaries to get external knowledge sources that can complement internal ones (Berchicci, 2013; Deng et al., 2021; Wynarczyk et al., 2013). Due to increased globalization, fast information technology growth and trade liberalization over the last years, this process has been simplified and facilitated, crossing national frontiers (Branstetter et al., 2019; Tomiura, 2009). Thus, international R&D outsourcing -also called R&D offshoring (Martinez-Noya et al., 2012)- has become critical for firms to get access to specific benefits of other countries and sources of international resources, including knowledge (Holl & Rama, 2014). In turn, the acquisition of new external knowledge inputs and technologies helps firms expand by launching new products and services or entering new markets, thereby increasing their growth and competitiveness (Naldi & Davidsson, 2014).

R&D outsourcing can be defined as investments in research and development purchased from external providers (Munjal et al., 2019; Un, 2017). The tendency to outsource knowledge is becoming more important for firms as a strategy to nurture innovative activities (Tojeiro-Rivero & Moreno, 2019). And, more concretely, international R&D outsourcing has become a topic of increasing relevance in the current global economy (García-Vega & Huergo, 2019). This is because globalization has made firms reconsider their view on the knowledge acquisition processes to get access to new knowledge and reduce production costs. Thus, although there are different reasons for outsourcing R&D from abroad, one of the key motives is gaining access to new technologies that are not available internally (Bertrand & Mol, 2013). Given countries' diversity in their levels and sources of innovations, international R&D outsourcing can allow firms to access these novel knowledge inputs, technologies, or skills (Chung & Yeaple, 2008).

Despite the relevance of R&D outsourcing and its critical role in fostering innovation, only a few studies investigate, particularly, the dimension of international R&D outsourcing and its main determinants (García-Vega & Huergo, 2011; Hijzen, 2007;

Naldi & Davidsson, 2014). To fill this gap, the focus of this study will be put on key factors related to internal technological resources and international experience, in order to show how they affect international R&D outsourcing. Despite some authors suggest there could be a negative relationship between these factors and R&D outsourcing (Jones et al., 2001; Mol, 2005a), most studies provide evidence for positive relations (Antolin-Lopez et al., 2015; García-Vega & Huergo, 2011; Spithoven & Teirlinck, 2015). Thus, the more international experience and technological resources a firm has, the more likely it will outsource R&D.

Further, a few or none of the studies about R&D offshoring have explored, specifically, how the intensity of such relationships may differ between young and older firms. Firm age is a critical variable in organization studies (Naldi & Davidsson, 2014; Santoro et al., 2021). Different behavior based on the level of maturity of the firm can exist within drivers that enhance the likelihood of their engagement in R&D activities (García-Quevedo et al., 2014), including R&D outsourcing. This is because firms can have different levels of accumulated resources, flexibility, and ability to handle uncertainty, as well as reputation and market position. All these drivers can help in facilitating networks around the world with customers, suppliers, and potential collaborators (Coad et al., 2016), thereby affecting the firm's propensity to acquire knowledge from abroad. Thus, it is important to analyze to what extent these factors can affect the decision to engage in international R&D outsourcing, and how firms' age can condition these relationships. Hence, this study aims to analyze the following research questions: how do the firm's internal technological resources and international experience affect firms' propensity to engage in foreign R&D outsourcing? In addition, how do these relationships may vary depending on the firm's age?

To answer these research questions, an empirical study using PITEC database was conducted, based on a sample of 3720 Spanish manufacturing firms over the years 2009 to 2016. The results of the analysis indicate that internal technological resources and international experience have a positive effect on the firms' propensity to outsource R&D from abroad. However, the strength of these relations differs depending on the level of maturity of a firm. In this sense, the younger firms are, the stronger the positive relationships between international experience and international R&D outsourcing.

Regarding the relations between internal technological resources and international R&D outsourcing, there is only partial support of the negative moderating role of firm age.

This paper contributes to the literature on innovation and R&D outsourcing (Asimakopoulos et al., 2023; García-Vega & Huergo, 2011; Grimpe & Kaiser, 2010; Mol, 2005a; Naldi & Davidsson, 2014; Teirlinck & Spithoven, 2013; Un, 2017) by providing both theoretical and empirical understanding of an under-researched area of international R&D outsourcing, in terms of international experiences of firms and their internal technological resources. In particular, the study shows that technological resources affect the firm's ability to recognize and integrate international external knowledge, which is a key to transform them into subsequent innovations, that may lead to higher levels of competitiveness on the market (Appio et al., 2019; Bertrand & Mol, 2013; Chung & Yeaple, 2008; Grimpe & Kaiser, 2010; Un, 2017). Along with it, international trade is an important channel that fosters the dissemination of technological knowledge and information across markets, which helps firms to get specific knowledge that is not available internally (Bertrand, 2011; Faria & Schmidt, 2012; García-Vega & Huergo, 2011; Tojeiro-Rivero & Moreno, 2019). Further, another contribution is considering firm age as a moderator in the relationships proposed. As suggested by past research, it is necessary to take into account the differences in the behavior of younger and older firms in terms of how distinct drivers stimulate their engagement in R&D activities (García-Quevedo et al., 2014), including international R&D outsourcing (Naldi & Davidsson, 2014). Thus, this research provides insights into the field of international entrepreneurship by discussing the behavior of young firms, in comparison with mature ones, in terms of the factors that influence their participation in international R&D outsourcing initiatives (Asimakopoulos et al., 2023; Naldi & Davidsson, 2014). Finally, this study extends the KBV (Grant, 1996) by identifying the factors that enhance the acquisition of international knowledge inputs, thereby contributing to the maintenance of a competitive advantage.

The structure of the paper is as follows. In section 2, we present the theoretical background and the research hypotheses. Section 3 explains the methodology, including the description of the data, variables, and empirical strategy. Section 4 shows the models and describes the main results obtained. Section 5 explains the robustness test. Finally,

Section 6 presents the conclusions, explains the main limitations of the study, and provides some ideas for further research.

2. Theoretical background and hypotheses

In recent times, firms need to adapt to fast-changing global markets to grow and develop. To cope with these challenges, firms are implementing different innovation strategies and developing their technological capabilities (Triguero & Córcoles, 2013). This helps them adjust to the current market realities and requirements, develop learning processes, and find opportunities for further improvement. In this context, some of the reasons that justify why firms decide to implement outsourcing activities have been analysed in previous studies.

Past evidence suggests that external knowledge acquisition enhances the innovation performance of firms (Díaz-Mora, 2008; Tojeiro-Rivero & Moreno, 2019). R&D outsourcing allows reducing costs, risks, and the time required to implement innovation activities (Narula, 2004). For instance, manufacturing firms are progressively modernizing their processes and developing technologies that are more efficient. As a result, production costs are being reduced, and firms are increasing their profitability (Alarcón & Sánchez, 2013). In addition, R&D outsourcing helps to investigate new research areas with the lower commitment of resources and risks, in case of failure, and with comparatively lower capital investments (Teirlinck & Spithoven, 2013). Overall, R&D outsourcing has been considered as one of the key sources for the extension and the renewal of the firm's knowledge base (Spithoven & Teirlinck, 2015).

Although the acquisition of R&D may serve as a tool to get access to knowledge resources and reduce costs and risks, some authors find that outsourcing of knowledge and technologies can have a negative effect on firm's innovation performance after a certain point (Grimpe & Kaiser, 2010; Weigelt, 2009). Usually, externally produced knowledge or technologies are not unique and are not adapted to the specificities of a firm (Grimpe & Kaiser, 2010). Besides, potential competitors may also use the same resources and gain the same advantages. Further, there is a risk that new technologies may fail due to the absence of consumer acceptance (Weigelt, 2009). Moreover, R&D outsourcing demands a significant amount of additional managerial attention and control that it is usually hard to get (Grimpe & Kaiser, 2010). This is why firms engaging in R&D outsourcing must

be attentive and learn how to integrate the new external knowledge to their internal knowledge management systems to enhance their effectiveness (Spithoven & Teirlinck, 2015).

Despite the previous potential drawbacks, there is usually a wide consensus about the critical role of R&D outsourcing in driving innovativeness, competitiveness, and firm growth (Bertrand & Mol, 2013; García-Vega & Huergo, 2011; Rodriguez et al., 2017). As a result, past research has explored what are the factors that drive the decision to outsource R&D. These drivers can be classified into internal and external ones as it was done in previous studies about innovation (Doloreux et al., 2016; Romijn & Albaladejo, 2002). Usually, the former includes factors such as internal R&D (Jones et al., 2001; Spithoven & Teirlinck, 2015; Un, 2017), firm's size (Rodríguez & Nieto, 2016; Vega-Jurado et al., 2008), firm's age (Naldi & Davidsson, 2014) and human resources (Papa et al., 2018), among others. Regarding the latter, the literature classically discusses export intensity (García-Vega & Huergo, 2011), cooperation (Teirlinck & Spithoven, 2013; Tojeiro-Rivero & Moreno, 2019) and external public support (Afcha & León López, 2014).

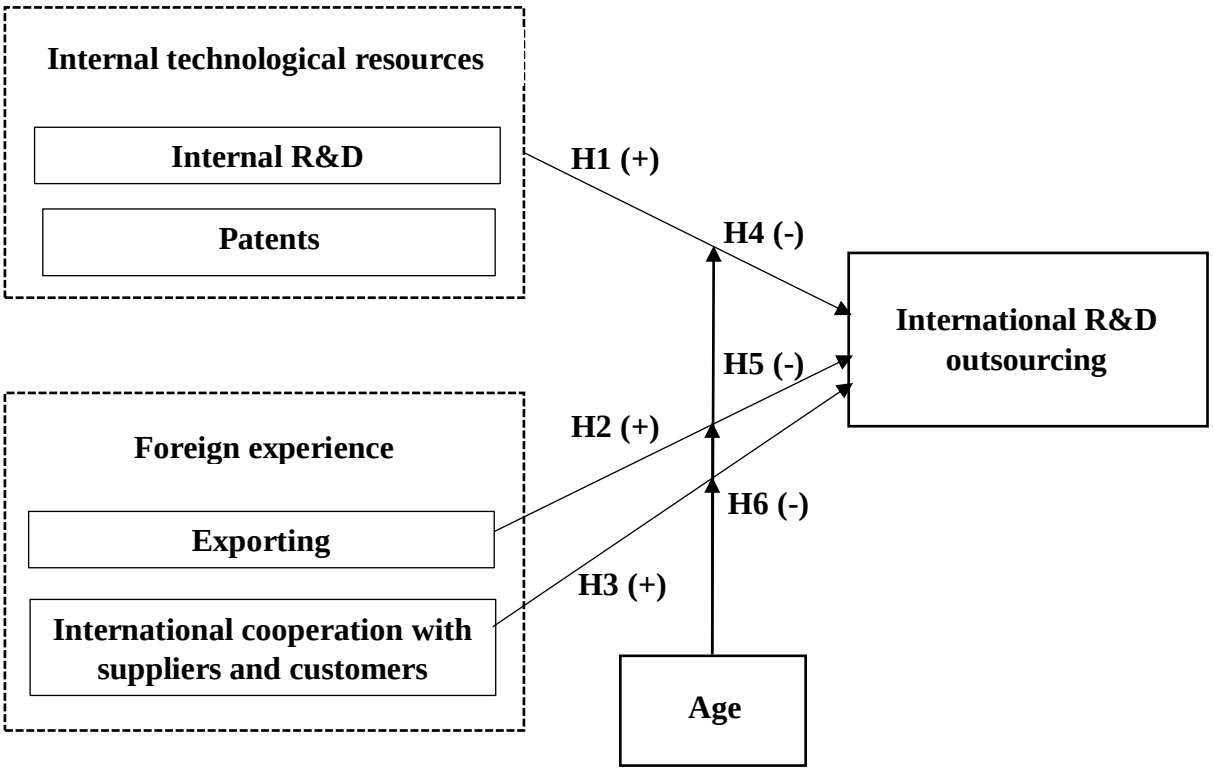
Although several studies address the factors affecting the outsourcing of R&D, few of them examine, particularly, the dimension of international R&D outsourcing and its main determinants. As we live in a global context, firms can become channels for international technology transfer and encourage technological changes, thereby increasing innovativeness (García-Vega & Huergo, 2019). Remarkably, international R&D outsourcing helps firms in gaining efficiency by increasing their diversity of knowledge, accessing new technologies and highly skilled employees, and discovering foreign markets (Contractor et al., 2010; García-Vega & Huergo, 2011; Garrigos et al., 2011; Un, 2017). In fact, the acquisition of foreign R&D allows accessing specific knowledge and technologies that cannot be obtained within the country where the firm is located (Nieto & Rodríguez, 2011), thus helping overcome firm resource constraints and accelerating growth in foreign markets (Naldi & Davidsson, 2014). Furthermore, international R&D outsourcing facilitates the process of providing new high quality products to fast-changing markets (Presutti et al., 2007) and accelerate product and process development (Lanctot & Swan, 2000). Thus, a quick reaction and adaptation to foreign markets allow firms to become more competitive in an international environment. Firms that are more

open to external knowledge sources can understand the nuances of international market functioning and meet local consumers' needs (Martinez-Noya et al., 2012).

Despite its relevance, to date little is known about what factors determine international R&D outsourcing, with few exceptions (Lampert & Kim, 2019; Martinez-Noya et al., 2012; Tamayo & Huergo, 2017). In this sense, we expect that higher internal R&D may ensure a higher ability to adapt and transform the foreign knowledge acquisition. In addition to that, other technology resources such as patents may be critical as a determinant of R&D outsourcing (García-Vega & Huergo, 2011; Martinez-Noya et al., 2012; Nasirov et al., 2022). This is because some firms may be reluctant to provide access to their knowledge and technologies to firms with weak intellectual property protection, given that their knowledge can become vulnerable (Jones et al., 2001). Thus, a high level of intellectual property protection in the company that decides to acquire R&D may have a positive effect on outsourcing knowledge. In what external factors refers to, García-Vega and Huergo (2011) showed that exporters are more likely to outsource R&D from abroad because it can allow reducing its financial constraints by being involved in trading. Moreover, since R&D outsourcing helps to access the distinctive technological capabilities of a specialized partner (Martinez-Noya et al., 2012), it is reasonable to consider international cooperation as one of the key drivers of international R&D outsourcing. As a result of accumulating experience in cooperating and contracting in different countries, firms can renegotiate more efficiently and use effective their contracts (Martinez-Noya et al., 2012).

Based on the previous arguments, in this research, we propose that firms' internal technological resources and their foreign experience constitute key drivers of international R&D outsourcing. In particular, internal technological resources are represented by internal R&D and patents, whereas foreign experience includes export and international cooperation with suppliers and customers. In addition, we explain how firms' age may negatively moderate these relationships. To clarify these ideas, Figure 2.1. shows the model proposed, that will be discussed in detail in the next section along with the expected relationships.

Figure 2.1. Model proposed.



Source: own elaboration.

2.1. Internal technological resources and international R&D outsourcing

The expansion of the firm's technological resources leads to an increasing probability of developing new or existing products (Breschi et al., 2000), while also improving the assimilation of newly acquired technologies to successfully perform processes of technological change (Voudouris et al., 2012). Thanks to their technological resources, firms improve their innovation outcomes and support future innovation activities (Breschi et al., 2000). Thus, firms that have higher technological capabilities and a greater ability to acquire and exploit external knowledge typically have a higher incentive to invest in R&D outsourcing. In turn, this helps firms innovate and compete more effectively (Un, 2017).

When analysing the effects of technological resources on R&D offshoring, in this study the focus will be put on internal R&D and patents, since this is considered particularly relevant in the literature (Bertrand & Mol, 2013; Mol et al., 2004; Rydehell et al., 2019; Spithoven & Teirlinck, 2015; Un, 2017; van de Vrande et al., 2009). Yet, it is important

to mention that there are ambiguous results regarding internal R&D as a determinant of international R&D outsourcing. Some authors have found a negative relation between internal R&D and R&D outsourcing in general. In this regard, some firms are more likely to develop external collaborative relations and acquire knowledge to compensate for their lack of internal technological capabilities and effectively substitute the internal innovative activities (Harrigan, 1985; Mol, 2005a). This would suggest that outsourcing is only needed for firms with incomplete or limited resources (Jones et al., 2001). Thus, the lower the R&D intensity, the higher the firm's propensity to outsource R&D. Nevertheless, there are opposite results regarding the international outsourcing of R&D. In these lines, several authors show a positive relation between internal R&D and the outsourcing of R&D (Bertrand & Mol, 2013; Un, 2017). In fact, internal R&D activities are complements rather than substitutes for R&D outsourcing (Delgado-Verde et al., 2021; Spithoven & Teirlinck, 2015). This is because internal and external R&D complement each other in a way that the firm can achieve higher levels of innovativeness (Lee & Kim, 2022; Un, 2017). Overall, it is reasonable to expect that the greater the internal R&D, the greater propensity to outsource R&D from abroad in order to complement existing knowledge.

As it is known from the literature, patents constitute key strategic technological resources that serve to differentiate a firm from its competitors, sustain its competitive advantage (Kotabe et al., 2007; Won, 2015), and prevent and protect innovations from being imitated by other firms (Fontana et al., 2006). Patents can provide a competitive advantage and support firms in technological investment decisions (Appio et al., 2019), including decisions about international R&D outsourcing. Patents show a firms' potential to identify and integrate acquired knowledge into firm's technologies (Appio et al., 2019; Li-Ying et al., 2016), and they are also associated with learning processes (Wang et al., 2016). Further, patents allow firms to identify the evolution of technology within markets (Appio et al., 2019; Grimaldi et al., 2015) -including international ones-, and the strategic relevance of knowledge sources (Grimaldi et al., 2015), helping recognize valuable knowledge and facilitating the process of adaptation. Patents can serve as an incentive for companies to engage in international outsourcing by offering a means to recover investment costs through licensing or royalty agreements. Moreover, patents play a crucial role in this context by facilitating collaborations and technology transfer agreements, ensuring that the knowledge gained through outsourcing is protected

(Cammarano et al., 2022). Thus, it is possible to expect that the greater the number of patents a firm has, the more likely it will outsource knowledge from abroad.

Based on the foregoing, we expect that internal technological resources will have a positive effect on international R&D outsourcing, with the potential to increase firms' innovative performance and its competitiveness on the market. Building on these ideas, we propose the following hypotheses:

Hypothesis 1a. The greater the firm's internal R&D, the higher the likelihood to outsource R&D from abroad.

Hypothesis 1b. The greater the number of patents, the higher the likelihood to outsource R&D from abroad.

2.2. Foreign experience and international R&D outsourcing

The link between international trade and innovation activities has received wide attention over time (Henley & Song 2020; Narula & Zanfei, 2005; Shu & Steinwender, 2019; Zahler et al., 2014). International experience –e-g- through trade- and international networks usually allow firms to make the outsourcing process cheaper, because they can reduce transaction costs and can abstain from signing complicated official contracts (Mol et al., 2005b). As García-Vega and Huergo (2011) argue, international outsourcing is relatively less costly for firms that export their products. Usually, these firms are more proactive to acquire new technologies and foreign knowledge to try to increase their competitiveness in international markets. Moreover, given that human resources play an important role in the innovation process by integrating resources of knowledge (Papa et al., 2018), the development of multicultural capabilities by exporting can translate into a faster and more efficient integration of acquired knowledge from abroad through outsourcing.

Despite it could be the case that the propensity to export products signals a firm's strength in terms of resources, which could subsequently lead to outsourcing less from abroad (Mol, 2005a), it is still reasonable to expect that higher levels of exports will lead to a greater probability to be engaged in international R&D outsourcing. Overall, firms that distribute their products to foreign customers develop an ability to identify consumer preferences and needs along with the value of their products abroad (Salomon & Shaver,

2005). As a result, they tend to invest more in R&D outsourcing in order to adapt their products faster to foreign markets they serve. Therefore, these ideas support the following hypothesis:

Hypothesis 2. The higher the level of exports, the greater the probability to outsource R&D from abroad.

As discussed previously, firms need to be innovative and quickly adapt to dynamic and changing global markets (Tojeiro-Rivero & Moreno, 2019). Therefore, firms' integration in global innovation networks is becoming more important for their competitiveness and growth (Ebersberger & Herstad, 2013). For this reason, it is common for firms to engage in international cooperation that allows them to access a specific partner's assets, including new technologies, to enhance their competitiveness on the market and to share the costs and risks of product development (Antolin-Lopez et al., 2015; Faria & Schmidt, 2012; Gómez et al., 2022).

International vertical collaborations can be particularly relevant in this context since engaging in collaborations with suppliers can facilitate the process of international R&D outsourcing by helping firms reduce costs, while that with customers may allow firms to produce and enhance market-oriented products (van Beers & Zand, 2014; Yu & Lee, 2017). Moreover, collaborations with international suppliers can generate additional opportunities for creating valuable and difficult to imitate resources, by sharing knowledge and technology between a firm and its partners (Belderbos et al., 2015). Further, cooperations with foreign suppliers and customers can enhance the likelihood of acquiring country specific resources, including new technologies, which are not available internally (van Beers & Zand, 2014). In other words, international cooperation creates additional opportunities for firms to acquire valuable resources and knowledge (Belderbos et al., 2015), considering a global context. Furthermore, participating in international cooperation may increase the propensity to outsource knowledge from abroad, given that these networks increase the ability to understand partners' behavior and reduce potential conflicts of interest (Yli-Renko et al., 2001).

In this regard, we contend there is a positive relationship between international cooperation and foreign R&D outsourcing.

Hypothesis 3. The greater the firm's engagement in international collaborations with suppliers and customers, the higher the probability to outsource R&D from abroad.

2.3. Internal technological resources and international R&D outsourcing: the moderating role of firm age

Previous hypotheses have discussed the positive impact that the firm's technological resources and international experience may have on the propensity to engage in R&D offshoring. However, firm age is a factor that may moderate (i.e. strengthen/weaken) the relationships hypothesized above. In this sense, one of the main purposes of this study is to identify the differences that might exist between mature and young firms in relation to their tendency to engage in international R&D outsourcing activities. This is because firm age is a critical variable in organization studies (Naldi & Davidsson, 2014), and different behavior based on the firm maturity levels can exist, as discussed next.

Young firms tend to be focused on a core area of expertise or a specific technology, but usually present deficiencies in others (Lichtenstein & Brush, 2001). Consequently, to improve their competitiveness, young firms may be more dependent on the knowledge from abroad, which is not available in their home country and is more varied, as a means to fill internal gaps (Friesl, 2012) and complement their existing technological resources. Although young firms may face the problems of resource constraints, newness (Hughes et al., 2021; Salimath et al., 2008), and difficulties to enter international markets, they can still have a higher propensity to outsource R&D from abroad than older firms can. This is because they have a higher ability to adapt and use new knowledge from abroad in order to complete and develop already existing technological resources (Yli-Renko et al., 2001), being less rigid than mature firms. In addition, Naldi and Davidsson (2014) note that young firms are more flexible in order to create and modify valuable products developed thanks to the knowledge acquired, consequently improving their level of competitiveness. Hence, building on these ideas, we propose the following hypotheses:

Hypothesis 4a. The positive relation between the firm's internal R&D and international R&D outsourcing will be stronger for younger firms.

Hypothesis 4b. The positive relation between the number of patents and international R&D outsourcing will be stronger for younger firms.

2.4. International experience and international R&D outsourcing: the moderating role of firm age

The link between international trade and innovation activities including R&D outsourcing has considerably strengthened over time (Buckley et al., 2022; Wu et al., 2017). It can be explained because international trade is an important channel that fosters the distribution of technological knowledge and information across markets (Bertrand, 2011; Buckley et al., 2022; Yoruk et al., 2021). In this scenario, more mature firms may have greater experience and funds that motivates them to increase their export intensity (Un, 2017), in turn investing more also in R&D outsourcing to quickly adapt their products to the foreign markets they serve. However, as local market competition tends to be quite high in multiple occasions, young and more flexible firms may have greater incentives to look for new opportunities overseas in order to avoid the intense competition in their home countries (Asimakopoulos et al. 2022; Lee et al., 2015). In addition, younger firms can learn faster from exporting than older firms (Asimakopoulos et al. 2022; Fernandes & Isgut, 2005). Due to their shortage of experience, young firms define actual customer needs or product quality through exports and, consequently, increase the likelihood to acquire knowledge in order to react quickly to changing conditions in the market.

Building on these diverse ideas, we expect that in younger firms, the relationship between exporting and international R&D outsourcing will be stronger. Younger firms present greater needs, fewer rigidities, and learn faster from exporting, which helps them search and adapt new knowledge from abroad more effectively than in mature firms. Thus, we propose the following hypothesis:

Hypothesis 5. The positive relation between exporting and international R&D outsourcing will be stronger for younger firm.

As it was noted before, firm competitiveness is also conditioned by how effectively the firm is integrated into international networks, which affects its ability to quickly absorb and integrate external knowledge from abroad (Belso-Martínez, 2010). Bearing this in mind, firm age is frequently associated with greater entrepreneurs' experience and more consolidated positions within networks (Martínez-Román & Romero, 2013). Thus, it may be possible that mature firms can take greater advantage of more solid reputations (Shinkle & Kriauciunas, 2010), that in turn allow them to acquire specialized skills and

knowledge through this international cooperation to a greater extent than younger firms. However, Antolin-Lopez et al. (2015) note that younger firms are more likely to be involved in international cooperation than older firms, because they may be more interested in the process of assimilating knowledge from external partners. Young firms tend to be particularly creative in generating new ideas or innovative products, but usually face the problem of newness and lack of resources to develop them. Hence, young firms may aspire to be more active in external knowledge acquisition from international partners to surmount the liability of newness and to acquire the resources required to innovate (Bolívar–Ramos, 2019).

All in one, international collaborations can assist young firms in complementing in greater depth their internal technological resources, which may not be available in their home country (Asimakopoulos et al. 2022). Furthermore, international cooperation with international suppliers and customers allows sharing costs and risks of product development (Faria & Schmidt, 2012), which is an advantage for young firms, because of their lack of resources and solid reputation in order to acquire knowledge. Thus, given their greater flexibility, younger firms may complement their current resources to a greater extent than more mature firms by outsourcing foreign knowledge.

Based on all of the above:

Hypothesis 6. The positive relation between international cooperation and international R&D outsourcing will be stronger for younger firms.

3. Methodology

3.1. Data

This study uses PITEC ("*Panel de Innovación Tecnológica"*), a panel database that is collected by the Spanish Statistical Office (INE), focusing on the period 2009-2016. PITEC provides wide information about technological and innovation activities of firms that belong to the principal sectors in the Spanish economy (Cruz-Castro et al., 2018; Garcia Martinez et al., 2019; Peñasco et al., 2017; Tojeiro-Rivero, 2021). One of the main advantages of using this database is that it allows for partial control over potential endogeneity issues, by introducing lags between independent and dependent variables (Badillo & Moreno, 2016). Moreover, PITEC includes information about foreign R&D

outsourcing from the same group of companies, different groups of companies, technology centers, public administration, universities, and private non-profit institutions, as well as other variables that are required to test the hypotheses proposed.

The analysis is restricted to the sample of innovative firms that present innovation expenditures during the period considered (Tamayo & Huergo, 2017). Given that manufacturing sectors spend more on R&D, compared with service firms (Guerrieri & Meliciani, 2005), the empirical analysis focuses only on the Spanish manufacturing sector; a common approach in past research (García-Vega & Huergo, 2019; Marchi, 2012).

According to Eurostat, the statistical office of the European Union, the classification of technology sectors contains high-technology manufacturing, medium-high technology manufacturing, medium-low technology manufacturing, and low-technology manufacturing sectors. The table 2.1. below represents the percentage of firms in these four categories. The final sample of the study includes 3720 firms that operate in the manufacturing sector.

Table 2.1. Distribution among different manufacturing technology sectors

Tech sector	**Number of firms**	**Percentage of firms in each tech sectors (%)**
High-technology manufacturing	395	10,62
Medium-high technology manufacturing	1351	36,32
Medium-low technology manufacturing	903	24,27
Low technology manufacturing	1071	28,79
Total	*3720*	*100*

3.2. Variables and measures

The selection of variables to test the model proposed was based on previous literature, as explained next.

International R&D outsourcing. This is the dependent variable. Consistent with past studies, it was measured as a binary variable that takes the value of 1, if the firm outsources R&D from abroad from the following sources: company from the same group, a different company, tech centers, public administration, universities, private and non-

profit institutions, and value 0 otherwise (García-Vega & Huergo, 2011; Tamayo et al., 2018).

In relation to the independent variables, these have been split into the main independent and moderator variables that go in line with the research hypotheses, and the control variables, which may also affect the decisions about international R&D outsourcing and therefore should be included in the model (Bertrand & Mol, 2013). All of them are explained in the following lines.

Internal R&D. As one of the key technological resources of the firm, we include the variable *Internal R&D*, consistent with past research (Bertrand & Mol, 2013; Chung & Yeaple, 2008; García-Vega & Huergo, 2019; Spithoven & Teirlinck, 2015). Internal R&D is measured by the internal R&D intensity of the firm, that is, R&D expenditures divided by firm sales (in logs), which usually has a strong correlation with the innovative output of the firm (Mol, 2005a). In this sense, Un (2017) indicates that higher internal R&D tends to ensure a higher ability to adapt and transform the knowledge acquired. Similarly, other authors also stress the significance of internal R&D activities in order to determine the value of the knowledge obtained and to apply it further to commercial ends (Ho et al., 2019; Spithoven & Teirlinck, 2015).

Patents. The variable *patents* is measured by the logarithm of a firm's total number of patents (García-Vega & Huergo, 2011), that were applied at the USPTO, the EPO, the Spanish Patenting Office (OEPM), and the Patent Cooperation Treaty (PCT), as indicated by PITEC. Along with internal R&D, patents also represent another important technological resource. Patents can be conceived as instruments that reflect part of the firm's absorptive capacity, i.e. the accumulated knowledge base (Grimpe & Kaiser, 2010). This, in turn, can affect the decision to acquire external knowledge, in order to complement the existing knowledge base.

Exports. We measured *Exports* as the logarithm of the total amount of export sales in euros, consistent with past research (Bertrand & Mol, 2013). Thanks to exporting, firms can obtain valuable information about customer needs and preferences. Consequently, this may lead to greater investments in international R&D outsourcing, as a means to adapt their products faster to the foreign markets they serve.

International cooperation. It is represented by a binary variable that reflects whether a firm cooperates with international suppliers and clients, coded as 1, and 0 otherwise (Teirlinck & Spithoven, 2013; Yu & Lee, 2017). When a firm cooperates with foreign suppliers and customers, it tends to increase its ability to identify and integrate the knowledge acquired from abroad (Un, 2017).

Firm age. Age is measured as the logarithm of the number of years the company has been operating since its foundation (Díez-Vial & Fernández-Olmos, 2015; Grimpe & Kaiser, 2010; Naldi & Davidsson, 2014). In this study, firm age plays a moderating role in the relationships between internal technological resources and international experience and the propensity to engage in international R&D outsourcing.

Control variables

Firm size. Size is measured as the logarithm of the firm's total number of employees (Tamayo & Huergo, 2017). We control for this variable as done in past research (Gilley et al, 2004; Rodríguez & Nieto, 2016), because firm size can have an impact on the firm's innovative activities (Triguero & Córcoles, 2013), including R&D offshoring.

High skilled employees. This variable is measured by the logarithm of the total number of paid staff with higher education within the firm. Traditionally, qualified employees facilitate the acquisition of external knowledge and make this process more efficient (Papa et al., 2018).

Tech sectors. This variable is presented by dummies that represent all the economic activities in the manufacturing sector, according to CNAE2009 (the Spanish acronym for Spain's National Classification of Economic Activities) (Cruz-Castro et al., 2018; Guisado-González et al., 2018).

Year. It was included in order to control for changing macroeconomic conditions over time (Nieto & Rodríguez, 2011; Oh & Yoo, 2021). The variable represents the current year in which firms operate.

All the variables and their measures are summarized in the Appendix.

3.3. Empirical strategy

Table 2.2. reflects the correlation matrix and the summary statistics for the variables of the research. As we can observe, the correlation is low between the main independent variables and international R&D outsourcing, and the results are positive and statistically significant.

Table 2.2. Summary statistics and correlation matrix

	Mean	S.D.	1	2	3	4	5	6	7	8
1 International R&D outsourcing	.088	.283	1.0000							
2 Size	4.429	1.292	0.1732*	1.0000						
3 High skilled employees	2.578	1.473	0.1830*	0.5723*	1.0000					
4 Firm age	3.385	.571	0.0545*	0.3026*	0.1768*	1.0000				
5 Internal R&D	12.472	1.501	0.2426*	0.6161*	0.5180*	0.1602*	1.0000			
6 Patents	.263	.648	0.1634*	0.2079*	0.2160*	0.0478*	0.2997*	1.0000		
7 Export	16.353	2.230	0.1709*	0.7426*	0.4697*	0.2204*	0.5444*	0.1922*	1.0000	
8 International cooperation	.147	.354	0.1972*	0.2997*	0.2428*	0.0609*	0.3698*	0.1935*	0.2834*	1.0000

To discard multicollinearity issues, we computed Variance Inflation Factors (VIFs). As a rule of thumb, VIF higher than 5 is regarded as a sign of severe multicollinearity (Hair et al., 2011). The results represented in Table 2.3. show that, in this case, VIFs are not that high to introduce corrective measures. Therefore, multicollinearity is not a problem.

Table 2.3. Multicollinearity check

Variables	VIF	1/VIF
Size	3.26	0.307072
High skilled employees	1.67	0.598823
Firm age	1.09	0.914321
Internal R&D	2.15	0.464322
Patents	1.14	0.880274
Export	2.39	0.418785
International cooperation	1.18	0.844729
Mean VIF	**1.67**	

In relation to the empirical approach, we define Probit estimation models in which the dependent variable is a binary variable that identifies whether the company has engaged in international R&D outsourcing during the period of the analysis $(IO_{i,t+1})$. We lag the independent and control variables for one year in order to avoid endogeneity issues and because the variables proposed may affect the dependent variable with some delay, in the next period (Un, 2017).

In order to select between the fixed and random effects estimators, the Hausman test was applied. Random effect was selected over the fixed effect (Wooldridge, 2010) in this case.

The first one is the general model:

$$IO_{i,t+1} = \alpha + T_{i,t}\beta + E_{i,t}\gamma + \chi_{i,t}\delta + \lambda_s + \lambda_{emp} + \nu_{i,t} + \varepsilon_{i,t}$$

i and t represent the identity of firms and considering period (from 2009 to 2016), respectively. $T_{i,t}$ represents a vector of variables accounting for internal technological resources of firms, such as internal R&D and patents. $E_{i,t}$ stands for a vector of variables for the firms' international experience, including export intensity and international cooperation. $\chi_{i,t}\delta$ represents firms' age. Further, the study includes control variables for the size (λ_s), high skilled employees (λ_{emp}), sector and yearly dummies. Finally, $\nu_{i,t}$, stands for a random effect (Wooldridge, 2010) and $\varepsilon_{i,t}$ represents a standard error (Kohler et al., 2011).

The second model includes the moderating role of firm age. This model can be divided into two equations in order to consider internal technological resources and international experience separately.

(1) $$IO_{i,t+1} = \alpha + T_{i,t}\beta + E_{i,t}\gamma + \chi_{i,t}\delta + T_{i,t}\beta \times \chi_{i,t}\delta + \lambda_s + \lambda_{emp} + \nu_{i,t} + \varepsilon_{i,t}$$

Where $\chi_{i,t}\delta$ is the firm's age and $T_{i,t}\beta \times \chi_{i,t}\delta$ is the interaction term created by multiplying $T_{i,t}\beta$ and $\chi_{i,t}\delta$ together. It shows how firm age affects the relationship between technological resources (internal R&D and patents) and international R&D outsourcing.

(2) $$IO_{i,t+1} = \alpha + T_{i,t}\beta + E_{i,t}\gamma + \chi_{i,t}\delta + E_{i,t}\gamma \times \chi_{i,t}\delta + \lambda_s + \lambda_{emp} + \nu_{i,t} + \varepsilon_{i,t}$$

Where $E_{i,t}\gamma \times \chi_{i,t}\delta$ interaction term created by multiplying $E_{i,t}\gamma$ and $\chi_{i,t}\delta$ together. It reflects how a firm's age impacts the relationship between international experience (export and international cooperation) and international R&D outsourcing.

Finally, the empirical model also included a full set of dummies for year and tech sectors. It was done in order to control changing macroeconomic conditions over the time and difference in firms' technological levels in the manufacturing sector.

4. Results

Table 2.4. displays the results from five different models. Model 1 contains the results of the base model and helps us test hypotheses 1-3. The rest of the models include different interaction terms in order to explore the moderating role of firm age, therefore analysing hypotheses 4-6.

Table 2.4. Probit models results. Dependent variable: international R&D outsourcing

	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Control variables					
Size, (log) (t-1)	.035	.048	.039	.038	.041
	(.064)	(.064)	(.064)	(.064)	(.064)
High-skilled employees (log) (t-1)	.041	.044	.042	.047	.038
	(.031)	(.031)	(.031)	(.031)	(.031)
Tech sectors	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Internal technological resources					
Internal R&D, (log) (t-1)	.205***	.701***	.207***	.212***	.205***
	(.042)	(.191)	(.042)	(.042)	(.042)
Patents, (log) (t-1)	.214***	.226***	.695**	.219***	.215***
	(.055)	(.056)	(.316)	(.056)	(.055)
Foreign experience					
Export, (log) (t-1)	.065*	.063+	.063*	.338**	.064*
	(.032)	(.032)	(.032)	(.129)	(.032)
International cooperation, (t-1)	.423***	.421***	.42***	.424***	1.601**
	(.093)	(.093)	(.093)	(.094)	(.536)
Firm age					
Firm age, (log) (t-1)	.038	1.887**	.093	1.388*	.168
	(.101)	(.702)	(.108)	(.622)	(.118)
Interactions (Age as moderator)					
Internal R&D x Firm age		-.142**			
		(.053)			
Patents x Firm age			-.134		
			(.087)		
Export x Firm age				-.080*	
				(.036)	
International cooperation x Firm age					-.338*
					(.151)
_cons	126.449***	120.035***	123.967***	121.791***	125.143***
	(30.807)	(30.993)	(30.835)	(30.95)	(30.839)
Observations	10016	10016	10016	10016	10016
Log likelihood	-1933.752	-1929.874	-1932.561	-1931.057	-1931.208
Chi^2	210.397***	209.651***	211.375***	208.711***	212.497***
Akaike's Crit	3889.504	3883.748	3889.122	3886.114	3886.415
Bayesian Crit	3968.836	3970.291	3975.665	3972.658	3972.959

*+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001. Standard errors are in parentheses*

In model 1, it is interesting to note that the control variables that refer to size and high-skilled employees are not statistically significant. This result is consistent with the

research of Martinez-Noya et al. (2012) that indicated that size is not a critical factor in explaining R&D outsourcing.

Considering the estimated parameters, internal R&D has a positive and significant effect on international R&D outsourcing ($\beta = 0.205$, $p < 0.001$), as well as patents ($\beta = 0.214$, $p < 0.001$). This means that technological resources have a positive relation with international R&D outsourcing, as expected in Hypothesis 1a and Hypothesis 1b. The results support the idea of acquiring knowledge from abroad in order to complement existing internal R&D. The next research hypotheses link international experience and international R&D outsourcing. The result shows there is a positive relation between export and international R&D outsourcing ($\gamma = 0.0645$, $p < 0.05$). Therefore, Hypothesis 2 is supported, confirming that exporting positively affects the firm propensity to invest in international R&D outsourcing. Exporting may facilitate international knowledge acquisition and integration, and make this process more efficient. In addition, international cooperation has a positive and significant effect on international R&D outsourcing ($\gamma = 0.423$, $p < 0.001$), which supports Hypothesis 3. Thus, participating in international cooperation with suppliers and customers may stimulate innovative efforts by increasing the acquisition of R&D from abroad.

In Model 2 and Model 3, we can observe different results in relation to Hypothesis 4a and Hypothesis 4b. The coefficient of the interaction term between age and internal R&D (Model 2) is negative and statistically significant ($\delta = -0.142$, $p < 0.01$), which supports Hypothesis 4a. Thus, for younger firms, the relation between internal R&D and international R&D outsourcing is stronger, as it was expected. However, the coefficient of the interaction term between age and patents (Model 3) is not statistically significant ($\delta = -0.134$, $p > 0.1$). It could be because the measure of patents reflects the number of patents applications, but does not show its volume and weight as a key technological resource. Thus, Hypothesis 4b is not supported.

In Model 4, the coefficient of the interaction term between age and exports is negative and statistically significant ($\delta = -0.0805$, $p<0.05$). Therefore, in younger firms, the relationship between exporting and international R&D outsourcing is stronger, which consequently leads to increasing their propensity to acquire knowledge from abroad. Thus, Hypothesis 5 is supported.

Finally, Model 5 presents the results that provide support for Hypothesis 6. The interaction term is negative and significant (δ = -0.338, $p<0.05$), which confirms that younger firms are more flexible and more efficient than mature firms in using their international networks to acquire knowledge from abroad.

5. Robustness check

Before settling on the above results, an alternate test for the proposed models was conducted. The dependent variable was measured in a different way, to check whether the results are robust. Previous studies differentiate the process of technology acquisition within the same business group (vertical integration relationship) and outside the business group (Martínez-Ros & Kunapatarawong, 2019; Tamayo & Huergo, 2016). Thus, in this alternative test, we decided to consider international R&D outsourcing based on the knowledge acquired outside the business group. Hence, international R&D outsourcing was measured as a binary variable that reflected whether (or not) firms purchased knowledge from the market and institutional channels abroad. The estimations show that the results remain mainly the same for the key variables of the research. All the results are presented in Table 2.5.

Table 2.5. Robustness check

	Model 1	Model 2	Model 3	Model 4	Model 5
Control variables					
Size (log) (t-1)	-.054	-.038	-.05	-.052	-.047
	(.066)	(.066)	(.066)	(.066)	(.066)
High-skilled employees (log) (t-1)	.06+	.065*	.061+	.067*	.057+
	(.033)	(.033)	(.033)	(.033)	(.033)
Tech sectors	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Internal technological resources					
Internal R&D (log)(t-1)	.234***	.853***	.235***	.241***	.235***
	(.043)	(.196)	(.043)	(.043)	(.043)
Patents (log) (t-1)	.218***	.232***	.528+	.223***	.218***
	(.056)	(.056)	(.316)	(.056)	(.056)
Foreign experience					
Export (log)(t-1)	.046	.043	.045	.327*	.045
	(.033)	(.033)	(.033)	(.128)	(.033)
International cooperation (t-1)	.487***	.483***	.484***	.487***	1.549***
	(.096)	(.097)	(.096)	(.096)	(.547)
Firm age					
Firm age (log)(t-1)	.027	2.34**	.064	1.416*	.15
	(.101)	(.72)	(.108)	(.618)	(.119)
Interactions (age as moderator)					
Internal R&D x Firm age		-.177**			
		(.054)			
Patents x Firm age			-.087		
			(.087)		
Export x Firm age				-.083*	
				(.036)	
International cooperation x Firm age					-.307*
					(.156)
_cons	98.769***	89.567***	97.48***	94.16***	97.74***
lnsig2u:_cons	1.13***	1.172***	1.139***	1.155***	1.14***
	(.096)	(.094)	(.094)	(.094)	(.094)
Observations	10016	10016	10016	10016	10016
Log likelihood	-1733.617	-1727.576	-1732.872	-1730.585	-1731.449
Chi^2	193.767	195.917	194.589	194.153	196.321
Akaike's Crit	3489.233	3479.152	3489.745	3485.171	3486.898
Bayesian Crit	3568.565	3565.695	3576.288	3571.714	3573.441

*+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001 Standard errors are in parentheses*

6. Discussion and conclusions

Previous studies have tackled the role of R&D outsourcing and its importance in the innovation management literature (García-Vega & Huergo, 2011; Martinez-Noya et al., 2012; Naldi & Davidsson, 2014), highlighting that innovative firms no longer rely

exclusively on their internal R&D activities to keep their technological competitiveness level (Bertrand & Mol, 2013; Lee & Kim, 2022; Martinez-Noya et al., 2012; Narula, 2001). As a result, they have increased the acquisition of external complementary resources and technological capabilities, that are not available within a firm (Martinez-Noya et al., 2012), or even home country. In the current context of globalization, firms are trying to build up their international networks and gain international experience to get specific knowledge from abroad that would help them to innovate and become more competitive. Nevertheless, past research about international R&D outsourcing has not paid much attention or provided enough theoretical and empirical evidence regarding the factors that drive this decision about outsourcing from abroad, along with the contingencies that affect this decision. Thus, this study has examined firm's technological resources and international experience as drivers of international R&D outsourcing. Consistent with H1-H3, the results of the study show that the greater the firm's technological resources, export sales, and degree of international collaborations, the greater the international R&D outsourcing (Un, 2017). In addition, we introduced firm's age as a moderator that may influence these relationships. Hence, this study has explored whether these drivers affect the propensity to outsource R&D from abroad, including the assessment of how that innovation behavior may differ between young and mature firms. Partially supporting H4, the findings of the research reveal that the relationship between the firm's internal R&D and international R&D outsourcing strengthens for younger firms. Also, in line with H5 and H6, the younger firms are, the stronger the positive relationship between international experience and international R&D outsourcing. These results support previous research suggesting that new ventures can enhance their absorptive capacity by accumulating internal knowledge (Gimenez et al., 2022; Zahra and George, 2002).

Overall, this study shows that internal technological resources such as internal R&D and patents have a positive and significant effect on the firm's propensity to outsource R&D from abroad (Nasirov et al., 2022). The finding suggests that firms with robust internal R&D capabilities may be better positioned to identify promising technologies and research areas for outsourcing overseas. Additionally, having a strong internal R&D function may enable firms to better manage the R&D outsourcing process, ensuring that it is aligned with the firm's overall innovation strategy and objectives. By investing in these resources, firms may be better positioned to leverage external expertise and

resources, ultimately leading to improved innovation outcomes and competitiveness in the global marketplace. Further, firms with a strong patent portfolio may be more likely to outsource R&D from abroad as a means of keeping strengthening their technological capabilities for maintaining their competitive advantage. In this context, R&D offshoring can be a cost-effective way for firms to access specialized knowledge and expertise that they may not have in-house but can complement internal sources. However, we have gotten only partial evidence that firm age moderates this relationship, particularly regarding patents.

By engaging in exporting and international cooperation with suppliers and customers, firms may be better positioned to acquire the knowledge they need to remain competitive in today's global marketplace, inducing international R&D outsourcing. The results of the research show that the more the firm engages in exporting, the higher the probability to outsource knowledge internationally. This relationship is stronger the younger firms are. Younger firms may have less developed internal R&D capabilities, making them more reliant on external sources of knowledge to support their innovation activities. As such, engaging in exporting may expose younger firms to new ideas and technologies, leading them to seek out additional knowledge sources to support their innovation efforts. In addition, there is a higher propensity to acquire knowledge from abroad in firms that engage in international cooperation with suppliers and customers. This is consistent with prior research that suggests that international cooperation can be an important source of knowledge spillovers and technology transfer (Belitz & Mölders, 2016). Considering the moderating role of firm age, younger firms may be more dependent on external knowledge sources to support their international expansion efforts, which makes them rely more on international R&D offshoring.

6.1. Theoretical, managerial and policy implications

By examining one of the most important strategies for obtaining diverse external knowledge sources from international locations, that can help firms achieve competitive advantage, this study contributes to the Knowledge-Based View of the firm (Grant, 1996). In particular, this study advances the understanding of the role of internal technological resources and international experience in order to make a decision to outsource R&D from abroad, thus advancing past research on the topic (García-Vega & Huergo, 2019; Lanctot & Swan, 2000; Martinez-Noya et al., 2012; Narula, 2001; Tomiura, 2009; Un,

2017). Further, it is worth mentioning that this research makes a theoretical contribution to the literature on international entrepreneurship and innovation. Specifically, it addresses previous calls for a better understanding of how firms' R&D offshoring decisions are influenced by their level of maturity (Naldi & Davidsson, 2014; Yli-Renko et al., 2001). This study contributes to the understanding of how the firm life cycle influences the adoption of this innovative strategy. The existing literature presents conflicting perspectives on whether mature firms, equipped with experience and more resources to handle the challenges of offshoring, are more inclined to pursue this decision, or if younger firms, with simpler organizational structures and greater adaptability, are more likely to engage in offshoring (Asimakopoulos et al., 2022). To be more concrete, the study draws a line between young and mature firms and shows the difference in their propensity to outsource knowledge internationally (Antolin-Lopez et al., 2015; Fernandes & Isgut, 2005; Lee et al., 2015; Naldi & Davidsson, 2014; Yli-Renko et al., 2001). This study shows that younger firms capitalize their learning advantages to induce to a greater extent than mature firms international R&D outsourcing; which is consistent with recent research that clarifies that international new ventures are able to succeed and benefit from heterogeneous external knowledge sources despite their constraints (Giménez-Fernández et al., 2022). Overall, this paper contributes to understand the importance of international R&D outsourcing in the global world and how young and mature firms can benefit from it.

This study also presents implications for both managers and policymakers. Managers should consider international R&D outsourcing as an efficient way of improving innovation performance and getting competitive advantages. Nieto and Rodríguez (2011) also highlight that managers should understand that the advantages of R&D outsourcing go beyond just cost reduction. Indeed, it helps firms to access specific valuable benefits of other countries (Holl & Rama, 2014), facilitates the process of providing new high quality products to fast-changing markets (Presutti et al., 2007) and boost innovation outputs (Nieto & Rodríguez, 2011). In this context, this study can guide managers on what factors can be useful when increasing the propensity to outsource knowledge from abroad. Thus, the research shows that internal R&D complements external R&D in a way that the firm can achieve higher levels of innovativeness. Further, firms that distribute their products abroad can develop an ability to identify consumer preferences and adapt to this quickly by acquiring knowledge or new technologies. Apart from that, it is also

common for firms to engage in international cooperation with suppliers and customers, which allows them to access a specific partner's assets and knowledge. Nevertheless, managers should consider the fact that young and mature firms behave differently, given their characteristics and level of resources, reputation and established networks. To develop and grow, young firms may have greater needs in terms of knowledge acquisition that may not be available in their home country, as more varied sources can be key to complement their existing resources.

In terms of public policy, the study can help in guiding some public policy strategies and decisions. Governments may consider implementing policies and incentives to encourage this strategy, with a focus on the specific needs and advantages of younger firms that engage in international R&D outsourcing. For instance, programmes oriented towards qualifying or training personnel (Tamayo & Huergo, 2016), such as language or technical courses, could be included, in order to improve the coordination and increase the efficiency of knowledge acquisition from abroad. Governments can facilitate the development of a more skilled workforce that is better equipped to engage in international R&D outsourcing and contribute to the overall competitiveness of the nation.

6.2. Limitations and future research

Despite all the implications and contributions mentioned above, this paper is not exempt from limitations. First, this study only analyzes drivers of international R&D outsourcing in general, so it does not consider concrete location advantages, by regions. In this sense, it would be also interesting extending the research by taking into account the cultural and institutional distance between firms and countries (Gimenez-Fernandez et al., 2021). Second, the binary nature of the dependent variable does not indicate how much it was invested in international R&D outsourcing. Third, the study does not analyze some other potential drivers that can also affect international R&D outsourcing. For instance, cooperations with universities or factors that prevent firms to innovate, such as financial or information constraints.

Finally, this investigation opens additional new opportunities for further research. Thus, it would be interesting to analyze the behavior in terms of international R&D outsourcing of new ventures that internationalise from inception and compare it with that of young firms that do it relatively later. Moreover, future studies could make a comparison of the factors affecting the propensity to outsource R&D from abroad in Spain and in other

countries, to analyze if the results are consistent in different geographical contexts. All these ideas provide promising lines of future research.

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Appendix. Variables and measures

Variable	Definition
Dependent variable	
International R&D outsourcing	Binary variable that represents whether (or not) a firm purchased R&D out of Spain, including the following sources: • Purchase of R&D from abroad from the same company group • Purchase of R&D from abroad from a different company • Purchase of R&D from abroad from technology centers • Purchase of R&D from abroad from public administrations • Purchase of R&D from abroad from universities • Purchase of R&D from abroad from private non-profit institutions
Control variables	
Size, (log) (t-1)	Number of employees
High-skilled employees, (log) (t-1)	Number of paid staff with higher education
Tech sectors	Dummy variables that represents in what technology sector firms operate: high-technology manufacturing if variable tech=1, medium-high technology manufacturing if tech=2, medium-low technology manufacturing if tech=3, and low technology manufacturing sector if tech=4. The variable tech represents all the economics activities in the manufacturing sector, according to CNAE2009 (*Clasificación Nacional de Actividades Económicas*).
Year	Current year in which firms operate (2009-2016)
Independent variables	
Internal R&D, (log) (t-1)	Total internal R&D expenditures in euros
Patents, (log) (t-1)	Number of patent applications
Export, (log) (t-1)	Total exports - in euros
International cooperation, (t-1)	Binary variable that indicates whether (or not) a firm cooperates with international suppliers and clients
Firm's age, (log) (t-1)	Number of years since the firm was founded

CHAPTER 3

THE EFFECTS OF THE FUNCTIONAL AND GEOGRAPHICAL BREADTH OF COLLABORATIONS ON RADICAL INNOVATION PERFORMANCE: THE MODERATING ROLE OF FIRM SIZE

Abstract

Due to the constantly increasing competitiveness along with complexity of knowledge, firms perceive cooperation as a key aspect that preserves firms' radical innovation performance. This paper contributes to the literature on radical innovation and open innovation by providing theoretical and empirical understanding on how the functional and geographical breadth of the firm's collaboration network affects its radical innovation performance. Further, it also explores the role of firm size as a moderator in the relationships proposed. To achieve this goal, an empirical study using PITEC database was conducted, based on a sample of 4677 Spanish firms over the period 2012 to 2016. The results show that there is an inverted U-shaped relationship between the functional breadth of collaborations and the firms' radical innovation performance. Along with it, the geographical scope of the collaboration portfolio and the firm's radical innovation performance also present an inverted U-shape relation. Moreover, the study finds partial support for the moderating role of firm size, in the sense that SMEs and large firms vary in their optimal number of diversity of partners. This paper concludes by discussing the implications of the study and further research suggestions.

Keywords: radical innovation, open innovation, collaboration portfolio, functional breadth of collaborations, geographical scope, firm size.

1. Introduction

In the context of rapid technological change, economic globalization and highly competitive markets, external knowledge has become especially important for companies looking to develop and introduce new products (Ahn et al., 2006, Ismail et al., 2022; Snihur & Wiklund 2019; Xie & Wang, 2020). Due to ever-increasing competitiveness and the complexity of knowledge, firms perceive cooperation to be a key aspect through which to preserve innovation performance (Gallego et al., 2013). In this sense, the importance of using external knowledge to increase innovation performance has long been noted by many researchers in the field of open innovation (Cheng & Huizingh, 2014; Kang & Kang, 2009; Parida et al., 2012; Torres de Oliveira et al., 2022; Zhao et al., 2016). Open innovation refers to the use of the required external knowledge to improve innovation performance, as well as identifying new market opportunities for external exploitation (Cheng & Huizingh, 2014). More concretely, Chesbrough and Bogers (2014) define open innovation as an innovation process built on managed knowledge and technology flows across firm boundaries, according to the purpose of the firm.

Remarkably, open innovation has become an effective driver to produce radical innovations that create wholly new technological frontiers. Opened boundaries to external knowledge allow firms to facilitate the acquisition of new and valuable information or knowledge, and then strengthen the ability to reveal progressive technologies in order to stimulate radical innovation development (Cheng et al., 2016). Radical innovation contains significantly advanced technologies and knowledge. It includes the highest order innovations and knowledge that fosters the creation of new products, markets or even industries; promoting the achievement of competitive advantages as competitors need time to create technologies that are able to compete with existing ones (Koberg et al., 2003; Torres de Oliveira et al., 2022). Thanks to these innovative activities, firms generate economic and social value that legitimizes the role they play in the economy and society (Colombo et al., 2017). Moreover, radical innovations can improve the quality of human life, for instance introducing new and more effective medical devices, and address and satisfy new societal needs, such as the development of autonomous vehicles. Indeed, firms' radical innovations approach societal problems in fundamentally novel ways and contribute to creating sustainable and social changes that spur scientific, technological, and economic progress. Given its repercussions for firms and society, multiple scholars

have recently emphasized that research on the effects of diverse external collaboration (Mendi et al, 2020) and firms' radical innovation performance require special attention at present.

Frequently, firms do not have all the knowledge inputs required to develop disruptive innovative outcomes (Haus-Reve et al., 2019), which boosts their engagement in knowledge sourcing strategies and cooperation. From the KBV, cooperation diversity triggers various knowledge flow mechanisms (Hagedoorn et al., 2018; Park & Lee, 2022). Thus, innovative firms have been trying to diversify their cooperation portfolio in order to respond to fast-changing environments and introduce new knowledge and products to the market; this is why a crucial aspect in cooperation is the selection of relevant partners (Lee et al., 2022; Nieto & Santamaria, 2010; van Beers & Zand, 2014). As the diversity in a firm's cooperation portfolio is determined by the proximities and differences among network partners (Delgado-Márquez et al., 2018), the existing literature reveals that partners' variety and their characteristics play crucial roles in innovative success (Capaldo & Petruzzelli, 2014, Elia et al., 2019). Consequently, in order to identify and select the most suitable cooperation partners, multiple studies pay close attention to the role of proximity to partners (Ardito et al., 2019; Capaldo & Petruzzelli, 2014; Delgado-Márquez et al., 2018; Knoben & Oerlemans, 2006). Existing studies suggest that proximity between different cooperation partners, in terms of geographic (Capaldo & Petruzzelli, 2014), cultural (Elia et al, 2019) and technological or organizational aspects, among others, facilitate coordination, and reduce uncertainty and conceptual ambiguity between them (Knoben & Oerlemans, 2006). Nevertheless, distant partners can also provide less redundant knowledge sources, which in turn could lead to enhanced innovation outputs (Bolívar-Ramos, 2019).

In line with previous arguments, a diverse collaboration portfolio reflects the degree of variance in partners, functional purposes, location and managerial strategies (Jiang et al., 2010), which facilitate improvements in knowledge flows and the enriching of information sources, but can also generate management problems. In this context, and more concretely, scholars have long noted the need to distinctly analyze the importance of functional diversity, i.e., the number of different partner types including suppliers, competitors, customers, universities, etc., with whom a firm collaborates (Hagedoorn et al., 2018), and the geographical diversity of the collaboration portfolio -from the

standpoint of different geographic areas in which partners act- in order to address how they affect firms' innovation performance (Capaldo & Petruzzelli, 2014; Trąpczyński et al., 2018; van Beers & Zand, 2014). Notably, diverse functional partners provide a dissimilar and complementary knowledge base, while geographically diverse partners induce a greater openness to new ideas (Bernal et al., 2022; Sarpong & Teirlinck, 2018). Despite this, it is vital to mention that overly distinct partners from different knowledge areas and locations can lead to situations of conflict that may negatively affect the introduction of radically new products (Cheng et al., 2016).

Despite acknowledging the crucial role of richer knowledge sources for radical innovation, empirical studies on the diversity in collaboration portfolios still offer contradictory arguments, specifically in terms of how the functional and geographical diversity of collaborations affect firms' innovation performance, including radical innovation. On the one hand, some scholars provide evidence of the existence of an inverted U-shaped relationship between the breadth (functional and/or geographical) of R&D cooperation and a firm's radical innovation performance (Carree et al., 2019; Delgado-Márquez et al., 2018). On the other hand, others have focused on the differential effects of geographical, functional and hierarchical cooperation portfolios on a firm's innovative output, suggesting linear relations between cooperation diversity and innovation output (Sarpong & Teirlink, 2018). As inconclusive results persist, the heterogeneity and diversity in collaboration portfolios and its effect on firms' radical innovation performance requires further attention. Thus, this paper focuses on two research directions in regards to partners' diversity: (1) the impact of the functional breadth of collaborations on radical innovation and (2) the impact of the geographical diversity of R&D partners on firms' radical innovation performance.

Further, our study also explores how firm size, which is one of the most important and debated firm-level contingencies affecting innovation activities (Petruzzelli et al., 2018), influences the relationships between the functional and geographical breadth of the collaboration portfolio and firms' radical innovation performance. To the best of our knowledge, scant research has tackled this topic (Carree et al., 2019), and a deeper understanding in terms of how these relations may vary in SMEs and large firms is required, as they differ in their organizational characteristics, resource base, innovation behavior and level of experience (Carree et al., 2019; Jang et al., 2017; Popa et al., 2017;

Shinkle & Kriauciunas, 2010; Veer et al., 2016). On the one hand, large firms may be involved in more diverse collaboration portfolios thanks to their resource base and experience, which ensures relevant networks (Jang et al., 2017). However, SMEs are more flexible and can rapidly adapt their processes to adopt radical innovations (O'Connor & DeMartino, 2006). Thus, this paper tries to shed some light on how firm size affects the relationships between diverse collaboration portfolios (i.e., functional and geographical) and firms' radical innovation performance.

Based on the previous arguments and research gaps, the main research questions this study addresses are: (1) How does the functional breadth of the collaboration portfolio affect firms' radical innovation performance? (2) How does the geographical scope of the collaboration portfolio affect firms' radical innovation performance? (3) How does firm size moderate the aforementioned relationships? To answer these research questions, an empirical study using the PITEC database was conducted based on a sample of 4677 Spanish manufacturing and service firms over the years 2012 to 2016. The results of the analysis indicate that there is an inverted U-shape relation between the functional breadth of the collaboration portfolio and firms' radical innovation. Further, the geographical scope of the collaboration network and firms' radical innovation performance also present an inverted U-shaped relationship. Moreover, firm size moderates the relationship between the functional diversity of collaborations and radical innovation performance, from the perspective that SMEs have a higher optimal number of functional partners compared to large firms, which may be explained due to the need to acquire knowledge and complementary resources and competencies from diverse sources (Zeng et al., 2010). Finally, the study does not find support for the moderating role of firm size on the relation between the geographical scope of the collaborations and firms' radical innovation performance.

This paper contributes to the literature on radical innovation (Bers et al., 2009; Duysters & Lokshin, 2011; Flor et al., 2018; Ismail et al., 2022; Song & Thieme, 2009; Torres de Oliveira et al., 2022) and open innovation (Bouncken et al., 2018; Chesbrough, 2004; Ritala et al., 2018; Torres de Oliveira et al., 2022; Trąpczyński et al., 2018; van Beers & Zand, 2014; Zhu et al., 2019) by providing both a theoretical and empirical understanding of how functional and geographical diverse collaboration portfolios affect radical innovation performance within a relation that presents an inverted U-shape. In doing so,

we also contribute to the existing literature on partner selection by discussing the role of partner characteristics to consider potential complementarities and synergistic effects (Capaldo & Petruzzelli, 2014), while also accounting for the costs involved. In addition, our study provides a deeper understanding of the differences in the behaviour of SMEs and large firms in terms of the distinctness of their engagement in cooperation and ability to implement radical innovation (Carree et al., 2019; O'Connor & DeMartino, 2006; Shinkle & Kriauciunas, 2010; Verhees et al., 2010). We demonstrate that SMEs can benefit more from engaging in more varied functional R&D cooperation, although after a certain point the benefits tend to reduce with increasing diversity in the cooperation network.

The structure of the paper is as follows. In Section 2, we present the theoretical background and the research hypotheses. Section 3 explains the methodology, including the description of the data, variables and empirical strategy, while Section 4 shows the models and describes the main results obtained. Finally, Section 5 presents the conclusions, explains the main limitations of the study and provides some ideas for further research.

2. Theoretical background and hypotheses

Radical innovations integrate a large volume of new knowledge due to revolutionary modifications in processes and technologies (Flor et al., 2018). Radical innovation can be defined as an innovation that generates an entirely new set of performance capabilities in order to bring improvements to existing performances, as well as a reduction in cost (Bers et al., 2009; Flor et al., 2018; Song & Thieme, 2009). New innovative products allow firms to achieve market differentiation and improve their current performance (Ritala et al., 2018). In addition, as Bers et al. (2009) pointed out, radical innovations induce technological progress and determine some of the most important advances in society in fields such as medicine, transportation, power or information technology, among others. Overall, these breakthrough innovations contribute to scientific development, economic growth and improvements in the quality of human life. To illustrate, in the context of the COVID-19 pandemic, it has been possible to develop and launch a novel vaccine, based on mRNA, thanks to the cooperation between companies such as Pfizer and BioNTech that have provided complementary resources and technologies. Thus, studying the mechanisms (e.g. external collaborations) that may help firms succeed in this process is

crucial, given its benefits not only for companies but also for society as a whole. Unfortunately, this long-term, risky and unpredictable process does not always bear fruit, to society's detriment (Bers et al., 2009). Radical innovations can have unclear technical or market outcomes, along with uncertainty between actions and results (Shaikh & O'Connor, 2020). Moreover, achieving radical innovation entails higher risks, and requires more tacit knowledge (Forés & Camisón, 2016) and a significant transformation of existing organizational structures, processes and foremost resources (Colombo et al., 2017). Overall, given its implications for firms and society, and due to the mixed evidence on how to obtain successful results, this topic requires further attention.

From the stance of firms' KBV, the obtaining, assimilation and implementation of relevant knowledge is critical to gain competitive advantages, and in turn improve firms' innovative performance (Grant, 1996). Along these lines, the open innovation literature (Bouncken et al., 2018; Chesbrough, 2004; Zhu et al., 2019) has emphasized that external knowledge sourcing has become a critical process for firms to develop and profit from innovations (Berchicci, 2013; Brunswicker & Vanhaverbeke, 2015). Hence, inter-organizational cooperation as a part of the external sourcing strategy becomes a powerful tool to enhance the development of new products (Bouncken et al., 2018). In other words, cooperation helps firms scan the competitive markets, develop new knowledge and ideas, and consequently pursue radical innovations (Ritala et al., 2018). In this realm, integration within different innovation networks allows firms to effectively structure their search for new knowledge and gain access to different technologies that can help them improve their innovative performance and competitiveness.

Cooperation with a diverse set of partners makes the firm more productive in innovation processes by increasing the learning of innovation skills (van Beers & Zand, 2014) and the acquisition of new knowledge (Hagedoorn et al., 2018). Extant research suggests that different innovation collaboration portfolios (i.e. in terms of partners and location diversity) can have different effects on firms' innovation performance (Sarpong & Teirlinck, 2018; Trąpczyński et al., 2018; van Beers & Zand, 2014). Diversity is related to the breadth of various types of partners (i.e., functional diversity) or the geographic areas in which partners are active (geographical diversity).

The functional breadth of collaboration allows firms to obtain access to richer information and knowledge combinations from partners, thereby accelerating the propensity to

innovate (Haus-Reve et al., 2019). For instance, cooperation with suppliers and customers provides relevant information on technologies, markets and customer needs, while cooperation with competitors is used in order to share risks and information about regulation (Badillo & Moreno, 2016; D'Agostino & Moreno, 2018). Regarding cooperation with universities and research centers, firms may access specialized infrastructures and equipment (Giannopoulou et al., 2019). Hence, firms with more specialized knowledge obtained from different partners have a greater chance of introducing brand new innovations. In addition, accessing foreign knowledge through the geographical scope of collaboration helps firms to adapt to local needs and regulations, procure highly skilled employees and gain external knowledge (Duysters & Lokshin, 2011), all of which are needed in order to facilitate radical innovation. As certain scholars have highlighted, collaboration networks that involve partners from diverse geographical locations are key to increasing knowledge diversity and the recombination of heterogeneous valuable inputs that firms need to produce the latest technological developments (Patel et al., 2014). Nevertheless, and although currently Information and Communication Technologies also facilitate cross-border knowledge management and innovative activities (Bolívar-Ramos, 2019), it is certain that too much diversity among the partners in the cooperation portfolio can be detrimental to the development of radical innovation outputs. This is because the greater the geographical distance among partners, the greater the difficulties to coordinate, acquire tacit knowledge, interact repeatedly and establish effective interactions due to cultural barriers (Ardito et al., 2019), which may hinder knowledge transfer, integration and exploitation into radically new products.

In line with previous arguments, there is evidence that increasing cooperation diversity may perform well up to a certain point. After this, the marginal costs of diversity tend to be superior to the expected advantages due to the increased complexity (Duysters & Lokshin, 2011). This view is also shared by Laursen and Salter (2006), who point out that although the breadth and depth of information sources improves innovation, there is a tipping point after which "over-search" in the breadth of open innovation may hinder innovation performance. Starting from this premise, and being more concrete in terms of the diversity of partners, current research has tried to clarify how the functional and geographical breadth of collaboration portfolios affect firms' radical innovation performance. In this sense, Carree et al. (2019), after analyzing a panel database of 3536 Dutch manufacturing firms, provided evidence of the existence of an inverted U-shaped

relationship between the breadth of R&D cooperation and firms' radical innovation performance. Moreover, they explored how firm size and the level of internal R&D-intensity moderate this relationship. The authors concluded that small and low R&D-intensive firms usually benefit more from R&D collaborations than their larger counterparts, despite these benefits also tending to decrease more rapidly when the number of types of collaboration partners increases. Despite the valuable insights of this study, the research did not explore the separate effects of the functional breadth of collaborations and the geographical scope of the cooperation portfolio. This extreme was considered by Sarpong and Teirlinck (2018), who investigated the differential effects of geographical, functional and hierarchical cooperation portfolios on firms' innovative output, although their study proposed linear relations between cooperation diversity and innovation output. In particular, they found that the diversity in the type and geographical spread of partners is positively associated with the introduction of innovations that are new-to-the-market. Also shedding some light on this topic, Delgado-Márquez et al. (2018) analyzed the effects of the functional and geographical breadth of networks on firms' radical innovation performance, proposing inverted U relationships. While they focus their attention on multinational and subsidiary inter-organizational networks, their study did not account for the differences between SMEs and large firms.

To summarize, past research on the effects of R&D collaboration has often found a curvilinear relationship (inverted U-shape) between the functional breadth of the collaboration portfolio and firms' radical innovation performance (Bayona-Sáez et al., 2017; Carree et al., 2019; Delgado-Márquez et al., 2018). However, inconclusive results persist, as explained. In addition, assessing how firm size may affect these relationships, as a contingency that clearly affects innovation activities, including knowledge search and its recombination (Messeni Petruzzelli et al., 2018), has been scarcely explored. As suggested by past research, SMEs and large firms differ in their engagement in cooperation and ability to introduce new knowledge and innovations (Carree et al., 2019; Shinkle & Kriauciunas, 2010; Verhees et al., 2010). Often, the difference between large firms and SMEs relates to their strengths; it follows that smaller firms typically have behavioral advantages, whereas large firms possess resource advantages (Nieto & Santamaría, 2010). SMEs have advantages in their organizational flexibility in communication and a faster market reaction. However, they may lack sufficient financial

resources and possess less experience in cooperation than large firms (Jang et al., 2017). Thus, tackling their differences becomes a critical aspect.

2.1 Functional breadth of the collaboration network and radical innovation performance

Past literature highlights that the open innovation process that provides knowledge from different partners and sources is a topic that has received increasing attention in the field of innovation management over the last decade (Popa et al., 2017). In terms of the KBV, relevant partner diversity facilitates various knowledge sharing mechanisms that may be associated with firm innovation performance (Hagedoorn et al., 2018). Functional partners typically include clients, suppliers, competitors, universities and private or public research centers (Sarpong & Teirlinck, 2018). Functional collaborations foster the acquisition of information and knowledge that are not available within the firm concerning different functional areas, such as customer demand and needs, market requirements or technological information about a product (Kobarg et al., 2019). Engaging in functional cooperation with different partners allows firms to gain access to knowledge that is more specialized and exceptional (Hagedoorn et al., 2018), thus increasing their chance to introduce brand new innovation, thanks to the recombination of this knowledge.

Moreover, functional partner diversity is important at different stages of the innovation process (Veer et al., 2016). For instance, at earlier stages, functional cooperation increases access to alternative concepts from competitors and valuable feedback from customers that might help firms in improving their existing strategy and processes. Furthermore, cooperation with universities, laboratories and research institutions can provide firms with new scientific and technological knowledge (Zeng et al., 2010). At later stages, firms might need the necessary financial and managerial resources in order to adapt to radical technological change (Rothaermel, 2001). Thus, cooperation diversity with various partners can facilitate the process of adopting new knowledge inputs. At all stages, it may lead to increasing radical innovation performance.

Nevertheless, the functional diversity in the collaboration portfolio may also bring negative effects after a certain point. A rising number of cooperation partner types generate growing managerial information demands and, consequently, transaction costs

(Rothaermel, 2001), which may lead to a negative effect. Consequently, the broader the functional diversity in the collaboration portfolio, the more likely the costs will outweigh the benefits after a certain point, resulting in a reduction of radical innovation efforts. Moreover, Veer et al. (2016) suggest that firms may also find it challenging to concentrate their efforts evenly among different partners. This could lead to a longer feedback cycle and a slower reaction to changes.

Based on these ideas, we propose the first hypothesis:

Hypothesis 1. There is an inverted U-shape relationship between the functional breadth of the collaboration portfolio and firms' radical innovation performance.

2.2. Geographical diversity of the collaboration network and radical innovation performance

Geographical diversity relates to the regional scope of the cooperation network, where firms collaborate with partners across different geographic locations (Shi & Weber, 2018). Past studies suggest that both geographical openness and the establishing of networks outside their area of activity affect firms' productivity and allow them to enhance their innovation performance (Belderbos et al., 2013; Jespersen et al., 2018; Sarpong & Teirlinck, 2018). In a geographic context, in order to choose the most appropriate partner, firms can rely on the physical, institutional or cultural distance between actors to evaluate this decision (Ardito et al., 2019; Capaldo & Petruzzelli, 2014). As Jespersen et al (2018) mention, the smaller the distance between the partners, the more efficient the informal interactions that lead to facilitating knowledge sharing and open innovation. However, on the other hand, local networks may create undesired spillovers and knowledge lock-in effects that hinder radical innovation (Capaldo & Petruzzelli, 2014).

In recent years, due to improvements in telecommunications as a result of technological progress, firms have been able to obtain more diverse specialized knowledge inputs from various appropriate networks, even though partners may be located across the globe. The utilization of dynamic capabilities of partners and advanced technologies like Zoom or Skype has enhanced international collaboration. This collaboration has the potential to drive innovation by enabling firms to acquire richer knowledge sources. Companies are actively participating in international collaboration to not only catch up with the

technological frontier but also surpass it (Fu et. al, 2022, Fu & Li, 2016). Thus, it can be expected that the more diversified the range of geographical areas, the more likely innovative firms will acquire the necessary information and knowledge required. This can subsequently lead to more fruitful combinations of complementary knowledge and improvements in firms' radical innovation performance (van Beers & Zand, 2014). In other words, a diverse geographical portfolio of R&D partners allows firms to gain access to a wider range of new knowledge, ideas and technologies, as well as market information that the firm needs. Moreover, the openness to new ideas and technologies from different locations might provide more flexibility to carry out innovation. Thanks to cooperating with partners in different locations, firms can access markets that are entirely new, thereby extending their production process (Dittrich & Duysters, 2007), and possibly facilitating radical innovation. In addition, through geographical diversity in collaborations, firms can adapt faster to local market needs, getting access to highly skilled staff, and obtain valuable knowledge about regulations in this location (Duysters & Lokshin, 2011).

However, firms' ability to obtain, absorb and adopt the new knowledge required to solve different problems is also crucial (Zahra & George, 2002) at all stages of collaboration. It can be argued that a cooperation portfolio in which there are broad cultural differences across partners may be a key barrier to technology transfer (Elia et al., 2019). Further, geographical distance decreases face-to-face contact, repeated interactions and greater opportunities to strengthen social relationships, which may reduce the benefits of geographic network diversity to foster the development of novel products (Bolívar-Ramos, 2019; Capaldo & Petruzzelli, 2014). Thus, a high geographical diversity may negatively affect ideas and knowledge spread, as it may cause a situation in which technologies and other inputs become too diverse (Beretta, 2019), creating exploitation problems. Further, there is a chance that employees cooperating in different locations may have different levels of experiences and cultural values (Zhang et al., 2020). This also increases coordination costs between partners from different locations, which negatively affects the process of adopting new knowledge and radical innovation performance.

Based on these findings, we expect there to be a curvilinear relationship between the geographical scope of the cooperation network and a firm's radical innovation performance, in such a way that the geographical diversity in the portfolio brings gains to firms, but after a certain point in which diversity is too high, it has a negative effect. Thus:

Hypothesis 2. There is an inverted U-shape relationship between the geographical scope of the collaboration portfolio and firms' radical innovation performance.

2.3 The moderating role of firm size on the relation between the functional/geographical diversity of collaborations and firms' radical innovation performance

Previous studies have shown that firm size is a factor that plays a crucial role in innovation activities (Petruzzelli et al., 2018; Nieto & Santamaría, 2010; Spithoven et al., 2013; Wang et al., 2015). Engaging in collaborations to obtain information and knowledge in SMEs may differ from that of large firms (Chiambaretto et al., 2020; Verhees et al., 2010). According to Popa et al. (2017), more severe resource constraints in SMEs may be a strong barrier to the adoption of open innovation practices, including cooperation with different partners. On the other hand, as SMEs may have a greater gap in human, financial and other resources, this fact may increase their enrollment in the diverse types and locations of cooperation. It is also plausible that large firms can take greater advantage of a more solid reputation and experience in cooperation networks with different partners (Shinkle & Kriauciunas, 2010). This, in turn, allows them to obtain specialized skills and knowledge through various cooperation portfolios to a greater extent than smaller firms. In addition, SMEs are likely to have higher marginal costs when operating in external collaborations, compared to larger firms (Carree et al., 2019). This links with the idea that larger firms already have established processes and may have sufficient financial resources to bear coordination costs.

Regarding functional cooperation, Jang et al. (2017) pointed out that SMEs tend to select partners related to development stages, while large firms prefer to cooperate with partners related to explorative stages and partners focused on the search for new technologies. Commonly, in their open innovation practices, due to their lower flexibility, larger firms may face greater challenges to keep pace with market changes during their establishment of networks with additional suppliers and competitors (Petruzzelli et al., 2018). However, on the other hand, large firms' past cooperation experiences and higher absorptive capacity can help to explain their ability to introduce radical innovations. In other words, larger firms may have a higher likelihood of implementing and exploiting diverse functional resources and benefiting from them due to their strong resource base and

bargaining power, which ensures relevant networks (Jang et al., 2017). Despite this, it could still be plausible that SMEs have a higher propensity to cooperate with more diverse partners in order to overcome the liability of newness and the financial and knowledge constraints required to innovate (Bolívar–Ramos, 2019). Further, SMEs are usually more flexible and can rapidly change processes in order to adopt radical innovations (O'Connor & DeMartino, 2006). Moreover, SMEs may benefit from broader collaboration networks aiming to achieve economies of scope and scale (Jespersen et al., 2018). Although small firms may lack sufficient financial resources and possess less experience in cooperation than large firms (Jang et al., 2017), SMEs' greater freedom from bureaucracy, smoother communications between managers and employees, and increased entrepreneurial orientation promoting innovative ideas creates a favorable environment in which to take advantage of more novel knowledge to facilitate valuable innovations (Petruzzelli et al., 2018), thus supporting radical innovations.

Despite the benefits of functional diversity in SME and large firm collaborations, an overly diverse cooperation portfolio may bring negative effects due to unwanted knowledge leakage, difficulties with control and communications, and costs related to imitation issues (Veer et al., 2016). In this context, even though SMEs may be in a weaker position in terms of their existing experience in cooperation and developed resource bases, compared to large firms they may have a stronger motivation to engage in more diverse functional cooperation portfolios to overcome their newness and lack of resources, therefore requiring a more diverse network in order to achieve their best level of radical innovation performance. We contend that for SMEs it may be easier to benefit from heterogeneous functional partners providing innovative competences because of their flexibility and adaptability to the new environment. However, SMEs may also suffer more when the functional breadth of collaboration becomes too diverse due to the absence of the necessary resources in order to adopt new information flows. Thus:

Hypothesis 3. The relationship between the functional breadth of the collaboration network and firms' radical innovation performance is moderated by firm size, in a way that SMEs have a higher optimal number of functional partners than large firms.

In terms of the geographical scope of the collaborations, large firms have financial and resource advantages that afford them the ability to cooperate with partners from different locations. As they may also possess more highly skilled employees, including scientists

and engineers (Carree et al., 2019), larger firms are more likely to better understand the cooperation process, recognize the value of unexploited knowledge (Petruzzelli et al., 2018) and facilitate the knowledge absorption from different locations in order to implement radical innovation. However, large firms' established routines and their bureaucratic structure is a factor that usually hampers their chances of benefiting from valuable novel knowledge for radical innovations (Petruzzelli et al., 2018). Thus, despite large firms may be better positioned to gain access to broader geographical networks, the resource constraints can motivate SMEs to engage with more diverse geographical partners in order to compete in different international markets (Dooley et al., 2016). Moreover, SMEs may have a higher propensity to diversify the geographical scope of collaborations for overcoming local constraints. In this way, SMEs can relocate activities into low-cost locations (Lejpras, 2015) and enter new markets. In addition, despite new markets potentially presenting different culture specifics, SMEs may possess more flexibility and ability to adapt to the new environment. Further, despite distance being a factor that can negatively affect SMEs' innovation activities (Capaldo & Petruzzelli, 2014), the actors (e.g. scientists) involved in partnerships for developing radical outcomes can easily collaborate beyond national frontiers thanks to their use of new technologies and standard and common codes (e.g. publications) (Bolívar-Ramos, 2019)

To summarize, when the geographical scope of the collaboration network is too broad, the knowledge inputs become too diverse, and business relations tend to be even more complex due to greater geographic and cultural differences (Capaldo & Petruzzelli, 2015; Elia et al., 2019). In this sense, SMEs may face a larger challenge due to coordination costs when managing different partners (Zhang et al., 2020). Nevertheless, in the case of large firms, it may be more difficult to adapt to any additional geographical network due to their organizational rigidities, in comparison to SMEs. Building on these diverse ideas, we expect that due to their higher needs of heterogeneous resources to favor knowledge re-combinations, greater flexibility and ability to adapt to new environments and develop nascent technologies, SMEs may rely on higher geographical diversity in collaboration networks to foster radical innovations compared to large firms. Nevertheless, this will occur up to a certain point at which increased communication with partners of dissimilar cultures, along with different backgrounds, is likely to negatively interfere in SMEs' management of the innovation process.

Hypothesis 4. The relationship between the geographical scope of the collaboration network and firms' radical innovation performance is moderated by firm size, in such a way that SMEs have a higher optimal number of geographic areas in the portfolio than large firms.

3. Methodology

3.1 Data

For our empirical analysis, we use the PITEC (*Panel de Innovación Tecnológica*) database, a panel of firms annually surveyed by the Spanish National Statistics Institute (*INE*) up to 2016, consistently with the Community Innovation Survey (Mendi et al., 2020). Spain is an appropriate setting for our study as it is a member of the European Union and represents a suitable environment for the research and study of technological and innovation activities (Coad et al., 2021; Delgado-Márquez et al., 2018). Regarding the use of PITEC, it is a database that follows the methodology of the OECD countries, provides information on more than 12,000 firms concerning their strategies and innovation activities and has been widely used by researchers to address the relation between cooperation and innovation (Delgado-Márquez et al., 2018). More generally, PITEC is designed to analyze the economic development and technological activities of Spanish manufacturing and services firms (Mavroudi et al., 2020). Notably, the database allows the analysis of the dynamics of innovation as it has a panel structure (Coad et al., 2021), that permits controlling for firm-specific, unobserved factors that may jointly affect the outcome and the independent variables (Mendi et al., 2020).

As discussed, in this research we test the inverted U-shape models and moderator effects using PITEC, focusing on the period 2012-2016. PITEC provides comprehensive information concerning firms' technological and innovation activities (Cruz-Castro et al., 2018), including the functional types of cooperation and firms' regional characteristics. One of the main advantages of using this database is that it allows for partial control over potential endogeneity issues by introducing lags between independent and dependent variables (Badillo & Moreno, 2016). Another advantage of using this database is the possibility of distinguishing between innovating and non-innovating firms (Carree et al., 2019), based on whether the firm has introduced (or not) new or developed innovations. Moreover, PITEC includes information about internal and external R&D activities,

product outcomes and different obstacles to innovation, as well as other variables that are required to test the hypotheses proposed. Finally, the analysis is restricted to the sample of firms that present innovation expenditures over the period 2012 to 2016 (Tamayo & Huergo, 2017); 4677 firms. This period was chosen for analysis as it directly followed the economic and financial crisis of 2008–2011, which was characterized by market instability and recession (Martin-Rios & Pasamar, 2018).

3.2. Variables and measures

Dependent variable

Radical innovation performance reflects the ability of the firm to produce radical innovations and shows how well a firm succeeded in introducing a new product to the market. Radical innovation represents completely new products and services in order to meet customer needs (Shi & Zhang, 2018). It is measured as the ratio of sales from products that are new to the market over total sales; a similar approach was used in previous studies (Delgado-Márquez et al., 2018; Carree et al., 2019). Moreover, in order to avoid simultaneity problems, the dependent variable is introduced with a *t+1* year lag (Cinyabuguma et al., 2005).

Independent and moderator variables

Functional breadth of collaborations. The combination of diverse partners in collaboration networks generates synergies and facilitates research productivity, thereby increasing the likelihood of introducing new knowledge that may be hard for rivals to replicate (Sarpong & Teirlinck, 2018). The functional breadth of collaborations was measured as the breadth of different partners with whom a firm cooperates (Delgado-Márquez et al., 2018). The functional breadth of collaboration includes: (1) suppliers (2) clients from the private sector (3) clients from the public sector (4) competitors (5) suppliers of software (6) laboratories (7) universities (8) public research institutions and (9) private research institutes. Hence, this variable takes values ranging from 0 if a firm did not cooperate with external partners, up to 9, when a firm collaborated with all categories of functional partners.

Geographical scope of collaborations. This variable considers information about different geographical regions, where firms intensively cooperate in the development of innovation activities. The geographical scope of collaborations was measured as the

breadth of different geographical regions in which firms cooperate (Delgado-Márquez et al., 2018). The Spanish innovation survey includes five different regions: (1) Spain (2) Europe (3) the United States (4) China and India, and (5) all countries mentioned. Thus, the geographical scope of collaborations is a variable with values ranging from 0 to 5 depending on the number of different geographical locations included in firms' network. A value of 0 reflects that a firm did not cooperate with any partners, and a value of 5 indicates that the firm cooperated with partners from each of the five aforementioned different locations.

Size. Consistent with past research, this variable is measured as the logarithm of firms' total number of employees (Tamayo & Huergo, 2017). In this study, firm size is the moderator variable, in line with arguments that suggest that large firms and SMEs have different abilities to access key resources and undertake radical innovation (Cheng et al., 2016).

Control variables

Product innovation. This variable has traditionally been associated with positive effects on company success and competitiveness (Naranjo-Valencia et al., 2017). In this study, it is measured as a dummy variable equal to one if the firm introduced a product innovation at least once during the period analyzed (and zero otherwise).

Process innovation. In this study, this was measured as a dummy variable equal to one if the firm introduced a process innovation at least once during the period analyzed (and zero otherwise).

Knowledge, market and financial constraints. Firms may face different challenges, constraints and uncertainty about future market opportunities. These may induce firms to reduce their investments in innovation (D'Agostino & Moreno, 2018), including radical innovations. Constraints can include lack of knowledge and information on technologies, financial constraints and high barriers to market entry (Pellegrino, 2018). This study included knowledge, market and financial constraints as three binary variables, where one reflects that a firm faced each particular constraint, and zero otherwise.

Public support. Firms may need the external help of institutions and governments in order to overcome the scarcity of financial resources and foster open innovation. The public support variable is computed as the breadth of funding sources (Chapman et al., 2018) in

order to assess the support the firm receives from European Union offices, local or regional administrations and the national government.

Internal R&D. Benefits from technological cooperation and further innovation performance depends on the absorptive capacity of the firm (Lopez, 2008). This is captured by the logarithm of internal R&D expenditures of the firm.

Number of patents. The patents variable is measured by the logarithm of a firm's total number of patents, as in previous research (Mendi et al., 2020). Even though patents can be costly, firms that produce new knowledge may increase their chances of developing patentable inventions in order to secure new knowledge as a result of imitations (Sudipto Bhattacharya et al., 2014), which can also condition their innovativeness.

Technology Park. This binary variable indicates whether a firm is located in a Science or Technology Park, which can have an effect on firms' innovation performance due to location advantages.

Tech sectors. As in Cruz-Castro et al. (2018), this variable is presented by dummies that represent all the economic activities in the manufacturing sector, according to CNAE2009 (the Spanish acronym for Spain's National Classification of Economic Activities).

Year. This variable represents the current year in which firms operate, and its inclusion helps to control for changing macroeconomic conditions over time (Nieto & Rodríguez, 2011).

3.3. Empirical strategy

Table 3.1. reflects the correlation matrix and the summary statistics for the research variables. As can be observed, the correlation is low between the main independent variables and radical innovation, and the results are statistically significant.

Table 3.1. Descriptive statistics and correlation matrix

Variables	**Mean**	**SD**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
Radical innovation performance (1)	5.743186	7.210499	1.0000												
Product innovation (2)	.5867409	.4924328	0.3170*	1.0000											
Process innovation (3)	.2681399	.4430037	0.2392*	0.0427*	1.0000										
Knowledge factors (4)	.2025405	.4019045	0.0064	0.0191*	0.0097	1.0000									
Cost factors (5)	.5167914	.4997325	-0.0092	-0.0417*	0.0532*	0.1884*	1.0000								
Market factors (6)	.3216171	.4671105	0.0169*	0.0574*	0.0275*	0.2660*	0.2178*	1.0000							
Public support (7)	.7880633	.9099726	0.1433*	0.0250*	0.1719*	0.0414*	0.0837*	0.0445*	1.0000						
Internal R&D (log) (8)	12.55593	1.59886	0.2539*	0.1315*	0.1876*	-0.0269*	-0.0655*	-0.0262*	0.3990*	1.0000					
Number of patents (log) (9)	.2323149	.6112017	0.1720*	0.1282*	0.0744*	0.0023	-0.0093	-0.0017	0.2468*	0.3489*	1.0000				
Technology Park (10)	.0834058	.2765027	0.0409*	-0.0293*	0.1096*	0.0087	0.0491*	0.0299*	0.2289*	0.1661*	0.1168*	1.0000			
Functional breadth of collaborations (11)	.5879009	1.352385	0.2183*	0.1246*	0.2275*	0.0083	0.0269*	0.0232*	0.3770*	0.4215*	0.2956*	0.1386*	1.0000		
Geographical scope of collaborations (12)	.8551708	1.073445	0.2278*	0.1466*	0.2218*	0.0299*	0.0234*	0.0384*	0.4049*	0.4271*	0.2787*	0.1273*	0.7599*	1.0000	
Size (log) (13)	4.370006	1.520066	0.1634*	0.0900*	0.1162*	-0.0750*	-0.1659*	-0.0904*	0.1133*	0.5336*	0.1951*	-0.0384*	0.2442*	0.2536*	1.0000

To rule out multicollinearity problems, we computed Variance Inflation Factors (VIFs). Hair et al. (2012) indicate that, as a rule of thumb, VIFs higher than 5 reflect a sign of severe multicollinearity. The results displayed in Table 3.2. show that the study's VIFs are below the acceptable threshold. Hence, multicollinearity is not a problem in the research.

Table 3.2. Multicollinearity check

Variables	VIF	1/VIF
Process innovation	1.15	0.866520
Product innovation	1.14	0.877712
Knowledge factors	1.10	0.909526
Cost factors	1.11	0.898331
Market factors	1.12	0.889338
Public support	1.39	0.720483
Internal R&D	1.91	0.523360
Number of patents	1.20	0.832776
Tech park	1.10	0.912040
Functional breadth of collaborations	2.51	0.398493
Geographical scope of collaborations	2.57	0.389195
Size	1.52	0.656948
Mean VIF	**1.43**	

The methodology used in this study is conditioned by the nature of the dependent variable, radical innovation performance *RI* (measured in the period *t+1)*. In line with the study and the research hypotheses, we introduce four different models:

(1) Equation for Model 1 (Hypothesis 1).

$$RI_{t+1} = \alpha + \beta_1 FC_{it} + \beta_2 (FC_{it})^2 + \beta_3 FirmSize_{it} + \gamma X_{it} + \nu_{it}$$

(2) Equation for Model 2 (Hypothesis 2).

$$RI_{t+1} = \alpha + \beta_4 GC_{it} + \beta_5 (GC_{it})^2 + \beta_6 FirmSize_{it} + \gamma X_{it} + \nu_{it}$$

(3) Equation for Model 3 (Hypothesis 3).

$$RI_{t+1} = \alpha + \beta_7 FC_{it} + \beta_8 (FC_{it})^2 + \beta_9 FirmSize_{it} + \beta_{10}(FC_{it} \times FirmSize_{it}) + \beta_{11}((FC_{it})^2 \times FirmSize_{it}) + \gamma X_{it} + \nu_{it}$$

(4) Equation for Model 4 (Hypothesis 4).

$$RI_{t+1} = \alpha + \beta_{12} GC_{it} + \beta_{13} (GC_{it})^2 + \beta_{14} FirmSize_{it} + \beta_{15}(GC_{it} \times FirmSize_{it}) + \beta_{16}((GC_{it})^2 \times FirmSize_{it}) + \gamma X_{it} + \nu_{it}$$

In all models, *i* and *t* represent the identity of firms and the period considered (from 2012 to 2016), respectively. $FC_{i,t}$ represents the functional breadth of collaborations, which ranges from 0 to 9, as explained previously. GC_{it} considers the geographical scope of the collaboration network, which ranges from 0 to 5. Furthermore, $FirmSize_{it}$ is the moderator, measured by the logarithm of the number of employees employed by the firm. Further, the study includes a vector of control variables X_{it}; this accounts for product and process innovation variables, obstacles to innovation, patents number, internal R&D, public support, and sectoral and yearly dummies. Additionally, $\nu_{i,t}$, contains industry and time fixed effects. Finally, in Models 3 and 4, the interaction terms of firm size and the functional and geographical diversity in their cooperation portfolios were represented. $FC_{it} \times FirmSize_{it}$ represents an interaction term calculated by multiplying the functional breadth of collaborations and firm size, whilst $GC_{it} \times FirmSize_{it}$ represents the interaction term created by multiplying the geographical scope of collaborations and firm size.

In the next step, the Hausman test was applied in order to select between the fixed and random effects estimators. We ran the Hausman test for the proposed models. The rejection of the null hypothesis H0 assumes that there is a difference in fixed and random effects, therefore the fixed effect should be selected over the random effect (Frondel & Vance, 2010), as in this case.

4. Results

Table 3.3. illustrates the results for the four different models. Models 1 and 2 contain the results of the base models and help to test hypotheses 1-2. The rest of the models include different interaction terms in order to explore the moderating role of firm size, therefore analyzing hypotheses 3-4.

Considering the estimated parameters, in Model 1 the coefficients $\beta_1 = 0.398$ ($p < 0.05$) and $\beta_2 = -0.0689$ ($p < 0.05$) have the expected signs to support the curvilinear effect proposed, thus suggesting the existence of an inverted U-shaped relationship between the functional breadth of the collaboration network and firms' radical innovation, which provides empirical support for hypothesis 1. These results also confirm the idea that engaging in different types of functional cooperation increases firms' radical innovation performance, although it also brings negative effects after a certain point.

The next research hypothesis links the geographical scope of collaborations and firms' radical innovation performance. The results show that the coefficients $\beta_4 = 0.577$ ($p < 0.01$) and $\beta_5 = -0.155$ ($p < 0.01$), along with their significance levels, reveal the existence of an inverted U-shaped relationship. Thus, hypothesis 2 is supported, reinforcing the idea that engaging in geographically diverse cooperation networks enhances firms' radical innovation performance. Nevertheless, this only occurs up to a certain point at which innovation performance decreases, likely due to the increased complexity of managing diverse knowledge sources from different locations.

In Model 3, the estimated coefficients of $\beta_{10} = 0.216$ ($p < 0.05$) and $\beta_{11} = -0.0397$ ($p < 0.05$) confirm the moderating effect of firm size in the inverted U-shape relation between the functional breadth of collaborations and firms' radical innovation.

Table 3.3. Fixed-effects (FE) models. Dependent variable: radical innovation

	Model 1	**Model 2**	**Model 3**	**Model 4**
Control variables				
Product innovation	.679***	.661***	.682***	.661***
	(.184)	(.185)	(.184)	(.185)
Process innovation	.649***	.635**	.637**	.63**
	(.215)	(.214)	(.215)	(.214)
Knowledge factors	.063	.068	.055	.066
	(.233)	(.233)	(.233)	(.233)
Cost factors	-.266	-.269	-.257	-.27
	(.188)	(.187)	(.188)	(.187)
Market factors	-.018	-.019	-.019	-.018
	(.194)	(.194)	(.194)	(.194)
Public support	.173	.163	.179	.164
	(.125)	(.125)	(.125)	(.125)
Internal R&D (log)	.181+	.173+	.176+	.172+
	(.105)	(.105)	(.105)	(.105)
Number of patents (log)	.283+	.309+	.282+	.308+
	(.166)	(.166)	(.166)	(.166)
Technology Park	1.979*	1.924*	1.972*	1.919*
	(.806)	(.806)	(.802)	(.807)
Tech sectors	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Main variables				
Functional breadth of collaborations	.398*		-.702	
	(.182)		(.561)	
Functional breadth of collaborations Squared	-.0689*		.142	
	(.036)		(.117)	
Geographical scope of collaborations		.577***		.205
		(.195)		(.6)
Geographical scope of collaborations Squared		-.155**		-.118
		(.057)		(.163)
Size (log)	.439	.435	.43	.386
	(.356)	(.356)	(.36)	(.357)
Interactions				
Functional breadth of collaborations x Size			.216*	
			(.115)	
Functional breadth of collaborations Squared x Size			-.0397*	
			(.023)	
Geographical scope of collaborations x Size				.0819
				(.13)
Geographical scope of collaborations Squared x Size				-.00895
				(.033)
_cons	661.1***	659.4***	661.3***	659.4***
Observations	15209	15209	15209	15209
R-squared	.108	.107	.107	.107
F-stat	7.559***	7.945***	6.751***	6.978***

*+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001. Standard errors are in parentheses*

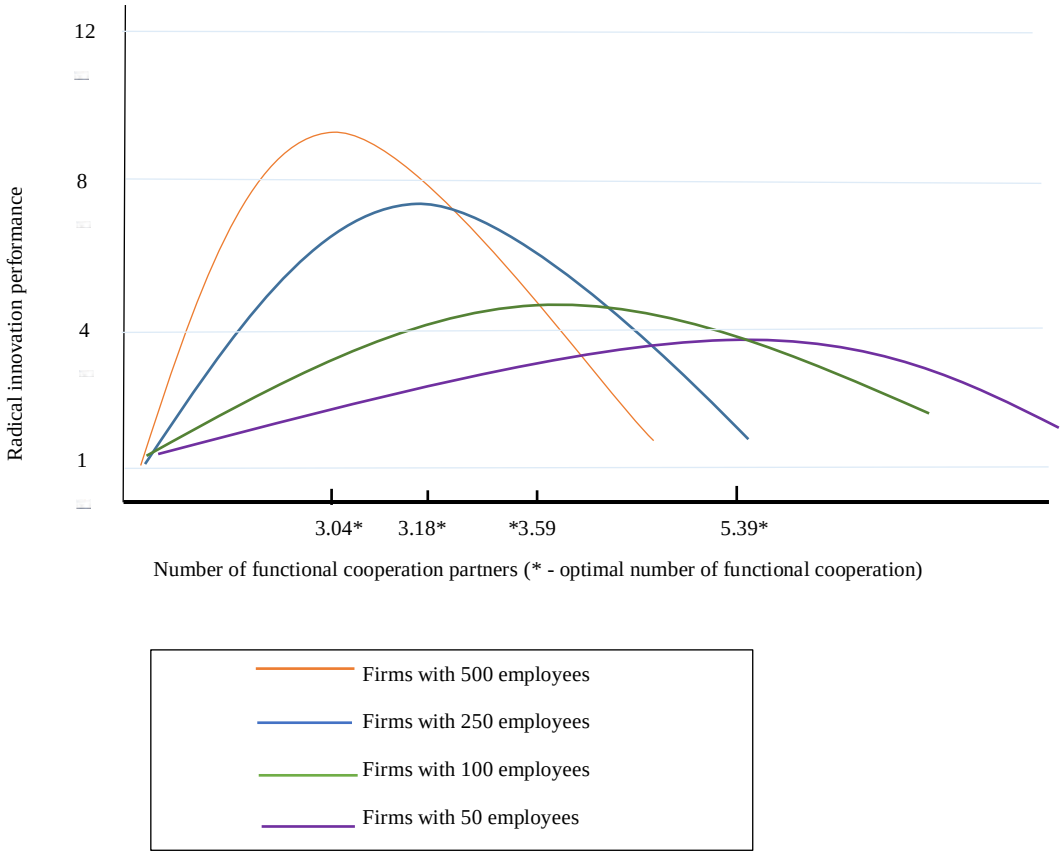
In order to calculate the tipping point after which the diversity in the breadth of collaborations has a decreasing effect on radical innovation, we followed the method used by Carree et al. (2019). First, we divided small and large firms depending on the number of employees working in the firm. A common approach in the literature is to define SMEs as those firms that have fewer than 250 employees; whereas large firms are those that possess more than 250 employees (Badillo et al., 2017; Moller et al., 2018). As size was computed as the logarithm of the total number of employees, we estimated the tipping point as a value of firm size. Second, the tipping point is calculated by using the formulas:

(5) Tipping point for the functional breadth of collaborations:

$$-0.5 \times \frac{\beta_7 + \beta_{10} \times \log\,(size)}{\beta_8 + \beta_{11} \times \log\,(size)}$$

Thus, the optimal number of functional collaborators for large firms with 500 employees is 3.04, whilst with 250 employees it is 3.18. In addition, the optimal functional breadth of collaborations for SMEs with 100 employees is 3.59 and 5.39 for SMEs with 50 employees. These ideas support hypothesis 3, in the sense that the smaller the firms are, the higher their optimal number of functional R&D partnerships for radical innovation. Figure 3.1. depicts these results.

Figure 3.1 Optimal number of functional cooperation partners for SMEs and large firms



Regarding Model 4, there is not empirical support for the moderating role of firm size on the relation between the geographical scope of collaborations and firms' radical innovation performance ($p > 0.1$ for coefficients β_{15} and β_{16}). Thus, the results are not significant and hypothesis 4 is not supported.

Finally, before settling on the aforementioned results, additional robustness tests for the proposed models for alternative periods (available upon request) were conducted. The estimations show that the results largely remain the same for the key variables of the research.

5. Discussion and conclusions

The importance of using external knowledge, including cooperation, to increase innovation performance has been analyzed by numerous researchers in the field of open innovation (Cheng & Huizingh, 2014; Kang & Kang, 2009; Parida et al., 2012; Popa et al., 2017; Zhao et al., 2016). In turn, open innovation has become an effective driver to introduce new products. Thanks to opened boundaries to external knowledge flows, firms

can facilitate the acquisition of valuable knowledge and technologies in order to enhance radical innovation (Cheng et al., 2016).

Constantly advancing technologies, economic globalization and increasing competitiveness justify the importance of diversifying the cooperation portfolio as a key external search strategy to responding to fast-changing environments and introducing new knowledge and products to the market (Nieto & Santamaria, 2010; van Beers & Zand, 2014). Along this line, past research shows that different innovation collaboration portfolios affect firms' innovation performance differently (Sarpong & Teirlinck, 2018; Trąpczyński et al., 2018; van Beers & Zand, 2014). Nevertheless, previous studies have not paid significant attention or provided sufficient theoretical and empirical evidence regarding the different impacts of the functional breadth of collaboration and the geographical scope of collaborations on firms' radical innovation performance. Thus, this study has examined this research gap by analyzing how the functional and geographical breadth of the cooperation portfolio affect firms' radical innovation performance. This investigation reveals that engaging in diversified functional and geographical cooperation enhances firms' radical innovation performance, although innovation returns decrease after a certain point at which the diversity of partners is too high.

5.1. Theoretical, managerial and policy implications

Under the framework of the KBV, this study emphasizes the significance of acquiring, assimilating, and implementing relevant knowledge to enhance firms' competitive advantage and innovative performance. The research is inspired by the open innovation literature, which highlights the importance of collaborating with external partners such as customers, suppliers, and stakeholders to co-create new products, services, and processes. Leveraging external knowledge sources allows firms to access a wider range of ideas and expertise, reducing the risks and costs associated with internal R&D efforts (Badillo & Moreno, 2016; Cheng et al., 2016). This paper makes a valuable contribution to the open innovation literature (Chesbrough, 2004) and the selection of relevant partners, by elucidating the impact of the diversity in collaboration portfolios, both in terms of functional aspects (such as customers, suppliers, etc.) and geographical aspects (such as national and international) on the firms' radical innovation performance, proving the existence of inverted U-shape relationships.

Another contribution of this study consists of shedding some light in terms of how SMEs and large firms diversify their cooperation portfolios and benefit from it for radical innovation. In particular, we found that firm size moderates the relations between the functional breadth of collaborations and radical innovation performance, in the sense that SMEs tend to have a higher number of collaboration partners compared to large firms. The literature has presented contradictory arguments, since larger firms may have more diverse functional collaboration portfolios and a greater ability to exploit diverse resources, thanks to their strong resource bases (Jang et al., 2017). As suggested by Carree et al. (2019), SMEs are less able to manage the increased diversity of cooperation because of the limited resources and higher marginal costs of managing an additional partner. However, the results of this research suggest that SMEs have a higher propensity to diversify their cooperation portfolio in terms of functional partners, likely due to their higher flexibility and openness, which is required to overcome their lack of internal resources (Nieto & Santamaria, 2010; O'Connor & DeMartino, 2006). These different results may be explained by the fact that this research accounts for the differences between the functional and geographical diversity of partners, whereas previous studies addressed this issue from a unified perspective.

From a managerial point of view, this research highlights that paying more attention to proper partner selection allows firms to establish more effective partnership relationships and benefit from its diversity. In other words, firms should seek partners that complement their functional characteristics and involve a certain degree of internationalization (but not excessively so) to generate the knowledge that would allow them to produce radical innovative outcomes. Moreover, the paper emphasizes the significance of balanced diversity in functional and geographical collaboration portfolios in order to favor innovation output, including radical innovation. To be more precise, this study guides managers trying to balance diversity in firms' collaboration portfolios, as even though increasing the functional breadth of the collaborations and their geographical scope may benefit firms' radical innovation performance at the beginning, this can be a disadvantage after a certain point. Hence, managers should take into account all the risks and costs incurred in order to avoid engaging in overly diverse functional/geographical collaboration networks. Further, this study draws a line between the optimal number of functional partners in cooperation portfolios for SMEs and large firms. Managers should consider the fact that SMEs and large firms behave differently, given their respective

levels of resources, experience and flexibility. For instance, to introduce radical innovation, SMEs may have a greater need to diversify their functional cooperation portfolios in order to gain access to alternative concepts from competitors and receive valuable feedback from customers, which might help firms in improving their existing strategies and processes. Therefore, SMEs can benefit more from the functional diversity of collaboration portfolios. However, SMEs also have to pay greater managerial attention to balancing these types of networks, as they usually have fewer assets with which to adopt new information flows.

5.2. Limitations and future research

Despite all the implications and contributions mentioned, this paper is not exempt from limitations that open new opportunities for further research. First, in this analysis we only considered Spanish firms. Future studies could compare the relations between the diversity in open innovation networks and its effects on firms' radical innovation in Spain versus other countries, to analyze if the results are consistent in different geographical contexts. Second, the study does not analyze a number of other potential moderators that could also affect the relations between radical innovation and the functional and geographical scope of collaborations. To illustrate, given that the absorptive capacity defines firms' ability to identify, absorb and exploit external knowledge (Zahra & George, 2002), exploring this variable as a moderator may enhance our understanding of how firms benefit from diverse cooperation networks for innovating, according to their internal capacity. Finally, for theoretical reasons (i.e. radical innovations are new to the market) the study fails to tackle the distinction between radical and incremental innovations. However, diversity in cooperation portfolios may also have different effects on firms' ability to introduce incremental innovations; a topic that future research may address.

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CHAPTER 4

THE EFFECTS OF INTERNATIONAL EXPLOITATIVE AND EXPLORATIVE COLLABORATIONS ON ECO-INNOVATION IN SMEs AND LARGE FIRMS

Abstract

Nowadays, there is an increasing political and social awareness of the importance and significance of sustainable innovations development. Environmental concerns for innovation are becoming more and more common as firms are increasingly being pressured by different stakeholders that require firms to address environmentally related issues. This paper contributes to the literature of eco-innovation and international collaborations by providing theoretical and empirical evidence on how both SMEs and large firms benefit from the knowledge sources international partners provide, for explorative and exploitative purposes, in order to gain competitive advantage by means of the development of environmental innovations. To achievethis goal, an empirical study using the Community Innovation Survey (CIS) for the period 2012-2014 was conducted, based on data of SMEs and large firms from eleven European Union countries. This paper also provides managerial and policy implications to understand the importance of distinguishing the motivations of SMEs and large firms in order to be involved in collaboration with international partners and how they can benefit from it for eco-friendly innovative purposes.

Keywords

International collaborations, exploration, exploitation, eco-innovation, SMEs, large firms

1. Introduction

Eco-innovation growth and sustainable development are priorities for business and policy agendas in many countries around the world (Cecere et al., 2020; Ghisetti et al., 2015). To illustrate, since the Rio de Janeiro Earth Summit in 1992, the European Union has been taking different actions to address environmental problems, including policies implementationand subsiding research programs (Colombo et al., 2019). Remarkably, innovation and environmental research are key priorities of the Europe 2020 Strategy that defines sustainable growth as a main factor for the European Union to develop a more competitive, resource efficient andgreener economy (Cecere et al., 2020). As for the firm level, environmental concerns for innovation are becoming more common as firms are increasingly being pressured by local policy regulations, clients, and cooperation partners, among others, to address environmentally related issues (González-Moreno et al., 2019; Pirani & Secondi, 2011; Sáez-Martínez et al., 2014). As a result, there is an increasing political and social awareness of the importance of sustainable innovations development (Díaz-García et al., 2015).

Over the last decades, taking into account the dynamics of innovation with a sustainable perspective, the phenomenon of eco-innovation emerged in the literature (Pereira et al., 2020). In line with most definitions in past research, Calza et al. (2017) describe eco-innovations as "new products and processes, which provide customer and business value but significantly decrease environmental impacts" (p.3). In other words, eco-innovation can be defined as a new or modified product or process, which allows contributing to environmental sustainability and benefiting from it (Triguero et al., 2017).

While eco-innovation can bring its fruits, some businesses have been slow to substitute non-sustainable products and services with sustainable ones (Kahupi et al., 2021). One of the main reasons is that eco-innovation requires more knowledge inputs from heterogeneous sources in comparison with non-environmental innovations, because of the more multidisciplinary knowledge inputs they embed (Ghisetti et al., 2015; Triguero et al., 2017). It means that firms need to go beyond their core competencies and pay attention to key channels to access external knowledge sources (Ghisetti et al., 2015). Consequently, a critical aspect to promote eco-innovation is being open to external collaborations and the selection of relevant partners (Nieto & Santamaria, 2010; van Beers & Zand, 2014).

In particular, firms need to identify those partners that possess valuable expertise and knowledge on environmental activities (González-Moreno et al., 2019).

As we live in a global world, when firm's internal resources, competencies and incentives are not sufficient to introduce eco-innovation, firms are more likely to turn to inter-organizational collaborations with partners from all over the world, that provide richer knowledge inputs. This can be also explained because firms are increasingly being influenced to carry out environmental protection activities to respond local environmental policies as well as international environmental regulations (Juniati et al., 2019). Thus, international alliances are an important step to enhance the knowledge exchange across different countries (Corrocher & Mancusi, 2021). As the knowledge inputs are usually limited on a national level, firms may benefit more from the larger set of eco-oriented knowledge and technologies provided by international partners, consequently facilitating knowledge spillovers (Hottenrott & Lopes-Bento, 2014). This is why the importance of international collaborations for eco-innovation purposes has long been noted in the literature (Araújo & Franco 2021; Chang & Gotcher, 2020; De Marchi, 2012; González-Moreno et al., 2019; Pereira et al., 2020), thus representing the focus of this paper.

Nevertheless, we cannot ignore that firms may face some difficulties in their cooperation strategy design to achieve the goals set, resources allocation, and decision-making, considering both short-term and long-term objectives as well as different partners' motivations (Wen & Fang, 2018), especially when they come from other countries. Further, eco-innovation strategies do not only address the improvement or development of existing technologies, but also the development of completely new competencies and technologies (Faems et al., 2005). Thus, to provide a deeper explanation on how international collaborations may affect eco-innovation development, we also distinguish between different types of cooperations according to their purpose, depending on exploitation and exploration distinct models (Li et al., 2018; March, 1991). While exploitative collaborations are based on existing knowledge and complementary resources, explorative collaborations are focused on discoveries and completely new knowledge (Bolivar-Ramos et al., 2020; March, 1991). Accordingly, international exploitative collaborations includes cooperation with foreign customers and suppliers, while cooperations with international universities, research laboratories, and centers reflects the essence of international explorative collaborations (Faems etal., 2005).

As discussed, the process of developing eco-innovations can be very complex and drives the need for sourcing additional or completely new expertise from external partners (Spithoven et al., 2013). Depending on the level of internal resources, consumers' awareness, and international competitiveness, firms may have different motives to be engaged in cooperation beyond their boundaries (De Marchi, 2012), including international alliances. As SMEs and large firms differ in their organizational characteristics, separating collaboration motives in both of them is necessary to identify the specific outcomes for eco-innovation. While previous research on this topic has provided evidence on the positive role of international collaboration for eco-innovation (Chang & Gotcher, 2020; De Marchi, 2012; Pereira et al., 2020; Nielsen & Gudergan, 2012; Schachter et al., 2013) we still need to know more on how exploitative and explorative international collaboration distinctly affect eco-innovation due to their nature, while also taking into account the organizational differences between SMEs and large firms.

Based on previous arguments and research gaps, the main research questions this study tackles are: how do international exploitative and explorative collaborations affect eco-innovation? And do these effects differ in SMEs and large firms? To answer these questions, an empirical analysis using the Community InnovationSurvey (CIS) for the period 2012–2014, restricted to the data from 11 European countries, was carried out. The results show that international exploitative collaborations have a positive effect on eco-innovation in SMEs. Meanwhile the positive effect of international explorative collaborations on eco-innovation in SMEs is not supported. Moreover, we found that international explorative and exploitative collaborations have a positive effect on eco-innovation in large firms, where the focus is mainly on exploring new opportunities. In addition, we found that the positive effect of international exploitative collaborations on eco-innovation is stronger in SMEs than in large firms. Also, international explorative collaborations have a stronger impact on eco-innovation in large firms than in SMEs.

Overall, this study advances past research on the topics of eco-innovation and inter-organizational collaborations (Jové-Llopis & Segarra-Blasco, 2018; De Marchi, 2012; Pereira et al., 2020; Sáez-Martínez et al., 2016), by particularly addressing the role of international exploitative and explorative collaboration for environmental innovation. Thus, the research combines insights from the inter-organizational collaborations and

international business literatures for eco-innovation objectives. Further, the study also contributes to the literature by analyzing the differences between SMEs and large firms, and how they use their collaboration strategies to improve eco-innovative performance (Davciket al., 2021; Sáez-Martínez et al., 2014; Spithoven et al., 2013), thus examining the differences in innovative strategies due to the firm size (Jang et al., 2017). Finally, the research, under the framework of the Knowledge-Based View, provides theoretical and empirical evidence on how both SMEs and large firms benefit from the knowledge sources international partners provide, for explorative and exploitative purposes (March, 1991), in order to gain competitive advantage by means of the development of environmental innovations.

The structure of the paper is as follows. In section 2, we present the theoretical background and the research hypotheses. Section 3 explains the methodology, including the description of the data, variables, and empirical strategy. Section 4 shows the models and describes the main results, while section 5 explains the robustness check. Finally, Section 6 presents the conclusions, explains the main limitations of the study, and provides some ideas for further research.

2. Theoretical background and hypotheses

Eco-innovation allows customers and firms to shift to more sustainable practices and reduce negative environmental impacts (Zubeltzu-Jaka et al., 2018). In recent times, climate change awareness is boosting firms to develop products/services and adopt processes in an environmentally friendly manner (Avellaneda Riveraet al., 2018). That is why environmental responsibility is becoming one of the key strategies for firms (Torrecillas & Fernández, 2022). Eco-innovation is a way of integrating innovation and sustainability that can serve to achieve firms' growth and a better quality of life in society as a whole (Bossle et al., 2016). The desired outcomes become through decreasing pollution, environmental risks, and impacts of resources use (Pacheco et al., 2017). As a result, any time more and more customers are increasingly changing their behavior into sustainable practices, even if they have to pay additional costs for eco-friendly choices (Kim et al,. 2020). To illustrate, eBay Inc., one of the biggest e-commerce businesses, created an additional website, *green.eBay.com*, where it offered only products with environmental friendly attributes that can meet current demands (Bateman et al., 2017). Overall, firms can improve their performance thanks to eco-innovative activities, by

increasing product quality, corporate reputation, new customers and learning capabilities that promote differentiation (Bansal & Roth, 2000).

However, while addressing the development of eco-innovations, firms may face a lack of resources, appropriate organizational structure and effective management (Lee et al., 2018). Thus, firms engage in inter-organizational collaborations to fill internal resource gaps. In this sense, previous literature has largely suggested there is a positive effect of firm's collaborations on eco-innovation (Christensen et al., 2019; González-Moreno et al., 2019; De Marchi, 2012). In a relevant study in the field, De Marchi (2012) tackled the difference between cooperation types and their effects on eco-innovation. After considering vertical, horizontal and lateral cooperations, the interactions with suppliers, KIBS and universities were found to be the most relevant ones for environmental innovations development. In another study, González-Moreno et al. (2019) also emphasize the importance of relying on cooperation with stakeholders to improve environmental innovations by fostering knowledge sharing and transfer among partners. More specifically, these authors, after analyzing a sample of 279 firms in Spain, found that suppliers are the main source of knowledge used by these firms to develop eco-innovations.

Notably, knowledge and new technology creation processes in innovative firms has become upwardly global (Guridi et al., 2020), which also affects eco-innovative outcomes. Firms that are located in countries with less developed innovation strategies might face difficulties with exploiting and exploring eco-innovation because of a lack of resources and infrastructure, insufficient expertise, and weak integration into a global scientific network (Guridi et al., 2020). To make up for these constraints, firms collaborate with international partners to get new knowledge and facilitate eco-innovation adoption.

With a focus on an international setting, collaboration with international partners allows firms to learn about cleaner production systems or eco-innovative practices abroad, which gives firms new business opportunities for new products/processes launches (Torrecillas & Fernández, 2022). Moreover, international collaboration has an ex-post effect on the level of eco-innovation (Torrecillas & Fernández, 2022) and provides opportunities for the adoption of cleaner production and sustainability strategies (García-Quevedo et al., 2020). Apart from that,collaborations with international partners facilitates entering into

new foreign markets by fulfilling the ecological requirements of a specific country and by meeting the environmental needs of international consumers (Juniati et al., 2019). In contrast, despite all the benefits of collaboration with international partners, it is important to mention that diverse international partners come from different knowledge areas and locations, which may lead to situations of conflict, resulting in negative innovation performance including introducing new products such as eco-innovation (Cheng et al., 2016).

Past literature has theoretically and empirically addressed how international cooperation affects eco-innovative performance (Cainelli et al., 2012; Pereira et al., 2020; Torrecillas & Fernández, 2022). Pereira et al. (2020) found positive relations between international cooperation and eco-innovation in the sense that cooperation with international partners allows firms to access relevant knowledge flows from more environmentally oriented partners and adjust their processes to environmental standards. In another research provided by Cainelli et al. (2012), the importance of global collaboration was highlighted as a factor that promotes the adoption of environmental innovations in multinational firms. However, studies in this context, providing deeper explanations that consider simultaneously the role of internationalization and the nature of the collaboration (explorative versus exploitative) is still scarce; a research gap this paper aims to fulfil.

Eco-innovation, as an innovation in product or service, or business process that reduces environmental impact, is based on the transformation of business processes (Alos-Simo et al., 2020). Constant change in the competitive environment creates a growing need to search novel solutions but also adapt knowledge inputs. Striking the balance in these conditions is essentially difficult since exploitation and exploration strategies show considerable differences (Schildt et al., 2005).Many studies have analyzed exploitative and explorative innovations since the seminal work of March, (1991) that considered the relationship between exploitation of existing activities and exploration of new possibilities (Calantone & Rubera, 2012; Guan & Liu, 2016). On the one hand, *exploitation* activities are based on a firm's existing knowledge-base and strengthen its current competences, whereas *exploration* activities include firms' behavior directed towards new search, experimentation and discovery (Calantone & Rubera, 2012). Hence, in the literature, exploitative collaborations are described through cooperations with customers and suppliers, whereas cooperations with universities and research centers

belong to the explorative collaborations type (Faems et al., 2005). Given that exploration and exploitation have different motives (March, 1991; Wang et al., 2017), firms should proactively search for different set of international networks depending on their main strategy (Bolivar-Ramos et al., 2020). This allows promoting economic benefits and environmental sustainability simultaneously (Chang & Gotcher, 2020), as discussed next.

In a global context, rapid technological change, economic growth and intensified competition drive firms to strengthen existing competencies through exploitative innovation (Wen et al., 2021). Exploitative activities refer to a firm's ability to recombine, modify and develop new approaches for existing knowledge as well as to generate new knowledge that enhance firms' innovative performance (Chang & Gotcher, 2020). In this context, collaborations with foreign customers and suppliers is an instrument to optimizing existing core competencies (Faems et al., 2005) to improve eco-innovative performance. It also allows firms to increase efficiency through systematic cost reductions and the improvement of existing knowledge, expertise, and capabilities (Nielsen & Gudergan, 2012). Moreover, apart from the access to suppliers' innovation capabilities, collaboration with foreign suppliers encourages knowledge sharing about eco-innovation and facilitates inter-organizational problem-solving processes (Potter & Graham, 2019). Nevertheless, Nielsen and Gudergan (2012) pointed that too much focus on international exploitative collaboration may lead to conflicts of interests and suboptimal relationships. In addition, firms may face inter-firm trust issues in international buyer-supplier collaboration (Xie et al., 2010). Yet, exploitative collaborations at the international level can help sharing innovative pollution-prevention knowledge with suppliers, generate new environmental oriented ideas from customers, and recombine new uses for existing knowledge (Chang & Gotcher, 2020).

In addition to that, international explorative collaborations can influence firms' eco-innovation by providing completely new and diverse knowledge inputs that were not available in the home country. This, in turn, also leads to gaining competitive advantages (Ha, 2021). Nevertheless, there is also the risk that international explorative collaborations involve high experimentation costs without sufficient returns and benefits (Nielsen & Gudergan, 2012). For eco-innovation, universities and research centers play a key role in introducing new knowledge and increasing viable alternative models that are driven by environmental care (Sáez-Martínez et al., 2014).

Finally, to shed light on this topic, the differences in eco-innovative behavior due to the firm size cannot be overlooked (Davcik et al., 2021; Spithoven et al., 2013). SMEs typically have more limited resources and capabilities compared to larger firms. Therefore, they may be more likely to seek out exploitative collaborations to access the complementary resources needed to develop new environmental technologies or expand into new markets. In contrast, large firms typically have more resources and capabilities, and better infrastructures, so they may benefit more from forming explorative collaborations to gain access to novel discoveries and tap into new markets and technologies. Thus, prior research suggests that SMEs tend to select partners related to development stages, while large firms prefer to collaborate with partners related to explorative stages, focused on the search of new technologies (Jang al., 2017). In the next section, we deepen our knowledge on how international explorative and exploitative collaborations affect environmental innovations in the context of SMEs and large firms.

2.1. International explorative and explorative collaboration and eco-innovation in SMEs

SMEs usually show more innovative and sustainable business models that help them develop their competitive advantages (Valdez-Juárez & Castillo-Vergara, 2021), including being more eco-friendly. The development of SMEs' eco-innovativeness is usually based on their natural flexibility, adaptability and exploitation of market opportunities (Matejun, 2018), for example, through international collaboration. In this sense, SMEs turn to be engaged in international collaboration with suppliers due to insufficient access to local environmental resources. It allows to get various combinations of materials and components with lower impact (Buttol et al., 2012), thereby meeting local needs to be more eco-friendly. Moreover, collaborations with foreign suppliers may help SMEs enter new foreign markets (Sinha et al., 2011) by overcoming the lack of information about foreign environmental regulations, meanwhile facilitating the production of eco-friendly products/services to meet new market needs. However, there is always the risk of engaging in a collaboration with an unreliable supplier, which leads to unexpected costs and the loss of reputation that is essential for SMEs (Sinha et al,. 2011). It can happen in a context in which different countries and cultural backgrounds are involved.

Besides collaborating with foreign suppliers, SMEs tend to collaborate with foreign

customers to gain knowledge about eco-innovation. Hence, SMEs may collaborate with international clients to adapt business processes to the market demands, taking into account consumption patterns (Buttol et al., 2012). However, customers from developing countries with low economic growth may reduce the purchase of green products or services due to the price rise reflecting the costs on eco- innovation implementation (Pacheco et al., 2017).

In addition to previous arguments, international explorative collaborations can bring new knowledge or technology for eco-innovation that SMEs may lack, due to their common resource constraints. International universities and research centers link the private sector, especially SMEs, with societal demands (Scarpellini et al., 2012). Moreover, collaborations with international universities and research centers allow SMEs to get highly qualified specialists to facilitate the process of eco-innovation adoption (Scarpellini et al., 2012). However, as Pacheco et al. (2017) note, due to the limited financial resources of SME, their capability to exploit foreign knowledge may be lower, affecting eco-innovation. Nevertheless, collaborations with international universities and research centers is still likely to be interesting for SMEs to promote cost-savings thanks to the acquisition of knowledge for a better use of materials and energy (Triguero et al., 2013). This can allow them to achieve a greater competitive advantage, be more innovative, and improve their corporate performance results (Rabadán et al., 2019).

It could occur that SMEs may not able to absorb new international knowledge due to their lack of experience, internal resources and skilled employees (Guan & Liu, 2016). In fact, SMEs may prefer to collaborate with international partners only to exploit diverse combinations through new materials with lower impact and adaptation of business processes to the customer demands (Buttol et al., 2012). Apart from this, SMEs may also choose to collaborate with national partners to explore eco-innovation rather than international ones, thanks to different national investment funds that support eco-innovative projects in their country (Pacheco et al., 2017).

Despite the potential risks of international collaboration with suppliers and customers, we expect that these international exploitative collaborations will bring advantages for SMEs to exploit eco-innovative market opportunities, due to their flexibility and the acquisition of valuable knowledge inputs. We also expect that international explorative collaborations with universities and research centers have a positive effect on eco-

innovation in SMEs thanks to SMEs' benefits from exploring knowledge. In addition, we suggest that SMEs mostly rely on developing existing knowledge and complementing their internal resources through international exploitative collaborations for acquiring the complementary resources required to eco-innovate.Based on the foregoing:

Hypothesis 1a. In SMEs, international exploitative collaborations have a positive effect on eco-innovation.

Hypothesis 1b. In SMEs, international explorative collaborations have a positive effect on eco-innovation.

Hypothesis 1c. In SMEs, the effect of international exploitative collaborations on eco- innovation is greater than that of international explorative collaborations.

2.2. International explorative and exploitative collaboration and eco-innovation in large firms

As Torrecillas and Fernández (2022) point out, going beyond national markets offers the prospective to learn from technologically advanced partners, and demanding customers in foreign markets. It makes a firm reacts more efficiently on the increased demand for eco-oriented products and services. International collaborations allow firms accessing relevant knowledge inputs globally dispersed, which can be valuable for eco-innovation, as international partners may be more involved in environmentally responsible activities regulated by environmental standards (Pereira et al., 2020). The nature of eco-innovations and its high level of uncertainty give large firms additional opportunities to exploit existing technologies and explore new knowledge (Jové- Llopis & Segarra-Blasco, 2018). To meet the pressure to be more eco-oriented and improve the level of eco-innovative performance, large firms engage into international collaborations with different partners for technological complementarities or for searching new technologies (Schachter et al., 2013).

Large firms may be slow to adapt to economic changes on international markets and to respond to new eco-innovations requirements (Minguela-Rata et al., 2014). However, large firms have more extensive resource bases and perform operations on a larger scale, including international markets that increase the likelihood to generate eco-innovative technological solutions (Pichlak & Szromek, 2021). In addition to that, large firms may

use their experience and bargaining power to select and collaborate with better suppliers for eco- innovative performance improvement (Leiponen & Byma, 2009). Further, large firms are likely to use their reputation and high-skilled employees in order to understand customers' needs that lead to new eco-innovative products or services.

Regarding explorative motives for eco-innovation, large firms, by financing research activities in international research center or laboratories, are allowed to interact with the university scientists and get familiar with the basic knowledge of eco-innovation (Arora & Gambardella, 1990; Veugelers & Cassiman, 2005). Also, Veugelers and Cassiman (2005) pointed that thanks to information and know-how protection activities, large firms are willing to engage in international explorative collaborations for improving eco-innovation. This also leads to increasing the effectiveness of investments by reducing duplication of efforts (Schachter et al., 2013). In addition, large firms are expected to have larger funds to transfer resources such as personnel, financial capital, equipment and expertise, which enables them to handle all the objectives of the university as a partner (Schartinger et al., 2001). Despite all the benefits, there is also the risk that collaboration with international universities and research centers can bring high experimentation costs without sufficient returns in the long-term (Nielsen & Gudergan, 2012).

Based on the above, we expect that thanks to their solid experience and resource base, large firms are likely to collaborate with international suppliers and customers in order to exploit knowledge and technologies for eco-innovation performance. Moreover, the effective transfer of the know-how from research centers/universities and their patenting activities usually requires a sufficient research capability that large firms are likely to have (Veugelers & Cassiman, 2005). All in one, with different words, we expect a positive relationship between international exploitative collaborations and eco-innovation in large firms. In addition to that, we expect that large firms are more oriented to explore new knowledge through international collaborations as they have a sufficient base of internal knowledge to maintain current processes and absorb new knowledge or technologies for eco-innovative activities. Thus:

Hypothesis 2a. In large firms, international exploitative collaborations have a positive effect on eco-innovation.

Hypothesis 2b. In large firms, international explorative collaborations have a positiveeffect on eco-innovation.

Hypothesis 2c. In large firms, the effect of international explorative collaborations on eco-innovation is greater than that of international exploitative collaborations.

2.3. The difference between SMEs and large firms

Firms' eco-innovation strategies have recently been characterized by a trend towards increased openness; relying more on external information sources (Spithoven et al., 2013), including from abroad. Separating SMEs and large firms is necessary to identify and differentiate search strategies, specific barriers these firms may face and their particular research collaboration directions.

On the one hand, while large firms are more likely to invest in eco-innovation to increase their environmental efficiency, SMEs may find it more challenging to carry it out due to insufficient resources for the development of eco-innovations (Cecere et al., 2020). However, collaboration can bring in market-based knowledge that SMEs can exploit due to their flexibility, pragmatism and responsiveness to market changes (Spithoven et al., 2013), which consequently may lead to eco-innovation growth.

Both SMEs and large firms may benefit from a wider pool of knowledge and technologies provided by international collaboration partners that facilitate knowledge spillovers and increasing eco-innovation (Hottenrott & Lopes-Bento, 2014). International collaboration also allows accessing knowledge that is not available in the local country and facilitates entering to new international markets. Given the difference in internal resources and firms basic characteristics, past literature suggests that SMEs normally search for exploitative collaboration with foreign companies to make up for their lack of complementary resources and improve their eco- innovative performance (De Marchi, 2012; Jang et al., 2017; Minguela-Rata et al., 2014). On the opposite side, large firms may be more oriented towards explorative collaborations in comparison with SMEs, including abroad, due to their solid reputation experience and sufficient resources (Jang et al., 2017).

Usually, large firms face more difficulties in adapting quickly to economic changes on international market and responding to new eco-innovations requirements, compared to

SMEs (Minguela-Rata et al., 2014); e.g. from international customers and suppliers, because they may have procedures standardized and routines internalized, causing inertia. Nevertheless,large firms may have strong economies of scale based on their resources base, broad market scope and trusted networks due to their bargaining power (Jang et al., 2017). Even though large firms may have enough internal resources, they may face difficulties to develop new knowledge internally due to the specific eco-oriented knowledge needs. Thus, they focus on acquiring knowledge inputs for eco-innovation improvement through international collaborations with research centers, laboratories or universities that may have specific knowledge or know-how. Thanks to their resources and experience, large firms can afford to collaborate with partners from different locations and facilitate novel knowledge combination and absorption in order to implement new technologies (Carree et al., 2019).

Regarding SMEs, despite the complexity of international knowledge and different partners' culture, SMEs thanks to their flexibility can adapt rapidly to international partners, complement existing knowledge and get competitive advantages in the local market, by providingbetter eco-innovative solutions for their customers (Buttol et al., 2012). However, due to resource and experience constraints it may be difficult for SMEs to get completely new eco-innovative knowledge from international universities and research centers and absorb those (Guan & Liu, 2016). That is why we can expect SMEs to be more focused on collaborations with international partners such as suppliers and customers to exploit knowledge and complement existing resources through new eco-oriented solutions that are not available locally (Buttol et al., 2012).

Hypothesis 3a. The positive impact of international exploitative collaborations on eco-innovation is greater in SMEs than in large firms.

Hypotheses 3b. The positive impact of international explorative collaborations on eco-innovation is greater in large firms than in SMEs.

3. Methodology

3.1 Sample and data

Databases with information on firms' environmental activities are rare and hard to get and only some of them include the main determinants and outcomes of eco-innovation

(Stojčić, 2021). This research uses the Community Innovation Survey (CIS) for the period 2012–2014, due to the advantages it presents in this context. First, CIS is a systematically collected and harmonized database on a biannual basis with a wide European coverage (Ghisetti et al., 2015). It contains information on the CIS survey, in which firms reported directly whether they had implemented an eco-innovation strategy (Silva et al., 2021). Moreover, The CIS 2012-2014 survey questionnaire contains comprehensive data on various aspects of firms, including number of employees, staff training and qualifications, investment and expenses related to research and development, turnover, collaborations, and financial support received from the public sector (Leitão et al., 2019). For reasons of data availability, we restrict the analysis to firms that belong to eleven European Union countries: Bulgaria, Czech Republic, Germany, Estonia,Hungary, Italy, Lithuania, Latvia, Portugal, Romania and Slovakia. The heterogeneous European Union countries reflect a similar geographical focus as in the research by Ghisetti et al. (2015). In this study, to test the model proposed, we identify SMEs as those firms with a number of employees up to 249, and large firms as those with a number of employees higher than 250, consistent with previous research (Hervás-Oliver et al., 2021; Martínez Ros, 2019). The final samples contain only innovative firms from different sectors.

3.2. Variables and measures

Dependent variable

Eco-innovation. The development of eco-innovation usually assumes investment in knowledge and technologies that modifies the firm's capacity from the standpoint of knowledgedevelopment (Triguero et al., 2017). This variable reflects the breadth of the ten different types of eco-innovation activities that the CIS provides as it was done in the previous research (Bammens & Hünermund, 2020; Ghisetti et al., 2015). To be more concrete, these activities refer to product, process, organizational and marketing innovations which lead to environmental benefits[1].

[1] The CIS user manual contains the following eco-innovative activities: Reduced material or water use per unit of output - obtained within the enterprise; Reduced energy use or CO2 'footprint' (reduce total CO2 production) - obtained within the enterprise; Reduced air, water, noise or soil pollution - obtained within the enterprise; Replaced a share of materials with less polluting orhazardous substitutes - obtained within the enterprise; Replaced a share of fossil energy with renewable energy sources - obtained within the enterprise; Recycled waste, water, or materials for own use or sale - obtained within the enterprise; Reduced energy use or CO2 'footprint' - obtained during the consumption or use of a good or service by the end user; Reduced air, water, noise or soil pollution - obtained during the consumption or use of a good or service by the end user; Facilitated recyclingof product after use - obtained during the consumption or use of a good or service by the end user; Extended product life through longer-lasting, more durable products - obtained during the consumption or use of a good or service by the end user.

Independent variables

International exploitative collaborations. Collaboration with suppliers and business clients allows firms to be closer to their production cycles, consider eco-friendly behaviour andenhance recyclability (De Marchi, 2012). This variable is measured as the breadth of collaborations with suppliers and public and private customers (Faems et al., 2005), that particularly act in international locations such as EU/EFTA/EU-CC, US, China or India, and other countries. Thus, the variable ranges from 0 to 3.

International explorative collaboration. Collaboration with universities and research laboratories and centers allows firms to achieve more radical eco-innovations (del Rioet al., 2015), as firms develop their internal R&D while reducing the environmental impacts (Pereira et al, 2020). The variable is measured as the breadth of collaborations with universities, research centers and laboratories (Bolivar-Ramos et al., 2020; Faems et al., 2005), that act in international locations such as EU/EFTA/EU-CC, US, China or India, and other countries. Thus, this variable has values from 0 to 3.

Control variables

National collaboration. Along with introducing international collaborations, one of the main control variables in our study is national collaborations. National collaborations create thestructure of the system where culture, norms, and public policies are similar for all stakeholders (Băzăvan, 2019). Pereira et al. (2020) also mention that national networks can generate positive externalities for eco-innovators. In our study, the variable has been measured as the breadth of different collaboration types, which are located in the same country.

Patents. Patents constitute key strategic technological resources that serve to differentiate a firm from its competitors and sustain its competitive advantage (Kotabe et al., 2007; Won, 2015). In the literature of eco-innovation, patents related to this type of innovation are defined as inventions that contribute to the environmental performance (Mavi & Mavi, 2021). In our research, patents are represented by a binary variable that reflects whether a firm applied for a patent, coded as 1, and 0 otherwise (Athreye et al., 2021).

Product innovation. This variable has been classically related with a positive effect on company success and competitiveness (Naranjo-Valencia et al., 2017). In this study, it is

measured as a dummy variable equal to one (and zero otherwise) if the firm introduced into the market a new or significantly improved product.

Process innovation. Process innovation is an important variable as it may include an accordance to environmental standards established by different stakeholders that it intends to serve (Jové-Llopis & Segarra-Blasco, 2018). In this study it was measured as a dummy variable equal to one (and zero otherwise) if the firm introduced into the market a new or significantly improved service.

Internal R&D. The literature is ambiguous on the question of how internal R&D affects eco-innovation. Cainelli et al. (2015) found a positive relation between internal R&D and eco-innovation, while De Marchi. (2012) discussed that intensity of R&D has no effect on eco-innovations (Doloreux & Kraft, 2019). This variable has a binary nature and shows whether a firm engages in intramural R&D (Schmiedeberg, 2008; Spithoven & Teirlinck, 2015).

External R&D. Acquiring external R&D services is relevant in order to introduce eco-innovations (Jové-Llopis & Segarra-Blasco, 2018), since firms may acquire knowledge that isbetter developed and not available internally. The variable is measured as a binary one and shows whether a firm engages in extramural R&D (Schmiedeberg, 2008).

Turnover. Improving the quality of technology and developing innovation, including eco-innovation, is usually associated with growing turnovers (Gallucci et al., 2019; Pichlak & Szromek, 2021). In our research, the variable has been measured as the natural logarithm of the total turnover in 2014.

Public support breadth. This variable shows the number of sources from which firms receive financial support, that include public funding from local or regional authorities, public funding from central government, public funding from the EU, and funding from the EU's Framework Programme. The variable ranges from 0 to 4.

Group. Binary variable that represents whether a firm is part of an enterprise group.

3.3. Empirical strategy

Table 4.1. and Table 4.2. contain the correlation matrix and the summary statisticsfor the main variables of the research in the context of SMEs and large firms. As it can be

observed, the correlation is low between the main independent variables and eco-innovation, and the results are statistically significant.

To rule out multicollinearity problems, we computed Variance Inflation Factors (VIFs). Hair et al. (2011) indicate that, as a rule of thumb, VIFs higher than 5 reflect a sign of severe multicollinearity. The results displayed in Table 4.3. show that VIFs are below the acceptable threshold. Hence, multicollinearity is not a problem in this study.

Table 4.1. Descriptive statistics and correlations - SMEs

Variables	**Mean**	**SD**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Eco-innovation (1)	1.096797	2.202337	1.0000											
International Exploitative Collaboration (2)	.2445066	.8850612	0.0307*	1.0000										
International Explorative Collaboration (3)	.1133396	.5572266	0.0014	0.5682*	1.0000									
National Collaboration (4)	.8755244	1.542411	0.0063	0.4698*	0.4029*	1.0000								
Patent (5)	.1142857	.3181669	0.0564*	0.1671*	0.1956*	0.1912*	1.0000							
Turnover (6)	15.34064	1.509831	0.0239*	0.0438*	0.0126	0.0779*	0.0344*	1.0000						
Public Support (7)	.5862069	.8791738	-0.0108	0.2529*	0.3283*	0.4012*	0.2451*	-0.0335*	1.0000					
Product Innovation (8)	.4795222	.4995934	0.1278*	0.1119*	0.0686*	0.1192*	0.1957*	0.0762*	0.1165*	1.0000				
Service Innovation (9)	.2841779	.4510336	0.0611*	0.0823*	0.0795*	0.1259*	-0.0046	-0.0969	0.0485*	-0.0231*	1.0000			
Internal R&D (10)	.6800582	.4664663	-0.0344*	0.1191*	0.1230*	0.2296*	0.1797*	0.0801*	0.2523*	0.2065*	0.0221*	1.0000		
External R&D (11)	1.341474	.4742258	0.1028*	-0.0999*	-0.1150*	-0.1550*	-0.1511*	-0.0639*	-0.1733*	-0.0966*	-0.0441*	-0.0283*	1.0000	
Group (12)	.4042824	.4907656	-0.0532*	0.1079*	0.0448*	0.1541*	0.0483*	0.4051*	-0.0003	0.0401*	0.0090	0.0723*	-0.0530*	1.0000

Table 4.2. Descriptive statistics and correlations – large firms

Variables	**Mean**	**SD**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Eco-innovation (1)	1.769522	2.846199	1.0000											
International Exploitative Collaboration (2)	.5906294	1.490466	0.1629*	1.0000										
International Explorative Collaboration (3)	.3038334	1.047271	0.1423*	0.6589*	1.0000									
National Collaboration (4)	1.34327	2.01128	0.1512*	0.5814*	0.4938*	1.0000								
Patent (5)	.2371693	.4254147	0.2453*	0.2299*	0.2619*	0.2813*	1.0000							
Turnover (6)	18.72837	1.649088	-0.0764*	0.0931*	0.1494*	0.0745*	0.1883*	1.0000						
Public Support (7)	.69099	1.067981	0.0649*	0.2527*	0.2882*	0.3674*	0.3010*	0.1279*	1.0000					
Product Innovation (8)	.5387607	.49856	0.2522*	0.1778*	0.1164*	0.1903*	0.3033*	0.0535*	0.1835*	1.0000				
Service Innovation (9)	.3271173	.4692213	-0.0446*	0.1234*	0.1102*	0.1916*	-0.0645*	0.0711*	0.0629*	-0.0615*	1.0000			
Internal R&D (10)	.7741322	.4182023	0.0664*	0.1414*	0.1331*	0.1893*	0.2899*	0.2418*	0.2346*	0.2441*	0.0124*	1.0000		
External R&D (11)	1.197971	.3985355	0.0678*	-0.0876*	-0.0969*	-0.0918*	-0.1892*	-0.2134*	-0.1369*	-0.1337*	0.0010	-0.1132*	1.0000	
Group (12)	.8364865	.3698752	0.0006	0.0743*	0.0599*	0.1127*	0.0790*	0.3177*	0.0596*	0.0874*	0.0123*	0.1368*	-0.1039*	1.0000

Table 4.3. Multicollinearity check

	SMEs		Large Firms	
Variable	VIF	1/VIF	VIF	1/VIF
International Exploitative collaboration	1.63	0.614907	2.02	0.495020
International Explorative collaboration	1.61	0.619920	1.81	0.552069
National collaboration	1.56	0.639100	1.80	0.554672
Patent	1.11	0.900888	1.20	0.835459
Turnover	1.19	0.838047	1.20	0.835914
Public Support	1.35	0.738340	1.32	0.759926
Product Innovation	1.05	0.948474	1.11	0.902812
Service Innovation	1.05	0.954791	1.06	0.941709
Internal R&D	1.00	0.996659	1.02	0.976131
External R&D	1.06	0.940518	1.10	0.909155
Group	1.18	0.849817	1.10	0.908179
Mean VIF	**1.26**		**1.34**	

To perform the empirical analysis, we used the Tobit regression model (Hendrickx, 2002; McDonald & Moffitt,1980). As in past research, the Tobit models were estimated to take into account that the dependent variable, Eco-innovationn, is censored (García-Sánchez et al, 2021; Segarra-Ciprés & Bou-Llusar, 2018).

In line with the study and the research hypotheses related to eco-innovation (EI), we introduce the same model that was applied for SMEs and large firms separately:

(1) SMEs $EIsms_t = \alpha + \gamma X_{it} + \nu_{it}$

(2) SMEs $EIsms_t = \alpha + \beta_1 IET_{it} + \beta_2 IER_{it} + t + \nu_{it}$

(3) Large firms $EIlarge_t = \alpha + \gamma X_{it} + \nu_{it}$

(4) Large firms $EIlarge_t = \alpha + \beta_3 IET_{it} + \beta_4 IER_{it} + \gamma X_{it} + \nu_{it}$

In all models, *i* and *t* represent the identity of firms and the period considered (2012 - 2014), respectively. $\beta_1 IET_{it}$ represents international exploitative collaboration for SMEs, while $\beta_3 IET_{it}$ refers to international exploitative collaboration for large firms. Then, $\beta_2 IER_{it}$ and $\beta_4 IER_{it}$ represent international explorative collaboration for SMEs and large firms, respectively.Finally, in both equations, the variable γX_{it} represents the vector of control variables that include national collaboration, patents, turnover, public support, product and process innovation, internal R&D, external R&D, and group.

4. Results

Table 4.4. displays the results of the empirical analysis for four models related to SMEs and large firms. Model 2 contains the results for hypotheses 1a-1c, whereas Model 4 refers to the analysis of hypotheses 2a-2c. Moreover, both models show the difference between SMEs and large firms which is required to test hypothesis 3a and 3b.

Table 4.4. Tobit regression model with eco-innovation as the dependent variable

Variables	**SMEs**		**Large firms**	
	Model 1	**Model 2**	**Model 3**	**Model 4**
Independent Variables				
International Exploitative collaborations		0.104*** (3.48)		0.149** (2.76)
International Explorative collaborations		-0.00264 (-0.06)		0.325*** (4.63)
Control Variables				
National collaboration	0.0589*** (3.98)	0.0341* (2.09)	0.0882* (2.57)	-0.0354 (-0.91)
Patents	0.598*** (9.45)	0.594*** (9.34)	1.555*** (9.87)	1.455*** (9.31)
Turnover (log)	0.0751*** (4.80)	0.0769*** (4.91)	0.154** (3.02)	0.122* (2.40)
Public support	-0.0822*** (-3.35)	-0.0883*** (-3.50)	-0.166* (-2.49)	-0.227*** (-3.42)
Product innovation	0.649*** (14.58)	0.644*** (14.43)	1.143*** (7.90)	1.103*** (7.70)
Process innovation	0.492*** (9.97)	0.488*** (9.86)	-0.0996 (-0.69)	-0.145 (-1.02)
Internal R&D	-0.133 (-0.33)	-0.117 (-0.29)	0.693 (0.79)	0.702 (0.81)
External R&D	0.630*** (13.16)	0.627*** (13.06)	0.942*** (5.33)	0.943*** (5.42)
Group	-0.0590 (-1.22)	-0.0638 (-1.32)	0.0378 (0.20)	0.0585 (0.31)
_cons	-1.398** (-2.96)	-1.430** (-3.03)	-3.669** (-2.80)	-3.006* (-2.31)
Number of observations	9660	9608	2000	1989

*+ p<0.1, * p<0.05, ** p<0.01, *** p<0.001. Standard errors are in parentheses*

Considering the estimated parameters, in Model 2 the coefficient β_1= 0.104 (p < 0.001) has a positive and significant effect, which support the positive relation between

international exploitative collaborations and eco-innovation in SMEs (hypothesis 1a). In Model 2 we can also observe that β_2= -0.00264 (p > 0.1), but the results are not statistically significant. Therefore, hypothesis 1b, that considered there is a positive relation between international explorative collaboration and eco-innovation in SMEs, is not supported. These results also confirm the idea that international exploitative collaborations are the most important for eco-innovation performance in the context of SMEs (coefficient β_1= 0.104 (p < 0.001), compared to international explorative collaborations (β_2= -0.00264 (p > 0.1)). Thus, hypotheses 1c is also supported.

Regarding Model 4, the coefficient β_3= 0.149 (p < 0.05) supports hypothesis 2a, which states that there is a positive relationship between international exploitative collaboration andeco-innovation in large firms. Furthermore, the coefficient β_4= 0.325 (p < 0.001) confirms the positive relations between international explorative collaborations and eco-innovation, thus supporting hypothesis 2b. Moreover, these two coefficients from Model 4 also confirm hypothesis 2c, which stated that for promoting eco-innovation, international explorative collaborations have a higher positive impact than international exploitative collaborations in large firms (coefficient β_4= 0.325 (p < 0.001), higher and more significant than coefficient β_3= 0.149 (p < 0.05)).

Finally, to compare the coefficients in models 2 (SMEs) and model 4 (large firms), and test hypotheses 3a and 3b, we followed Clogg et al. (1995) guidelines and performed Z-tests.

$$Z = \frac{\mu_1 - \mu_2}{\sqrt{\frac{(SD_1)^2}{Sample\ Size} + \frac{(SD_2)^2}{Sample\ Size}}}$$

Where, μ_1 and μ_2 represents the means and SD – Standard Deviation.

First, the coefficient β_1= 0.104 (p < 0.001) represents international exploitative collaboration and its effect on eco-innovation in SMEs, meanwhile coefficient β_3= 0.149 (p < 0.05) represents international exploitative collaboration and its effect on eco-innovation in large firms.

After running a Z-test, the Z coefficient = -14.53 is significant at p < 0.001, which supports Hypothesis 3a and the existence of a stronger positive effect of international exploitative collaborations on eco-innovation in SMEs than in large firms. Finally, the

coefficient β_2= -0.00264 ($p > 0.1$), represents international explorative collaboration and its effect on eco-innovation in SMEs, meanwhile the coefficient β_4= 0.325 ($p < 0.001$) that represents international explorative collaboration and its effect on eco-innovation in large firms. After running a Z-test, $z = 19.75$ is significant at $p < 0.001$. Thus, Hypothesis 3b is supported, and international explorative collaborations have a stronger impact on eco-innovation in large firms than in SMEs.

5. Robustness check

To test the robustness of these results, an alternate test for the proposed models was conducted by using different measures of the main independent variables. Thus, we measured international exploitative collaborations considering the breadth of international collaborations with suppliers and customers from distinct international locations (variable with values from 0 to 20). Then, international explorative collaborations were measured by the breadth of international collaborations with universities, research centers and laboratories from different international locations (variable with values from 0 to 13). The estimations (available upon request) show that the results remain the same for the key variables of the research.

6. Discussion and conclusions

In current economies, the role of eco-innovation is crucial for supporting rapid economic growth, due to the increasing importance of sustainable development (Cecere et al., 2020; Ghisetti et al., 2015). In this context, this research has provided theoretical and empirical evidence on how the international nature of the alliances and the purpose of the collaboration (i.e. explorative and exploitative) affect the firm's eco-innovation performance. As eco-innovations require richer and novel knowledge combinations, that typically come from diverse partners and geographies, this is a critical topic nowadays (González-Moreno et al., 2019).

One of the main contributions of our study lies in exploring the difference between international explorative and exploitative collaborations and their impact on environmental innovation. These two important directions show to what extent inter-firm collaborations can constitute valuable channels for knowledge exchanges in eco-innovation, depending on the firms' innovation motivations (Belderbos et al., 2010; March, 1991). Along with that, another contribution results from the differences of the

relations described above in the context of SMEs and large firms. Thus, we found that international exploitative and explorative collaborations have a positive effect on eco-innovation in large firms. Moreover, large firms tend to be more engaged in international explorative collaboration than in exploitative ones for this purpose. International explorative cooperations often involve developing new technologies or entering new markets. These firms often have established research and development departments, extensive networks, and expertise in their industries, but tend to be rigid to pursue novel discoveries due to inertia. This is why these explorative alliances can provide important inputs for eco-innovation.

Regarding SMEs, the findings of the research reveal that international exploitative collaborations have a positive effect on eco-innovation, although there is no statistical support for the effect of international explorative collaborations on eco-innovation. Hence, collaboration with international partners in order to exploit makes sense for SMEs to overcome their resource limitations. As SMEs are usually more flexible in terms of pursuing novel discoveries ("exploration"), but lack complementary assets required to exploit them to the commercial stage, it thus seems logical that international exploitative partners will be more relevant in helping SMEs develop eco-innovations. Further, SMEs may be also more focused on short-term gains and survival than long-term growth, which may justify why they are less likely to engage in international explorative collaborations, which can take longer to yield benefits.

6.1. Theoretical, managerial and policy implications

This research also presents some implications for theory and practice. First, this study advances the theory of eco-innovation and international collaborations by explaining the importance of distinguishing international exploitative and explorative motivations of SMEs and large firms, and how firms can benefit from them to enhance eco-innovative performance (Li et al., 2018; March, 1991). While both exploration and exploitation motives can lead to eco-innovations, they have different implications for companies and their sustainability goals (De Marchi, 2012). Thus, under the framework of KBV (Grant, 1996), the study reveals that exploitative collaborations can result in gradual advancements in already existing eco-innovations that lead to improved efficiency and a decreased negative impact on the environment. This can help firms cut down costs, increase their market competitiveness, and reduce their environmental impact. Additionally, exploitative collaborations can encourage knowledge sharing and best

practices exchange between firms, which in turn can accelerate the integration of eco-innovations into different industries. Additionally, by joining international alliances, the geographical scope of collaborations expands, which opens new opportunities for green innovation. Further, this study enriches the discussion on how the firm size affects this innovative strategy (Buttol et al., 2012; Hottenrott & Lopes-Bento, 2014; Jang et al., 2017).

Regarding managerial implications, managers can consider exploitative collaboration (with their suppliers and customers) to develop ways to reduce the environmental impact of their supply chain. For example, they can work with suppliers to reduce packaging waste, improve transportation efficiency, or switch to more sustainable materials that would be in line with customers' demand. Also, managers can participate in industry collaborations to share best practices and develop new eco-innovations that benefit the entire industry. Further, if managers have an objective of knowledge exploration, they could partner with academic institutions and universities to access and explore new knowledge and technologies for eco-innovation.

In addition, the distinct characteristics of SMEs and large firms must be addressed when considering their engagement in international collaborations and their effects on eco-innovation. In line with our findings, collaborative strategies in large firms may be more focused on international explorative collaborations with partners such as international universities and research centers. Managers can benefit from learnings how to effectively collaborate with other companies or institutions, including building strong relationships, defining clear goals and objectives, and sharing resources and knowledge for inducing the development of sustainable eco-innovations. Additionally, managers can learn from successful cases of eco-innovation collaborations, such as identifying best practices and potential pitfalls, and adapting them to their specific contexts.

For SMEs, international exploitative collaborations can be a more feasible and effective way to advance eco-innovation, as they usually have more limited complementary resources and capabilities to launch eco-friendly discoveries to the market. For large firms, international explorative collaborations may be more significant as a way to access the most recent and novel discoveries in green technologies and eco-friendly markets, by partnering with international universities or research centers.

Finally, for policy designers, the study shows the importance of encouraging coordinated

international collaboration with different partners in which sustainability goals are pursued. For instance, in order to support international explorative collaborations in large firms, public authorities must support networks and internships between firms and universities at the international level. It is also important to encourage cooperation between international research centers/laboratories and large firms in order to combine different knowledge and competences for the development of eco-innovations that are not available locally. As for SMEs, costs are essential constraints, so authorities should consider different grants to support collaboration with international suppliers or customers, who provide better eco-innovative solutions.

6.2. Limitations and future research

In spite of the contributions of this research, this paper has some limitations that open new opportunities for future research. First, the study is cross-sectional and, as we do not work with panel data, the information analyzed is more limited. Second, the study focuses on firms'size as differentiation criteria. However, future studies may provide additional empirical evidence by distinguishing how new ventures and more mature firms differ in their decision to collaborate at the international level in order to increase their eco-innovative performance. Another limitation is that the independent variables only consider the breadth of partners and do not capture the number of international partners firms cooperate with. Further, future research should also consider how the specific location in which international partners (either explorative/exploitative) are affects the development of environmental innovative solutions, as different countries involve different regulations and institutional settings. Finally, future research should also consider the sector's role in eco-innovation to account for variations across industries. All these aspects suggest future and promising new research lines in the field.

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CHAPTER 5

CONCLUSIONS, IMPLICATIONS, AND FUTURE RESEARCH

The concluding part of this dissertation provides a summary of the key findings from the papers of this doctoral thesis, as well as a discussion of the main implications for theory, business practice, and policy-makers. Further, it presents its main limitations and also suggestions for future research. The main objective of this study was to enrich the existing literature on external knowledge sourcing strategies in a global context, by examining R&D offshoring and international collaboration networks to assess how these strategies impact firms' innovation performance. Furthermore, the dissertation emphasized the crucial role of firm age and size in understanding firm's innovative behaviors.

5.1. Conclusions and main findings

As introduced, in global terms, this dissertation aimed to examine the drivers and impacts of international external knowledge-sourcing strategies on the advancement and performance of innovative firms, while also investigating how these effects may be influenced by the contingencies of firm size and age. As a reminder from Chapter 1, three main research objectives were established:

I. To analyze what factors trigger international R&D outsourcing, in relation to technological resources and the firm's international experience, and how these relationships may vary depending on the firm age.
II. To explore how the functional breadth and the geographical scope of the firm's collaboration network affect its radical innovation performance. Further, understanding how firm size moderates these relationships.
III. To examine how international exploitative collaborations (with suppliers and customers) and international explorative collaborations (with universities, research institutions and laboratories) affect eco-innovative performance in SMEs and large firms.

Overall, and in other words, this dissertation has aimed to explore how international R&D outsourcing practices and collaboration portfolios impact the firm's innovation performance, with a focus on the development of radical innovations and eco-innovations. Further, it has considered critical contingencies such as the size and age of the firm to provide a more nuanced understanding of the relationship between external knowledge

sourcing strategies and innovation performance. By considering these key factors, this dissertation provides valuable insights into the complex interplay between firms' external knowledge sourcing strategies and their ability to innovate.

Regarding the first objective of the dissertation, the findings of Paper 1 (Chapter 2) highlight the critical role of internal technological resources and international experience in shaping a company's international R&D outsourcing decisions. By investing in their internal R&D capabilities and protecting their innovations through patents, companies can position themselves to better leverage the benefits of outsourcing R&D from abroad. In addition to that, the results of the analysis reveal a positive relationship between a company's engagement in exporting and cooperation and its propensity to outsource knowledge internationally. It highlights the importance of strategic partnerships and collaborations for enhancing a company's global competitiveness. Another contribution from this Chapter of the dissertation refers to the moderating role of firms' age. The results show that the younger firms are, the stronger the relationship between internal R&D, exporting, cooperation and international R&D outsourcing. In this context, international R&D outsourcing can allow young firms to tap into new markets and technologies, expand their product portfolio, and diversify their business risks. The study shows that younger firms have a higher propensity to engage in international R&D outsourcing than mature firms, not only to complement their more limited internal resources and international experiences, but also due to their higher flexibility for innovative strategies.

The second objective of the dissertation, connected to paper 2 (Chapter 3), was to examine how the functional breadth and the geographical scope of the firm's collaboration network affect its radical innovation performance. The findings reveal that engaging in different types of functional cooperations increases firms' radical innovation performance, although it also brings negative effects after a certain point (inverted U-shape relationship). Along with that, engaging in geographically diverse cooperation networks enhances the firms' radical innovation performance. Nevertheless, this only occurs up to a certain point in which innovation performance decreases, likely due to the increased complexity of managing diverse knowledge sources from different locations. In addition to that, the aim of this Chapter was to understand how firm size moderates these relationships. The results on this part suggest that the smaller the firms are, the higher their optimal number of functional R&D partnerships for radical innovation.

The third objective of the dissertation, related to the third paper (Chapter 4), was to examine how international exploitative collaborations (with suppliers and customers) and international explorative collaborations (with universities, research institutions and laboratories) affect eco-innovative performance in SMEs and large firms. The findings of this research show that there is a positive relationship between international exploitative collaborations and eco-innovation in SMEs. Regarding large firms, a positive relationship between both international exploitative and explorative collaborations and eco-innovation was confirmed. Further, to promote eco-innovation, international explorative collaborations have a higher positive impact than international exploitative collaborations in large firms. Finally, the positive effect of international exploitative collaborations on eco-innovation is greater in SMEs than in large firms.

Table 5.1. provides a global summary of the findings of this dissertation through the hypotheses tested in each one of the three papers presented in Chapters 2, 3 and 4.

Table 5.1 Summary of findings based on the research hypotheses

Paper	Hypothesis	Result
Paper 1	**Hypothesis 1a.** The greater the firm's internal R&D, the higher the likelihood to outsource R&D from abroad.	Supported
	Hypothesis 1b. The greater the number of patents, the higher the likelihood to outsource R&D from abroad.	Supported
	Hypothesis 2. The higher the level of exports, the greater the probability to outsource R&D from abroad.	Supported
	Hypothesis 3. The greater the firm's engagement in international collaborations with suppliers and customers, the higher the probability to outsource R&D from abroad.	Supported
	Hypothesis 4a. The positive relation between the firm's internal R&D and international R&D outsourcing will be stronger for younger firms.	Supported
	Hypothesis 4b. The positive relation between the number of patents and international R&D outsourcing will be stronger for younger firms.	Not Supported
	Hypothesis 5. The positive relation between exporting and international R&D outsourcing will be stronger for younger firm.	Supported
	Hypothesis 6. The positive relation between international cooperation and international R&D outsourcing will be stronger for younger firms.	Supported
Paper 2	**Hypothesis 1**. There is an inverted U-shape relationship between the functional breadth of the collaboration portfolio and firms' radical innovation performance.	Supported
	Hypothesis 2. There is an inverted U-shape relationship between the geographical scope of the collaboration portfolio and firms' radical innovation performance.	Supported
	Hypothesis 3. The relationship between the functional breadth of the collaboration network and firms' radical innovation performance is moderated by firm size, in a way that SMEs have a higher optimal number of functional partners than large firms.	Supported

Paper	Hypothesis	Result
	Hypothesis 4. The relationship between the geographical scope of the collaboration network and firms' radical innovation performance is moderated by firm size, in such a way that SMEs have a higher optimal number of geographic areas in the portfolio than large firms.	Not Supported
Paper 3	**Hypothesis 1a.** In SMEs, international exploitative collaborations have a positive effect on eco-innovation.	Supported
	Hypothesis 1b. In SMEs, international explorative collaborations have a positive effect on eco-innovation.	Not Supported
	Hypothesis 1c. In SMEs, the effect of international exploitative collaborations on eco-innovation is greater than that of international explorative collaborations.	Supported
	Hypothesis 2a. In large firms, international exploitative collaborations have a positive effect on eco-innovation.	Supported
	Hypothesis 2b. In large firms, international explorative collaborations have a positive effect on eco-innovation.	Supported
	Hypothesis 2c. In large firms, the effect of international explorative collaborations on eco-innovation is greater than that of international exploitative collaborations.	Supported
	Hypothesis 3a. The positive impact of international exploitative collaborations on eco-innovation is greater in SMEs than in large firms.	Supported
	Hypotheses 3b. The positive impact of international explorative collaborations on eco-innovation is greater in large firms than in SMEs.	Supported

Source: Own elaboration

5.2. Contributions and implications of the dissertation

5.2.1. Theoretical implications

This dissertation extends past research on international external knowledge sourcing strategies, specifically international R&D outsourcing and international collaborations, by also providing important insights on the role of firm size and firm age, making relevant contributions to the field and previous literature.

In global terms, this thesis examines the drivers of international R&D outsourcing and the impacts of international collaborations on firms' innovative outcomes. The dissertation sheds some light on how firms can leverage external knowledge sources for innovation and potential competitive advantage. Through a detailed examination of these critical knowledge sourcing strategies, this study contributes to the KBV of the firm (Grant, 1996), and open innovation literatures (Chesbrough, 2003), by providing valuable insights into the mechanisms that underpin firms' successful innovation outcomes (radical innovation and eco-innovation), as discussed next. Further, the role of firm size and age as key contingencies affecting such innovative behaviours is also explored.

First, this dissertation (Chapter 2) contributes to the Knowledge-Based View of the firm (Grant, 1996), by explaining the drivers that boost the acquisition of international knowledge inputs, by means of R&D offshoring, for sustaining competitive advantage. Despite the relevance of R&D offshoring as a knowledge sourcing strategy, scant research has focused on investigating, concretely, the determinants of international R&D outsourcing (García-Vega & Huergo, 2011; Hijzen, 2007; Naldi & Davidsson, 2014), and none of them have simultaneously explored how firm age conditions this strategy. Thus, this research identifies the factors that affect the acquisition of international knowledge inputs, in terms of internal technological resources (Appio et al., 2019; Un, 2017) and international experience (Belderbos et al., 2015; Mol, 2005; Yu & Lee, 2017). In addition to that, this study advances the international entrepreneurship literature, shedding some light on how the firm life cycle affects this innovative strategy, as the literature has provided opposite views on whether mature firms, with accumulated experience and more prepared to manage the complexities of offshoring, will be more prone to pursue this decision, or whether younger firms, with simpler organizational structures and greater flexibility, will be more likely to offshore (Asimakopoulos et al., 2023). This study shows that younger firms capitalize their learning advantages to induce to a greater extent than mature firms international R&D outsourcing; which is consistent with recent research that clarifies that international new ventures are able to succeed and benefit from heterogeneous external knowledge sources despite their constraints (Giménez-Fernández et al., 2022). Thus, all in one, Chapter 2 offers insights into how organizations can leverage their particular strengths and weaknesses to effectively pursue their knowledge acquisition strategies in the global marketplace.

Chapters 3 and 4, continuing with external knowledge sourcing strategies, focus on the inter-organizational collaboration literature to provide insights into how firms can effectively collaborate with relevant partners to achieve innovation objectives; in particular radical innovation (Carree et al., 2019; Cheng et al., 2016) and eco-innovation (De Marchi, 2012; González-Moreno et al., 2019). Again, under the framework of KBV, these Chapters stress the importance of acquiring, assimilating, and implementing relevant knowledge for firms to gain a competitive advantage and enhance their innovative performance. Along with it, the open innovation literature that inspires this research underscores the importance of engaging with external partners such as customers, suppliers, and other stakeholders to co-create and co-develop new products, services, and processes. By leveraging external knowledge sources, firms can access a

broader range of ideas and expertise, reducing the risks and costs associated with internal R&D efforts (Badillo & Moreno, 2016; Cheng et al., 2016).

In line with the above, Chapter 3 contributes to the literature on open innovation (Chesbrough, 2004), and relevant partner selection, by explaining how the diversity in the collaboration portfolio, in functional (e.g. customers, suppliers, etc.) and geographical terms (e.g. national, international), affects the radical innovation performance of firms. It shows that despite the rich and diverse knowledge inputs they both provide, that produce valuable complementarities that positively impact the development of breakthrough innovations, an excess of diversity generates additional costs that decrease the chances to radically innovate (inverted-U relationships). While this is consistent with past research, this study goes a step further by analyzing separately the functional and geographical breadth of collaborations. Further, as a key contribution, chapter 3 underscores the differences in the behavior of SMEs and large firms, by analyzing the moderating role of firm size (Carree et al., 2019), as a critical factor affecting these relationships. Specifically, the study reveals that SMEs usually collaborate with a greater number of distinct functional partners than their larger counterparts do, which can be explained by their need of complementing existing resources and their flexibility in innovative activities. This resolves some divergent views on this topic in the literature, as some scholars pointed that larger firms may have more diverse functional collaboration networks due to their significant resource base in comparison with smaller firms (Jang et al., 2017). As this research separately analyzes the differences between the functional and geographical diversity of partners (without the common unified perspective in the literature), it also provides a deeper analysis on the topic that can explain the differences in the results. Finally, another important implication of Chapter 3 is that it help us understand how firms can promote radical innovations. Radical innovation matters for firms because it enables them to stay competitive with revolutionary new approaches, adapt to changing market conditions, and create new revenue streams (Wuyts et al., 2004). By promoting radical innovation, firms can position themselves for long-term success and growth in their respective industries (O'Connor & Ayers, 2005).

Finally, the dissertation (Chapter 4) contributes to the literature on inter-organizational collaborations and eco-innovation (De Marchi, 2012) (Chapter 4). In particular, it contributes to the literature on international alliances, exploration and exploitation purposes (March, 1991), and environmental innovation development. The differentiation

between international explorative and exploitative collaborations provides insights into the extent to which inter-firm partnership across national borders can serve as effective conduits for knowledge exchange in the realm of eco-innovation. Further, the research emphasizes the importance of considering the firms' innovation motivations (explore/exploit) when evaluating the potential benefits of such collaborations, without ignoring its potential drawbacks. Moreover, a significant contribution of this study arises from separating how these relationships unfold in the context of SMEs and large firms, that present distinct organizational characteristics. Therefore, this study advances the literature by showing that international exploitative collaborations induce the development of eco-innovation in both SMEs and large firms (Li et al., 2018; March, 1991), although international explorative collaborations only have a positive impact on the likelihood to eco-innovate in large firms; being also the most influential one in these large organizations. These implications are in line with previous findings in the literature, that support the idea that while SMEs may be more flexible to develop novel and eco-friendly ideas, they lack other resources to eco-innovate that provide exploitative partners. On the contrary, large firms may have greater resources along all the stages in the value chain, that can help them engage in more international alliances for eco-innovation, but tend to rely on explorative ones to a greater extent due to their typical rigidities and tendency to promote organizational inertia. Last, but not least, this study also contributes to explain how to promote eco-innovation development, a critical topic in the environmental innovation literature due to increasing regulatory pressures and environmental concerns (Lasisi et al., 2022; Díaz-García et al., 2015).

5.2.2. Managerial implications

This dissertation raises a number of practical implications, that are helpful for managers to understand how firms can benefit from international external knowledge sourcing strategies for innovation, while also considering the specific characteristics of their organizations (new ventures *vs* mature ones; SMEs *vs* large firms).

Managers should recognize that by engaging in international R&D outsourcing, firms could access specific valuable benefits of other countries, such as unique knowledge and expertise, specialized equipment and technologies, and access to new markets and customers (García-Vega & Huergo, 2019; Martinez-Noya et al., 2012). This study offers guidance to managers on the factors that can increase the likelihood of successfully outsourcing R&D knowledge from abroad. The research (Chapter 2) demonstrates that

external R&D from foreign locations can complement internal R&D; which can benefits firms increasing their absorptive capacity (Un, 2017), that is key to achieve higher levels of innovativeness. Furthermore, firms that distribute their products globally can gain a competitive advantage by quickly identifying and adapting to consumer preferences through acquiring new knowledge and technologies from foreign locations through R&D offshoring. In addition to that, managers need to bear in mind that international collaboration for firms seeking to gain a foothold in new markets and grow their businesses also induces learning processes, that can be further reinforced with the external knowledge gained in international R&D outsourcing activities.

To effectively leveraging international R&D outsourcing, managers should recognize that young and mature firms have distinct characteristics that condition their strategies (Naldi & Davidsson, 2014; Santoro et al., 2021). Young firms, in particular, may face greater challenges in terms of knowledge acquisition and resource availability (Hughes et al., 2021). By acquiring knowledge from foreign locations and partners, young firms can access a wider range of knowledge and expertise, complementing their existing resources and accelerating their innovation processes (Yli-Renko et al., 2001). This is particularly important for young firms that may not have established networks or reputations. Overall, the research shows that younger firms, despite potential drawbacks associated to their lower experience, benefit from their agility and flexibility to a greater extent than mature firms for engaging in R&D offshoring, with the potential subsequent gains this decision entails (Asimakopoulos et al., 2023).

This thesis also presents practical implications that can guide managers when choosing inter-organizational networks with foreign partners as a mechanism to enhance innovation. Thanks to diverse collaborations, firms can create new opportunities for growth (Elia et al., 2019). To illustrate, functional and geographical cooperation can play an important role in promoting the development and adoption of AI (Artificial Intelligence) within firms. By collaborating across different functions and geographies, firms can share knowledge and resources, identify new use cases for AI, and develop new business models that leverage AI technology. As discussed in Chapter 3, managers should consider that partner selection is a critical factor for the potential success of inter-organizational collaborations, as different types of partners (functional / geographical) bring to the table distinct benefits (Capaldo & Petruzzelli, 2014; Hagedoorn et al., 2018). Notably, managers can learn from this study that while expanding the functional range and geographic reach of collaborations may initially improve a firm's performance in

radical innovation, thanks to the rich knowledge sources provided, there comes a point where this approach can become detrimental (inverted U-shape) (Carree et al., 2019; Delgado-Márquez et al., 2018). Hence, managers should take into account all the risks and costs incurred in order to avoid engaging in overly diverse functional/geographical collaboration networks. Moreover, when it comes to fostering the introduction of radical innovations, managers should take into account that SMEs and large firms exhibit distinct behavior based on their available resources, experience, and flexibility (Carree et al., 2019). This research concludes that SMEs, in comparison to large firms, require a higher degree of functional collaboration diversity to access competing concepts and obtain valuable customer feedback for breakthrough innovations, ultimately improving their strategies and processes.

Finally, managers can benefit from learning how to effectively collaborate with other companies, depending on their main motivation they have, in order to increase eco-innovative performance. To be more concrete, through explorative cooperation, managers can gain access to new knowledge, expertise, and technologies from partners with different knowledge bases (De Marchi, 2012). This can help managers develop breakthrough eco-innovations that address environmental challenges in new and innovative ways. Exploitative cooperation can lead to the sharing of best practices, knowledge combination, and the pooling of resources between firms (Chang & Gotcher, 2020). This can accelerate the adoption of eco-innovations across industries and help firms improve existing eco-innovations, leading to cost savings, increased competitiveness, and a reduced environmental footprint. Further, managers can select the most appropriate cooperation strategy based on their firm's current eco-innovation needs and goals. In addition, managers who are aware of different cooperation strategies can identify potential collaboration partners who are best suited to their firm's eco-innovation needs. This can help firms establish more effective and efficient collaborations.

In line with the findings, collaboration strategies in large firms should be more focused on international explorative collaborations with partners such as international universities and research centers. As for SMEs, managers should prioritize building relationships with partners that have complementary strengths and expertise. This can help ensure that the partnership is mutually beneficial and that both parties can contribute to the development of eco-innovations. They can also leverage the resources and expertise of their partners to develop new eco-innovations or improve existing ones.

5.2.3. Policy implications

This dissertation also provides useful guidance for governments in developing public policy strategies and decisions. First, in relation to Chapter 2, policies that protect intellectual property can help firms maintain control over their proprietary knowledge and technology when outsourcing R&D to international partners (García-Vega & Huergo, 2011). This can be done through legal frameworks that enforce patent and copyright laws, as well as through contractual agreements with outsourcing partners. Second, governments that promote international collaboration can help firms identify and engage with potential outsourcing partners. This can be done through initiatives that foster collaboration between firms, universities, and research institutions across borders. Moreover, policies that facilitate the transfer of knowledge and technology across borders can help firms benefit from international R&D outsourcing. This can be done through initiatives that encourage the mobility of skilled workers and the transfer of technology and know-how between countries. Specifically, governments may consider implementing policies and incentives that target the unique needs and benefits of younger firms that engage in international R&D outsourcing. For instance, programmes that focus on qualifying or training personnel (such as language or technical courses) could be included to improve coordination and enhance the efficiency of knowledge acquisition from abroad (Tamayo & Huergo, 2016). Such initiatives can help develop a more skilled workforce that is better equipped to engage in international R&D outsourcing, ultimately contributing to the overall competitiveness of companies and the nation.

Further, considering Chapter 3, policies that promote regional development can help firms from different geographic locations collaborate and benefit from each other's expertise and resources. This may be possible through initiatives that encourage the development of innovation clusters, technology parks, and other regional networks that foster collaboration and knowledge exchange (Cruz-Castro et al., 2018). Further, policies that address legal and regulatory barriers can help firms overcome obstacles to functional and geographic cooperations. This can be done through initiatives that promote standardization, simplify regulatory procedures, and harmonize legal frameworks across different jurisdictions. In addition, in line with the research contribution regarding the moderating role of firm size, policies that encourage partnerships and collaborations between firms can be particularly beneficial for SMEs. For example, providing funding or support for joint R&D projects or incentivizing larger firms to partner with smaller

firms can help SMEs overcome resource constraints and gain access to new markets and technologies.

Finally, Chapter 4 also emphasizes the significance of engaging in international collaborations for promoting sustainability objectives by means of eco-innovation. Policies that support the development of regional or international networks for environmental innovation can facilitate both exploitative and explorative cooperations. Such networks can provide a platform for firms to collaborate and share resources and knowledge, and can facilitate the development of innovative solutions to reduce environmental challenges. Moreover, public authorities can support explorative collaboration in large firms by facilitating international networks and internships between firms and universities. Encouraging cooperation between international research centers/laboratories and large firms is also crucial for combining different knowledge and expertise to develop eco-innovations that may not be locally available. Meanwhile, SMEs face significant cost constraints, and authorities may consider providing grants to support their collaboration with international suppliers that can offer superior eco-innovative solutions. Last, but not least, policies and regulations that provide incentives for firms to eco-innovate needs to be a priority in public agendas.

5.3 Limitations of the research and future research lines

In this dissertation, several limitations have been identified, which in turn offer opportunities for further extensions and future research.

First, the first two papers of this thesis only analyze Spanish firms. Limiting the analysis to only one country can provide a narrow perspective on external knowledge sourcing. While the insights from the research are valuable, comparing the results with other countries can add a new dimension to the analysis and provide a broader understanding of the topic. Thus, it would be beneficial for future studies to compare the relationships between open innovation network diversity and innovation in Spain and other countries to determine if the results are consistent across different contexts. The same occurs when studying R&D offshoring strategies, as firms in other countries could follow distinct patterns in terms of R&D outsourcing from abroad.

Further, in Chapters 2 and 3 it was not possible to consider specific location advantages by concrete countries / regions, when studying international R&D outsourcing and

international collaboration-networks, due to data limitations. To address this issue, future research could explore the cultural and institutional distance between firms and countries.

Despite addressing the role of important contingencies in innovation studies (firm age and size), the study did not explore other potential moderators that could affect the relationships between different external knowledge sourcing strategies and innovation, such as the firm's absorptive capacity. Examining this variable could enhance our understanding on how firms benefit from diverse cooperation networks for innovating based on their internal capacity to absorb and exploit external knowledge (Zahra & George, 2002).

For future research it would be also important to consider the specific impacts of distinct partners on innovation outcomes, separately. Taking into account the specific individual effects of distinct partners can provide a more detailed analysis and enable the identification of valuable insights that would be missed if partners were not analyzed individually. This can lead to a more comprehensive understanding of the contribution of each partner and enhance the ability to leverage their strengths for better innovation outcomes.

Finally, some other methodological limitations are worth mentioning, as future studies could overcome these issues. In the first paper, unfortunately, the binary nature of the dependent variable did not provide information on how much companies spent in international R&D outsourcing. The limitation of a binary independent variable in research can be notable, as it oversimplifies the complexity of the phenomenon being studied. Thus, while binary independent variables are still helpful in research, there are steps that can be taken to improve their reliability. By using more complex or composite measures, and supplementing quantitative data with qualitative methods, further researchers can gain a more nuanced understanding and produce more accurate and reliable results. Hence, further research could provide a more accurate variable (i.e. exact amount) and verify whether the results hold. Moreover, following with the data limitations, the relationships explored on Chapter 4, regarding the impact of international explorative and exploitative collaborations and eco-innovation, should be analyzed in longitudinal studies, that will give us deeper information on this phenomenon than the cross-sectional study performed.

Finally, future studies could consider concrete sectors to provide valuable insights and deeper analyses on the topics analyzed in this dissertation.

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