New challenges in European innovation partnerships: SOEs, POEs and foreign MNEs during crises

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Abstract

Cooperation for innovation, not only enhances the innovative and economic performance of companies but also fosters growth and strengthens the resilience of firms in the realm of innovation activities. In this study, we delve into the cooperative activities of innovative Spanish companies with their European counterparts. We employ six logit models using panel data to scrutinize the impact of ownership on innovation cooperation and the determinants of collaboration across different phases of the business cycle, spanning from 2004 to 2016, which we divide into three sub-periods: the pre-crisis (2004–2007), the crisis (2008–2013), and the recovery (2014–2016). Throughout the businesses cycle, state-owned enterprises are the most prone to engage in cooperative innovation with European partners, while unaffiliated domestic firms are the least prone. Foreign subsidiaries clearly outperform unaffiliated domestic firms and slightly outperform domestic business groups in prosperous times, but do not outperform state-owned enterprises even during crises. The drivers of cooperation for innovation with European partners evolve over time, becoming particularly challenging during crises. The factors influencing cooperation with European universities exhibit distinct characteristics. The results contain policy and management implications.

1 Introduction

Firms are increasingly engaging in cooperation for innovation[1] with a variety of partners in order to access new technology, share expenditures, and reduce time to market. This strategy consists of the active participation of a firm in innovative activities

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[1] Also termed in the literature and in this article as collaboration for innovation.

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carried out either with other companies or with institutions, such as universities. The literature suggests that this is a worthy strategy. Firms that engage in cooperation for innovation are more likely than others to be innovative, and even to perform better and grow faster (Archibugi et al., 2013; Arvanitis & Bolli, 2013; Cantabene & Grassi, 2022; Fernández-Sastre, 2012; Freire & Gonçalves, 2022; Radicic et al., 2019; Srholec, 2014; Tether, 2002; Trigo & Vence, 2012; Vega-Jurado et al., 2009). According to certain authors, collaborations positively impact the internal R&D of the cooperative[2] firm, and vice versa (Colombo & Garrone, 1996; Veugelers, 1997). Most importantly, firms that are able to cooperate fare better than others during crises (D'Agostino & Moreno, 2018; Xie et al., 2022; Zouaghi et al., 2018). Even in the midst of the 2008 crisis, certain firms managed to boost their R&D investment for several reasons, one of which was their active participation in cooperation for innovation (Archibugi et al., 2013; Hansen & Nybakk, 2018; Holl & Rama, 2016; Paunov, 2012). Beyond its importance at the microeconomic level, cooperative innovation also contributes towards the development of the National Innovation System (NIS) and may be a tool of industrial policy (Freire & Gonçalves, 2022; Liu et al., 2017). International cooperation is often crucial for firms located in countries that are not at the forefront of science and technology since it enables them to access resources, knowledge, markets, and opportunities that may not be readily available within their own borders (Freire & Gonçalves, 2022). Collaboration with foreign universities may specifically help firms to transfer cutting-edge skills from academia into the industry. This scenario is particularly relevant for many peripheral European countries and emerging economies.

Mostly based on empirical evidence provided by the Community Innovation Survey (CIS) of the European Union (EU), the rich literature has now substantially increased our understanding of cooperation for innovation. Nonetheless, at least two aspects deserve further consideration. Despite the potential benefits of cooperation, it remains uncertain whether firms can successfully partake in collaborative endeavours, and what distinguishes those that can surmount such challenges during times of crisis. The existing literature seldom addresses these questions, with only a few exceptions (García-Sánchez & Rama, 2020, 2022; Wang, 2021), as most of the available evidence on cooperation primarily pertains to "normal" phases of the business cycle. Srholec (2015) notes that the majority of studies focused on cooperation for innovation lean on cross-sectional evidence, thus obscuring our understanding of the dynamics involved. This concern is also echoed by other scholars in the field of cooperation (Bianchi et al., 2019; Friedberg & Neuville, 1999). The creation of innovative networks across Europe stands as a crucial strategy for the EU in the realms of innovation, reindustrialization, and reducing global dependence. This is especially pertinent in critical sectors like defence, semiconductors, and sustainable energy.[3] However, there remains a notable lack of understanding concerning the dynamics of this cooperation. Therefore, there is a need for more longitudinal

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[2] In this article, the terms "cooperation" and "cooperative" refer to cooperation for innovation.

[3] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_ April 2023.

research in this area to address this limitation and gain a deeper understanding of the subject.

Secondly, the association of ownership and cooperation in the context of innovation has garnered significant attention from researchers (Arvanitis & Bolli, 2013; Cozza et al., 2018; Dachs et al., 2008; Ebersberger et al., 2011; Holl & Rama, 2014; Srholec, 2009; Veugelers & Cassiman, 2004). However, it remains incomplete as it seldom incorporates state-ownership into its analysis (García-Sánchez & Rama, 2022; Roud & Vlasova, 2020; Wang, 2021). Addressing this gap in the literature is crucial since stated-owned enterprises (SOEs) have traditionally played a major role in the economy of many European countries and emerging countries (Böwer, 2017; Bruton et al., 2015). Their numbers and significance have increased worldwide, since they are considered as a policy tool in times of crises (Gasperin, 2022; He et al., 2016; Nurgozhayeva, 2022; UNCTAD, 2021). However, their innovation strategies and, specifically, their cooperative behaviour have largely remained overlooked (Castelnovo, 2022; Gershman et al., 2016; González Álvarez & Argothy, 2019).

Finally, the EU has in place several programmes[4] to encourage collaboration between universities, business and other stakeholders of different EU member countries in order to bring to market new products and technologies. The promotion of collaborations between firms, especially multinational enterprises (MNEs), and universities was especially noticeable during the 2008 financial crisis (Gómez-Aguayo et al., 2024). However, dynamic analyses of partnerships with European universities are scarce or, in some cases, non-existent.

We strive to contribute towards filling the aforementioned gaps in the literature and, in doing so, the following questions are addressed. Which types of innovative firms are more likely to successfully navigate challenges during times of crisis and participate in cooperative efforts? Do drivers of cooperation change when a crisis erupts? Does ownership influence the probability that a firm participates in such partnerships during downturns? Are there specific drivers of innovation cooperation with European universities? Considering the aforementioned scarcity of analyses, our particular interest lies in comparing the behaviour of SOEs with that of Private-Owned Enterprises (POEs), national and multinational. The idea behind this inquiry is that SOEs are subject to unique institutional arrangements, constraints and stimuli that positively influence their cooperative behaviour.

In this article, panel data is employed to analyse a sample of firms located in Spain and their collaboration with European partners[5] (outside Spain) in 2004–2016, as well as the specific case of their partnerships with European universities. The period is divided into three sub-periods: a pre-crisis phase (2004–2007), a crisis phase (2008–2013), and a recovery phase (2014–2016). The first was characterised by high rates of growth, but Spain was subsequently badly hit by the 2008 financial

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[4] See, among others, https://eit.europa.eu/our-communities/eit-manufacturing, https://eit.europa.eu/our-communities/eit-digital, https://eic.ec.europa.eu/eic-funding-opportunities/business-acceleration-services_en October 2023.

[5] Includes EU-28 and EFTA countries.

crisis, and its recovery period started later than in other EU countries. The European Innovation Scoreboard labels Spain as a "moderate innovator".[6] During the crisis, Spanish enterprises often abandoned innovation (Brzozowski & Cucculelli, 2016; Holl & Rama, 2016; Zouaghi et al., 2018), and public finance devoted to innovation was substantially reduced (Cruz-Castro et al., 2018). The significant impact of the 2008 crisis on Spain's NIS makes it an intriguing case for the analysis of cooperation for innovation with European partners (CIEP) throughout the business cycle. On the other hand, the analysis of cooperation during the 2008 crisis may be of interest since this arrangement constitutes a coping strategy that can be applied to deal with other uncertain environments (Srholec, 2015; Wang, 2021). While different types of crises affect firms in varying ways, the pro-cyclical nature of innovation remains a consistent characteristic across diverse crisis scenarios (Archibugi et al., 2013; Brzozowski & Cucculelli, 2016; Busom & Vélez-Ospina, 2021; Friz & Günther, 2021; Geroski & Walters, 1995). This means that investment in innovative activities tends to decline during economic downturns and, conversely, increases during economic upturns. Given the recent succession of crises (e.g., the 2008 crisis, the COVID-19 pandemic, and war), understanding the cooperative behaviour of firms during downturns has become an urgent task.

In this article, two contributions are made to the literature. Being a pioneering study in dynamic analysis of intra-European cooperation across the business cycle, this article sheds light on how the determinants of cooperation undergo transformations under harsh economic conditions. Additionally, our findings underscore the significance of accounting for state ownership as a crucial factor in examining the interplay between ownership structures and cooperation dynamics.

In Sect. 2, we examine the relevant literature that forms the theoretical foundation and the context setting of our investigation, and articulate our hypotheses. Section 3 presents the methodology, and Sect. 4 the results and the discussion. Section 5 concludes.

2 Review of the literature and hypotheses

2.1 Defining international cooperation

International cooperation refers to partners located in different countries working together to develop new ideas, technologies, and products. Although there are exceptions (Arvanitis & Bolli, 2013; Cozza et al., 2018; De Faria & Schmidt, 2012; Ebersberger et al., 2011; Fernández-Sastre, 2012; Holl & Rama, 2014; Srholec, 2014), the majority of the available studies fail to distinguish between domestic and international cooperation for innovation. The question is important since cultural and institutional distance may raise specific impediments to international cooperation (Edwards-Schachter et al., 2013; Gershman, 2012; Posselt & Rauch, 2011;

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[6] https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_en October 2023.

Schmiele, 2012). Herein, the focus is on the collaboration of firms located in Spain with partners located in other European countries since, in this case, the institutional, regulatory, and business environment of such collaborations is likely to be relatively homogeneous.

Accessing new markets constitutes one of the goals of firms that engage in international cooperation (Arranz & Fernández de Arroyabe, 2008; Calvo, 2023; Edwards-Schachter et al., 2013), but not necessarily the most important. Analyses of EU firms signal size, absorptive capacity, appropriability, export experience, incoming spillovers, risk-sharing, and R&D cost-sharing as the major drivers of international cooperation (Arvanitis & Bolli, 2013; Barajas & Huergo, 2010; De Faria & Schmidt, 2012).

Certain authors note that cooperation with different types of partners, such as suppliers or universities, involves different drivers (Arranz & Fernández de Arroyabe, 2008; Badillo et al., 2017; Segarra-Blasco & Arauzo-Carod, 2008). For instance, in the specific case of partnerships with universities, it is crucial to consider the motivations of such institutions in collaborations. Perri et al. (2017) argue that partnerships initiated within research institutions, as commonly seen in industry-university collaborations, differ in motivations from those initiated within companies. The former are based on social ties and respond to "open science" incentives. With some exceptions (Rõigas et al., 2018; Segarra-Blasco & Arauzo-Carod, 2008), previous analyses of industry-university collaborations often fail to distinguish between local universities and those located abroad, and they also lack a dynamic perspective on these relationships.

2.2 Explaining cooperation

Our topic stands at the cross-roads of several lines of research. Three main theoretical approaches have sought to elucidate cooperation, each emphasizing distinct aspects: motives for cooperation, opportunities for cooperation, and conducive environments for establishing such arrangements. The resources-based-view (RBV) of the firm focuses on drivers of cooperation: firms cooperate in order to reduce the risks and costs of R&D, shorten the product life cycle, expand their product range, access new knowledge and new markets, and solve technical difficulties (Arranz & Fernández de Arroyabe, 2008; Bayona et al., 2001; De Faria & Schmidt, 2012; Edwards-Schachter et al., 2013; Miotti & Sachwald, 2003). This theoretical proposition has garnered empirical support. For example, in a study on a French sample, it was found that firms encountering impediments to innovation, particularly those related to financial challenges, tend to participate in cooperation for innovation (Antonioli et al., 2017). Similarly, the majority of prior studies have noted that knowledge-related challenges frequently motivate firms to embark on collaborative initiatives (Salazar-Elena et al., 2023).

However, other authors have argued that opportunities to collaborate should also be considered since possession of technical or commercial capital determines the attractiveness of a firm to potential partners (Ahuja, 2000). In choosing partners, companies appraise both their technical skills and their market potential (Bianchi et al., 2019;

García-Sánchez et al., 2017). When analysing industrial partnerships, Friedberg & Neuville (1999) observe that decisions are contingent upon the perceived quality of the firms involved. In the "market" for partnerships, they claim, organizations and their reputations are in competition. Each of these theories would yield distinct predictions regarding the role of crises as drivers of cooperation. The RBV suggests that firms confronting financial constraints for R&D funding or encountering market difficulties during crises are more inclined to engage in cooperation compared to their counterparts. Conversely, the argument focusing on cooperative opportunities suggests that companies facing fewer difficulties are more likely to collaborate than their counterparts, owing to their appeal to potential partners amidst challenging economic conditions.

Finally, the social capital theory identifies the environmental conditions that facilitate cooperation. Social networks provide an effective tool for the prevention of and punishment for opportunistic economic behaviour, and instead create trust between partners (Granovetter, 2005). In the context of partnerships, trust holds significant importance when it comes to managing uncertainty, as it signifies the ability to anticipate a partner's future actions (Vahlne & Johanson, 2021). Initially, the concept of social capital was linked to the idea of geographic proximity. However, in more recent literature, it has evolved to encompass the concept of international social capital. In the international scene, the concept incorporates a wide range of assets, such as an understanding of foreign-market institutions and of decision-making processes.

A variety of relationships and agreements provide opportunities to increase the social capital of a company and, consequently, its ability to cooperate, such as production subcontracting, common membership of associations, and professional connections (Granovetter, 2005). Interlocking directorates, which are formed when an individual participates in two or more boards of directors, also contribute towards creating social structures and trust (Aguilera, 1998; Cao et al., 2023; Wang, 2021). There are also transnational interlocking ties between firms, as demonstrated by Valeeva (2022) in her study of global cities connected through the exchange of transnational board members. She maintains that this corporate elite community is built upon well-established national networks of relationships. Structural holes may also create opportunities for actors who are able to bridge such holes. These are gaps between unconnected groups of economic players (Saglietto et al., 2020). A third player may obtain intermediation benefits by linking those unconnected groups, and the arrangement may create new opportunities since complex networks may generate a greater variety of ideas and resources. Therefore, extended networks might display both direct ties and indirect ties between players through an intermediary (Saglietto et al., 2020). The obtaining of a subsidy may signal the receiver as a valuable potential partner and, consequently, may also mitigate uncertainty and facilitate collaboration (Bianchi et al., 2019).

2.3 Cooperation and crises

Even though cooperation appears to be a resilience-enhancing factor, there has been a noticeable lack of comprehensive analysis concerning the collaborative behavior of firms during periods of crisis (D'Agostino & Moreno, 2018). The few available empirical studies on this subject reveal that firms tend to exhibit either

no countercyclical inclinations or, in some cases, a reduction in their cooperative initiatives during crises (Azagra-Caro et al., 2019; Hoffmann et al., 2017; Lincoln et al., 2017). Cooperation comes with associated costs, risks, agency problems and the challenge of identifying reliable partners, which can become even more daunting in times of crisis (Edwards-Schachter et al., 2013; Friedberg & Neuville, 1999; Williams & Ecker, 2014). Based on the limited available evidence, it appears that fostering domestic cooperation poses greater challenges in times of economic hardship; nevertheless, firms with cooperative experience demonstrate a resilience that enables them to maintain a cooperative stance (García-Sánchez & Rama, 2022). Persisting in cooperative activities has the potential to enable a company to expand its international social capital and enhance its managerial capabilities for collaboration, thus enabling it to overcome challenges. However, to the best of our knowledge, this particular question has not yet been explored in an international context. The primary obstacle seems to be the scarcity of available panel data.

Previous research suggests that cooperation with universities specifically may exhibit a different logic throughout the business cycle. For instance, a bibliometric study involving Spanish organizations, including both firms and universities, analysed data from 2000 to 2016 and found that university-industry co-authorships clearly exhibited countercyclical characteristics (Gómez-Aguayo et al., 2024). In our view, this suggests that collaborations between Spanish firms and universities, whether domestic or international, may also be countercyclical, as co-publications, to some extent, reflect the presence of industry-university collaborations. However, not all collaborations result in publications, and to the best of our knowledge, the specific evolution of industry-university cooperation throughout the business cycle has not been explored.

2.4 Cooperation and ownership

This subsection explores whether various types of ownership act as catalysts for international cooperation.

2.4.1 Group ownership

A business group consists of two or more legally defined enterprises under common ownership. Groups may be national or multinational. Group membership facilitates the engagement of a firm in cooperative innovation since groups provide access to greater resources, such as finance, equipment, and facilities (Arranz & Fernández de Arroyabe, 2008; Arvanitis & Bolli, 2013; Molero & Heijs, 2002). In contrast, unaffiliated firms are, in most cases, SMEs that experience difficulties in establishing cooperative relationships (Belderbos et al., 2006; Ebersberger et al., 2011; Radicic et al., 2019; Segarra-Blasco & Arauzo-Carod, 2008). Therefore, we expect that business groups are more likely than unaffiliated firms to sustain successful CIEP during downturns.

2.4.2 Foreign ownership

The concept of international cooperation in the context of foreign ownership has evolved through the convergence of studies on cooperation and the internationalization of R&D (Barajas & Huergo, 2010). Recent International Business (IB) literature highlights the network-like nature of international R&D activities (Papanastassiou et al., 2020), emphasizing that international innovation activities can be viewed as a distinct form of Foreign Direct Investment (FDI) (Schmiele, 2012). Calvo (2023) adds that firms can internationalize through cooperation, especially in knowledge and capital-intensive services, without necessarily engaging in FDI.

The impact of foreign ownership on cooperation has been extensively studied, often comparing foreign subsidiaries (FS) with domestic business groups (DBG) rather than unaffiliated domestic firms, to account for their inherent business group structures. Studies generally find that foreign ownership tends to increase international cooperation but can reduce domestic collaboration (Ebersberger et al., 2011). This pattern holds across various European countries including Belgium (Veugelers & Cassiman, 2004), Italy (Cozza et al., 2018), and several other EU nations (Srholec, 2009).

However, FS in Spain show a tendency toward local cooperation rather than international, especially in comparison to DBG (Fernández-Sastre, 2012; Holl & Rama, 2014; Álvaro – Moya et al. 2022). This may be influenced by the characteristics of the host country and the MNEs' objectives. FS in less developed countries, such as Portugal (De Faria & Schmidt, 2012), often use these locations as bases for broader European innovation activities due to local partnering challenges (Ebersberger et al., 2011; Srholec, 2009).

During crises, the relationship between foreign ownership and cooperation becomes complex. Studies suggest that during the 2008 financial crisis, FS in Italy and Latin America reduced collaboration with domestic partners (Brancati et al., 2017; Paunov, 2012). In Spain, FS in Information and Communication Technologies performed better than domestic POEs due to easier access to international finance (García-Sánchez & Rama, 2020). However, FS in Spanish manufacturing and services maintained higher levels of local cooperation than unaffiliated domestic firms, but not more than DBG; SOEs proved more capable than POEs, domestic or foreign, in sustaining domestic collaboration (García-Sánchez & Rama, 2022). We expect that foreign subsidiaries' ability to secure international credit facilitated international cooperation during the crisis, though their focus on local partnerships sometimes counterbalanced this effect.

In the realm of institutional theory, a parallel domain to the aforementioned literature has emerged, investigating the relationship between state ownership and economic efficiency. This particular strand of research compares SOEs and POEs, but, as noted, investigations in terms of innovation and cooperation have frequently been overlooked (Introduction). We contend that to attain a comprehensive understanding of the ownership structures influencing choices in innovation collaboration, it is crucial to integrate institutional theory. This is particularly relevant due to the substantial presence of state-ownership as a significant ownership structure in many economies. We address this question below.

2.4.3 State-ownership

According to the Organisation for Co-operation and Development (OECD), SOEs are enterprises where the state has substantial control through full, majority, or significant minority ownership (Medina et al., 2022). Within Europe, their presence is significant in countries such as France, Italy, Sweden, and in new-member countries of the EU. The goals of SOEs and POEs differ. Those of SOEs go beyond mere profit maximisation to also include societal goals, diversification of the economy, industrial policy, monopoly control, support to new technologies, knowledge diffusion, green transition, and defence (Antonelli et al., 2014; Archibugi & Mariella, 2021; Benassi & Landoni, 2018; Gershman et al., 2019; Palmberg, 2002; Steffen et al., 2022; Tönurist & Karo, 2016). In Europe, most SOEs have evolved towards more efficient forms of corporate organisation (He et al., 2016). According to the aforementioned authors, reform often entailed governance structures of a more complex character with new shareholders having a role to play in SOEs internationalization.

Are SOEs innovative? Landoni (2020) contends that the role of SOEs in innovation has been largely underestimated and certain empirical studies support this view. Italian business history (Antonelli et al., 2014; Gasperin, 2022) and case studies on Russian and Western European SOEs suggest that these firms are able to innovate (Archibugi & Mariella, 2021; Benassi & Landoni, 2018; Gershman et al., 2019; Palmberg, 2002; Rama & Ferguson, 2007). Furthermore, quantitative studies that focus on EU firms support the view that SOEs are more prone to innovating than are POEs, at least in certain sectors (Castelnovo, 2022; Steffen et al., 2022). Moreover, the institutional literature suggests that R&D spending tends to decrease when SOEs are privatised due to the reorientation of these firms to short-term benefits and the new managers' lack of interest in basic research (Sánchez Carreira & Vence Deza, 2009).

The literature suggests several explanations behind the innovativeness of SOEs. Due to their long-term perspective on profit-making ("patient capital") and their easier access to R&D funding, these companies are more prone than POEs to invest in basic research and in technological fields that are risky and/or slow to produce results (Antonelli et al., 2014; Landoni, 2020; Ortega, 2016; Li et al., 2022). Furthermore, coordination with governments provides SOES with strategic advantages in assessing linkages between different industries and knowledge fields (Benassi & Landoni, 2018).

Empirical evidence on their cooperative activities is still scarce. However, according to Benassi & Landoni (2018), SOEs frequently network with other organisations and, in doing so, constitute vehicles of possible recombination of knowledge. Case studies suggest that Russian and Western European SOEs participate in domestic cooperation for innovation with both domestic POEs and universities; and, in the West, also with FS (Alonso-Gil & Vázquez-Barquero, 2010; Antonelli et al., 2014; Calvo, 2019; Gershman et al., 2019; López et al., 2002; Rama & Ferguson, 2007). Recently, a few quantitative studies establish that compared to POEs, domestic or foreign, SOEs are more predisposed to cooperate *locally* for innovation (García-Sánchez & Rama, 2022; Roud & Vlasova, 2020; Wang, 2021). Within the EU, certain institutional mechanisms are at work to promote the engagement of

SOEs in European partnerships: for instance, institutional intermediaries (Landoni, 2018) and organisations in charge of public purchases (Callado-Muñoz et al., 2022). Several case studies report on the participation of SOEs in international cooperative networks (Abramovsky et al., 2009; Archibugi & Mariella, 2021; Benassi & Landoni, 2018; Calvo, 2023; Gershman, 2012; López et al., 2002; Sanz Menéndez et al., 1999) but, to the best of our knowledge, no systematic quantitative evidence is available.

In the international arena, SOEs can be perceived as an "institutional exception" (Orr & Scott, 2008) due to their distinct approach to investment return and a longer timeframe for transforming an invention into a marketable product ("patient capital"). Different logics and rules can potentially create cultural challenges with prospective foreign partners. Nonetheless, as stated in the discussion SOEs also bring certain advantages to the table as potential partners.

2.5 Spanish SOEs

Since 1985, non-profitable Spanish SOEs were sold mainly to foreign investors (Arocena, 2006), but the state preserved a certain degree of control over profitable SOEs. SEPI (State Corporation of Industrial Participation) remains a major state-owned group, with direct majority participation in 14 firms, minority participation in 10, and indirect control in over 100.[7] Indirect control involves a majority-owned SOE actively participating in the capital of another company.

As mentioned, a crucial requirement for a company to engage in collaboration is social capital. In this context, we argue that diverse factors may have contributed to the accumulation of social capital by Spanish SOEs, both domestically and internationally. Privatisations were sequential and involved relatively small public-offering selling blocks (Etchemendy, 2004). According to the aforementioned author, purchases by institutional investors and minority shareholders were preferred since such types of investors are less likely than large foreign MNEs to demand abrupt changes in corporate policies. The main objectives of these measures were to retain control of key sectors in Spanish hands and to prevent hostile foreign takeovers (Arocena, 2006). However, these measures also gave rise to significant inter-firm connections. Inter-firm linkages were promoted through cross shareholdings between companies and often included large banks. (Arocena, 2006; Bulfone, 2019; Calvo, 2019; Cuervo-Cazurra, 2018). These types of social networks may have a positive impact on innovation by assisting companies in obtaining R&D funding (Cao et al., 2023). Spanish SOEs have also been able to acquire substantial social capital due to their central position in subcontracting networks (Alonso-Gil & Vázquez-Barquero, 2010; Ortega, 2016; Rama & Ferguson, 2007; Rodríguez-Ruiz, 2015). Furthermore, interlocking has been a popular practice even preceding privatization policies (Aguilera, 1998; Calvo, 2019).

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[7] https://www.sepi.es/es, October 2023.

Second, Spain's economy stands out for its remarkable openness and extensive international connections. Between 2000 and 2018, Spain was the second most open economy in the Eurozone, with Germany leading the way (Xifré, 2019). Additionally, an analysis conducted by Valeeva (2022) spotlighted Madrid, Vienna, and Frankfurt as three cities of particular note for their high "betweeness" rankings. These cities play significant roles as hubs for interlocking directorates within their respective countries and the broader European context. Simultaneously, they serve as key brokers, connecting European corporate networks with elites from various global regions. In the case of Madrid, these connections extend to Latin American elites. This situation makes certain major Spanish companies attractive partners for third parties looking to enter the Spanish market, Latin American markets, or both (Calvo, 2023; Rama & Ferguson, 2007). It is important to note that while SOEs were not the sole beneficiaries of these developments in acquiring international social capital, they were pioneers in this regard. As of the 1950s, the only major Spanish companies that ventured into the international arena were SOEs (Binda, 2012). Indeed, this early exposure to international markets could have facilitated the establishment of personal contacts in foreign countries and bolstered their international experience.

The discussion implies that institutions and public policies have been instrumental in assisting Spanish SOEs in gaining international experience and social capital. This, in turn, could enhance their participation in CIEP.

Based on the discussion, the following hypotheses are proposed:

Hypothesis 1: The 2008 crisis in Spain acted as a dissuader for firms engaging in cooperation for innovation with European partners, an effect tempered by the firms' prior cooperative experiences.

Hypothesis 2: The ownership structure of a firm influences its ability to maintain cooperation during a crisis.

H2.a: Group ownership positively influences the ability of a firm to maintain cooperation during a crisis.

H2.b: Foreign ownership positively influences the ability of a firm to maintain cooperation during a crisis.

H2.c: State-ownership positively influences the ability of a firm to maintain cooperation during a crisis.

Hypothesis 3: The conditions for participating in intra-European cooperation for innovation become more challenging during a crisis.

Hypothesis 4: Cooperation with European universities displays specific drivers.

3 Methodology

The PITEC database utilised herein is annually collected by the Spanish National Statistics Institute (INE) and constitutes the Spanish contribution to the CIS of the EU. This database has the advantage of providing panel data and of being a mandatory survey. The balanced panel includes observations for companies that were continuously active in Spain's manufacturing and services during the entire 2004–2016 period. As stated, this period is subdivided into three sub-periods in accordance with the Spanish GDP path (García-Sánchez & Montes-Luna, 2022). Panel data for 2017 up to the present day has not yet become available. Those not engaged in innovation are not considered, as the survey specifically queries innovating companies regarding cooperation. In this context, innovators are defined as those who have introduced product or industrial process innovation, are currently involved in innovative endeavours, or have conducted innovation activities within the survey period and the two preceding years. This is a common feature of CIS surveys. According to the questionnaire, cooperation for innovation consists of two different organisations joining forces to share and develop knowledge. This definition excludes the acquisition of R&D services via the market or via R&D outsourcing but does include R&D collaboration. The database distinguishes between unaffiliated companies and companies belonging to a business group. Within the latter, information is provided regarding the location of the headquarters of the company. If it is located in a foreign country, then it is classified as an FS (*multinational*), otherwise it is classified as a DBG (*dom_group*). Companies not belonging to a group are classified as unaffiliated domestic firms (*unaffil*). The PITEC questionnaire also enquires as to whether the company is a SOE (*state-owned*). Firms are asked to indicate the geographic location of the partner. Collaboration with partners located in European countries is selected for analysis. The question refers to the physical location of the partner, and not to their nationality. The database includes information on the types of partners (clients, suppliers, competitors, universities, etc.). Intra-group cooperation is excluded.

Our research strategy consists of an iterative estimation of logit models with panel data (estimations are calculated with inferences based on robust panel standard errors):

$$P(CooperaEu) = 1|X_i^T, \beta^T, \alpha_i) = \Lambda(\alpha_i + \beta^T X_i^T) \tag{1}$$

$$P(CooperaEu\_uni) = 1|X_i^T, \beta^T, \alpha_i) = \Lambda(\alpha_i + \beta^T X_i^T) \tag{2}$$

The correlation matrix and subsequent Variance Inflation Factor (VIF) test indicate no significant multicollinearity issues. The mean VIF for different models ranges between 1.70 and 1.80, with all independent variables having VIFs below 5. Specifically, 60% of the variables have VIFs under 1.5, 80% have VIFs under 2.55, and only 5% have VIFs between 3 and 4.7. Detailed results are available upon request.

Following the methodology of Cassiman & Veugelers (2000), we first pool the data on cooperative agreements to uncover common characteristics of the cooperation decision. Next, we perform our analysis specifically for cooperative agreements with European universities.

The definition of the variables is in Table 5 (Annex).

Dependent variables: *CooperaEu*. An estimation is performed for determinants of CIEP in boom, crisis, and recovery phases. This is a dummy variable. Two challenges arise at this point: first, the use of a dummy variable has limitations, as it may obscure variations in cooperative partnerships regarding their duration, intensity or determinants. Second, there is a potential issue of sample selection bias, as noted in previous studies (Bayona et al., 2001; Cassiman & Veugelers, 2000; Colombo & Garrone, 1996; Kaiser, 2002; Piga & Vivarelli, 2003). This issue cannot be resolved with the available data because questions about cooperation are only asked to innovators (refer to the above definition of innovators). As a result, our analysis is limited to examining the determinants of cooperation among innovative firms. Both are common challenge faced by all studies based on CIS-type surveys (see, for instance, Cassiman & Veugelers, 2000; Belderbos et al., 2015; Dachs et al., 2008; Veugelers & Cassiman, 2004). Nevertheless, as stated, our database does provide data regarding collaborations by type of partner. To illustrate the potential differences in these arrangements, we specifically analysed collaborations with European universities. Due to space constraints, it is impossible to analyse all seven types of partnerships here. Partnerships with universities illustrate the distinct characteristics of industry-university collaborations. Unlike other types of partners, universities might place a greater emphasis on technological expertise and research capabilities when engaging in cooperation (Perri et al., 2017). Consequently, we also estimate the determinants of CIEP during boom, crisis, and recovery phases, specifically in the context of cooperation for innovation with European universities.

CooperaEu_uni, our other dependent variable, is defined in Table 5 (Annex).

Variables of interest. The variables of primary interest are those that delineate the firm's ownership structure: *multinational*, *unaffil* and *state-owned*, with our reference category being DBG (refer to the above definitions).

Building on the literature (Sect. 2), the model also incorporates the following variables to examine the determinants of cooperation and their changes over time.

Eu_persistence: we analyse the focal firm's experience in cooperating with European partners, as an increase in cooperative activities may reflect a cumulative effect rather than simply a reaction to the crisis (Belderbos et al., 2015; García-Sánchez & Rama, 2020; Srholec, 2016). Hence, the need to control for persistence. We also control for cooperative accumulated experience in other geographic settings (*Local_persistence* and *US_persistence)*.

r_turn. To control for firm size, we use a base 100 index of turnover compared to the industry average at the two-digit level. We opted against using the logarithm of turnover, a common practice, to avoid potential multicollinearity issues.

We also control for the innovativeness of the firm. Intensity is indicated by an "i" before the name of the variable. The following dummy variables signal whether the focal firm is more innovation intensive than the average firm that operates in its two-digit industry. Hence, our approach brings a novel element by comparing the

focal firm to the average firm within its industry, distinguishing it from the methodologies employed in previous studies. By comparing with the two-digit industry average, we can eliminate the influence of size and other industry-specific effects and trends when assessing companies operating in diverse industries. When the variables display a positive, statistically significant coefficient, this means that firms that are more innovative than average are prone to engaging in CIEP. The dataset includes details about the company's engagement in the two-digit industry. The classification is based on the Spanish Clasificación Nacional de Actividades Económicas (CNAE), which is comparable to the NACE Rev classification used in EU statistics. Except for a few cases (for instance, Ebersberger et al., 2011; García-Sánchez & Rama, 2022), the majority of prior examinations on collaborative innovation focus on a single innovation factor, typically internal R&D expenditures. The complementary theory asserts that conducting internal R&D complements engagement in cooperation, as having absorptive internal capacity is essential for capitalizing on external knowledge. However, this theory is not consistently substantiated in empirical studies (Vega-Jurado et al., 2009). Moreover, the aforementioned authors indicate the importance of approaching innovation from various perspectives. For instance, R&D "per se" may be insufficient to capture innovation in small and medium-sized enterprises (SMEs) and firms active in low-tech industries (Radicic et al., 2019). In accordance with the Oslo Manual, we focus on the following types of innovation expenditures: internal R&D expenditures, external R&D and "other innovative expenditures," which encompass all expenditures on innovative activities excluding R&D, such as those incurred for marketing a new product.

In accordance with Cohen & Levinthal (1990), the number of R&D employees (*i_RDpers)* indicates whether the focal firm possesses a higher absorptive capacity compared to the average company within its two-digit industry. The share of products new to the market (*i_newmar*) and new to the enterprise (*i_newent)* in turnover, point to the capacity of the firm to perform radical and incremental innovation (Zouaghi et al., 2018). *i_ownfund* measures the share of its own resources in the total resources used by the company to finance R&D.

The spillover variables measure the extent to which the firm employs different types of incoming spillovers to innovate. Knowledge spillovers involve the dissemination of information, insights, or innovations that were originally generated by one party and subsequently benefit other parties. These spillovers can be a result of various interactions, such as collaboration, communication, networking, or even competition. According to a review of the literature, firms that value external information are more likely to engage in cooperation (Freire & Gonçalves, 2022). The interaction between various knowledge flows (spillovers) and collaboration for innovation is complex (Cassiman & Veugelers, 2000). Hence, the necessity to control for different types of spillovers. In the PITEC questionnaire, firms rated the importance of available information for their innovation activities from the following sources: (i) the company itself and its business group; (ii) universities and research centres; (iii) sources of knowledge dissemination, such as scientific journals, conferences and associations; and (iv) from competitors. A positive, statistically significant coefficient indicates that firms enjoying a high capacity to absorb spillovers are prone to engaging in CIEP.

Table 1 Cooperation for innovation with European partners, by phase of the business cycle: boom (2004–2007), crisis (2008–2013) and recovery (2014–2016). Source: Authors' own based on PITEC data

Cooperate	Business cycle phase			Total
	Boom	Crisis	Recovery	
No: freq	6123	9141	4147	19,411
%	88.0	86.7	84.4	86.6
Yes: freq	836	1401	764	3001
%	12.0	13.3	15.6	13.4
Total: freq	6959	10,542	4911	22,412
%	100.0	100.0	100.0	100.0

Pearson $Chi^2(2) = 31.3495$ $Pr = 0.000$

Cramer's $V = 0.0374$

We also examine various challenges faced by innovators. PITEC identifies 11 distinct obstacles to innovation encountered by the firm over the past two years. Through factor analysis, we aggregated the data related to these 11 obstacles and subsequently re-categorized them into four groups: technological, economic, market, and competition obstacles. These obstacles are assessed using a 1–4 Likert scale, allowing for a comprehensive evaluation of their impact on the firm's innovation efforts. The independent variables employed in the model signal difficulties due to: i) insufficient information or skilled personnel (*h_knowl_diff*); ii) high costs of innovation (*h_eco_diff*); iii) a low demand for innovation (*h_mark_diff*); and iv) the presence of incumbents in the market (*h_comp_diff).

Markets. *mk_local/regl*: this dummy variable indicates whether the firm operates in a local/regional market (within Spain). *mk_Eu* indicates whether the firm exports to European markets (EU, EFTA and associated countries) and *mk_other_international* whether it exports to other international markets (outside Europe).

i_fund_EU: this variable shows whether the firm receives above-average funding for innovation from the EU. The majority of EU programmes require cooperation among firms and institutions of several member countries to grant R&D funding. Therefore, the use of a dummy variable as a proxy for subsidies would not be suitable since an automatic association between grants and the propensity to cooperate would exist. Instead, following Bianchi et al. (2019), the amount of funding awarded to the focal firm is considered. By taking it a step further, it is compared to the average EU funding received by firms in the same Spanish two-digit industry. Following the above-mentioned authors, it is assumed that the variable signals the market and technological value of prospective Spanish partners *vs.* that of their competitors.

We also account for sectors within the Spanish economy.

4 Results and discussion

4.1 Descriptive statistics

Our sample comprises 31,031 observations. Throughout the 2004–2016 period, SOEs were the companies most prone to cooperating with European partners (29%), and unaffiliated firms the least prone (6%). Cooperative firms accounted for approximately 20% each of DBG and FS. The data reveal a notable trend in the involvement of firms in CIEP and demonstrates that the percentage of firms engaged in such partnerships increased from 12% before the crisis to 13% during the crisis and further to 16% during the recovery (Table 1). The Pearson's χ^2 and Cramer's V indicate an association between cooperation engagement and the business cycle phase.

This suggests that even in the context of a "moderate innovator" like Spain, there is a growing inclination among firms to participate in such cooperative arrangements. The key question that arises from this observation is whether this surge in the percentage of cooperative firms was a reactive response by companies, adopting cooperation as a resilience strategy during the crisis. This question is addressed below.

Next, we examine the progression of the average number of diverse European partners (e.g., clients, suppliers, universities) per firm. The number of partner types increased during the crisis, followed by a decrease during the recovery period (Table 2). Pearson's χ^2 and Cramer's V indicate a significant association between

Table 2 Average number of European partnership types, by phase of the business cycle (2004–2016). Source: Authors' own based on PITEC data

Number of different types of partners	Business cycle phase			Total
	Boom	Crisis	Recovery	
None: freq	6123	9141	4147	19,411
%	88.0	86.7	84.4	86.6
1: freq	443	671	392	1506
%	6.4	6.4	8.0	6.7
2: freq	210	357	154	721
%	3.0	3.4	3.1	3.2
3: freq	104	165	93	362
%	1.5	1.57	1.9	1.6
4: freq	49	100	49	198
%	0.7	0.9	1.0	0.9
5: freq	24	78	48	150
%	0.3	0.7	1.0	0.7
6: freq	6	30	28	64
%	0.1	0.3	0.6	0.3
Total: freq	6959	10,542	4,911	22,412
%	100.0	100.0	100.0	100.0

Pearson Chi^2(12) = 70.2377 Pr = 0.000

Cramér's V = 0.0396

the average number of partner types and the phase of the business cycle. Furthermore, a Bonferroni test (not displayed) reveals statistically significant differences between the crisis and the boom, as well as between the crisis and the recovery phases. There appears to be a phenomenon of deepening cooperative arrangements, wherein firms with prior experience in cooperation extended their engagement to include new types of partners when the crisis emerged.

4.2 Results and discussion

4.2.1 Effects of the crisis

We begin by examining whether the sample firms turned to CIEP in response to the crisis. In the analysis spanning the entire period from 2004 to 2016, the variable representing the in-crisis period in Spain *(crisis 2008–2013)* exhibits a positive coefficient significant at the 5% level, suggesting that the downturn triggered CIEP (Table 3, column 2). However, when introducing *Eu_persistence* and variables indicating the persistence of cooperation in other geographic areas (*Local_persistence* and *US_persistence*) into the model (Table 3, column 3), the coefficient of *crisis 2008–2013* becomes negative and statistically significant at 5%. This indicates that extraordinarily critical circumstances in the home country did not act as a trigger for CIEP. In fact, the crisis itself had a detrimental impact on firms' likelihood to collaborate with European partners when the model controls for prior experience. This is in accordance with previous studies on the negative effect of crises on cooperation (subsection 2.1). Instead, the growing engagement of the sample companies in CIEP can be attributed to their accumulated cooperative expertise over the entire period. In their review of the literature, Freire & Gonçalves (2022) find that, while initially firms may find it difficult to cooperate with foreign partners, such a difficulty dissipates with time. On the other hand, it is plausible that this experience leads to a deepening of cooperation and an increase in network complexity during the crisis (as discussed in the previous subsection). Nevertheless, due to space constraints, we are unable to explore this concept further in this section. Persistence has a particularly significant impact on CIEP for firms with prior experience in, specifically, the European area. Throughout the entire period, these firms had, on average, an 11% higher likelihood of participating in CIEP (Table 3, column 4). Hypothesis 1 is supported.

4.2.2 The role of ownership

Table 4 shows the dynamics of cooperation with all types of European partners (columns 1, 3 and 5) and, specifically, with European universities (columns 2, 4 and 6). The results of estimations shown in columns report marginal effects (dy/dx). Results for the pre-crisis or boom period are in column 1 for all types of partnerships and on column 2 for, specifically, partnerships with European universities. Those for the period of crisis are in columns 3 and 4, respectively, for all partnerships and for partnerships with universities. Finally, results for the recovery period are in columns

Table 3 Determinants of cooperation for innovation with European partners (outside business group), 2004–2016. Source: Authors' own from PITEC data

	Apparent				Persistence—adjusted			
	Coef. (se)	Sig. (1)	Margins (se)	Sig. (1)	Coef. (se)	Sig. (1)	Margins (se)	Sig. (1)
r_turn	0.00048 (0.000)	***	0.00003	***	0.00046 (0.000)	***	0.00003	***
i_newmar	0.34763 (0.077)	***	0.01988	***	0.39525 (0.083)	***	0.02319	***
mk_EU	0.62281 (0.168)	***	0.03091	***	0.70999 (0.175)	***	0.03566	***
mk_other_intrnational (outside Europe)	0.91536 (0.160)	***	0.04803	***	0.92336 (0.163)	***	0.04860	***
i_intRDexp	0.16246 (0.094)	+	0.00929	+	0.26636 (0.100)	**	0.01563	**
i_extRDexp	0.42276 (0.082)	***	0.02417	***	0.41191 (0.086)	***	0.02417	***
i_other_innov_exp	0.33701 (0.072)	***	0.01927	***	0.42494 (0.077)	***	0.02494	***
i_RDemployees	0.42656 (0.096)	***	0.02439	***	0.26847 (0.102)	**	0.01576	**
spill_int	0.44428 (0.079)	***	0.02540	***	0.43586 (0.084)	***	0.02558	***
spill_tech	0.74485 (0.143)	***	0.04259	***	0.70052 (0.150)	***	0.04111	***
spill_dissem	0.23671 (0.137)	+	0.01353	+	0.23548 (0.145)		0.01382	
spill_valuechcompet	0.48160 (0.089)	***	0.02754	***	0.44719 (0.094)	***	0.02624	***

Table 3 (continued)

	Apparent				Persistence—adjusted			
	Coef. (se)	Sig. (1)	Margins (se)	Sig. (1)	Coef. (se)	Sig. (1)	Margins (se)	Sig. (1)
h_knowl_diff	0.37071	*	0.02120	*	0.38022	*	0.02231	*
	(0.160)				(0.168)			
h_comp_diff	0.15708	+	0.00898	+	0.09211		0.00541	
	(0.086)				(0.091)			
i_fund_EU	1.93314	***	0.11054	***	1.91691	***	0.11249	***
	(0.149)				(0.156)			
Crisis 2008–2013	0.15626	*	0.00866	*	− 0.16280	*	− 0.00949	*
	(0.068)				(0.078)			
Recovery 2014–2016	0.42498	***	0.02468	***	0.07088		0.00432	
	(0.081)				(0.091)			
State-owned	1.82723	***	0.17260	***	1.17802	**	0.10744	**
	(0.477)				(0.382)			
Unaffil	− 1.80893	***	− 0.10132	***	− 1.32668	***	− 0.07635	***
	(0.180)				(0.145)			
Dynamic (dynamic and RTA)	− 0.33942		− 0.02057		− 0.31771	+	− 0.01937	+
	(0.224)				(0.178)			
Withdrawal (non-dynamic and non-RTA)	− 0.76834	+	− 0.04330	+	− 0.48276		− 0.02850	
	(0.416)				(0.327)			
other_services	− 1.58735	***	− 0.07740	***	− 0.94321	***	− 0.05088	***
	(0.273)				(0.220)			
local_persistence					0.75339	***	0.04421	***
					(0.084)			

Table 3 (continued)

	Apparent				Persistence—adjusted			
	Coef. (se)	Sig. (1)	Margins (se)	Sig. (1)	Coef. (se)	Sig. (1)	Margins (se)	Sig. (1)
Eu_persistence					1.83178	***	0.10750	***
					(0.106)			
US_persistence					0.49382	*	0.02898	*
					(0.229)			
Constant	−4.78866	***			−4.84740	***		
	(0.249)				(0.235)			
lnsig2u	1.84209	***			1.16138	***		
	(0.072)				(0.092)			
Prob > chi^2	0.000				0.000			
N. of cases	22411				20740			
sigma_u	2.51192				1.78727			
Rho	0.65729				0.49263			

Variables i_newfirm, mk_local/regional, i_own_fundRD, h_eco_diff, h_mark_diff, multinational, and challenge sector type as well as KIBS do not exhibit statistically significant effects. Marginal effects (Apparent and persistence-adjusted)

(1) +p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001

Table 4 Drivers of cooperation for innovation with European partners throughout the business cycle (marginal effects): comparative analysis all-partners vs. universities. Source: Authors' own from PITEC data

	Boom (2004–2007)				Crisis (2008–2013)				Recovery (2014–2016)			
	All partners		Universities		All partners		Universities		All partners		Universities	
	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)
r_turn	0.00003	***	0.00001	*	0.00003	***	0.00001	***	0.00004	***	0.00002	**
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
i_newmar	0.02270	*	0.00445		0.02520	***	0.00553		0.01613		−0.00841	
	(0.202)		(0.439)		(0.127)		(0.246)		(0.186)		(0.393)	
i_newent	0.01115		0.00260		0.01189	+	0.00117		0.00900		0.00836	
	(0.193)		(0.410)		(0.121)		(0.237)		(0.170)		(0.341)	
mk_Eu	0.02834	+	0.00835		0.04736	***	0.01597	**	0.01286		0.00982	
	(0.416)		(1.004)		(0.262)		(0.510)		(0.382)		(0.690)	
mk_other_international (outside Europe)	0.03956	*	0.01762	*	0.05075	***	0.01752	**	0.05027	**	0.00791	
	(0.364)		(0.872)		(0.247)		(0.486)		(0.331)		(0.630)	
local_persistence	0.04715	***	0.00615		0.05755	***	0.00955	*	0.05623	***	0.01008	
	(0.217)		(0.484)		(0.132)		(0.291)		(0.183)		(0.405)	
Eu_persistence	0.04988	**	0.01728	**	0.12106	***	0.02865	***	0.14708	***	0.03456	***
	(0.379)		(0.607)		(0.177)		(0.293)		(0.234)		(0.406)	
US_persistence	−0.02480		0.02269	*	0.04608	*	0.01643	**	0.06810	*	0.02108	*
	(0.589)		(0.902)		(0.343)		(0.414)		(0.540)		(0.657)	
i_intRDexp	0.00821		−0.00097		0.00619		0.01022	*	0.03419	**	0.00651	
	(0.235)		(0.496)		(0.150)		(0.296)		(0.209)		(0.422)	
i_extRDexp	0.02119	*	0.01118	*	0.02592	***	0.00380		0.03367	**	0.00660	
	(0.207)		(0.432)		(0.129)		(0.244)		(0.189)		(0.365)	
i_otherinnovexp	0.03847	***	0.00874	*	0.02126	***	0.00464		0.03348	***	0.00756	
	(0.186)		(0.391)		(0.116)		(0.220)		(0.170)		(0.329)	

Table 4 (continued)

| | Boom (2004–2007) | | | | Crisis (2008–2013) | | | | Recovery (2014–2016) | | | |
| | All partners | | Universities | | All partners | | Universities | | All partners | | Universities | |
	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)
i_RDemployees	0.01597		0.00247		0.03025	***	0.00625		−0.01051		0.00850	
	(0.242)		(0.497)		(0.159)		(0.314)		(0.212)		(0.437)	
spill_int	0.02448	**	0.01213	*	0.02020	**	−0.00111		0.04537	***	0.00122	
	(0.204)		(0.491)		(0.130)		(0.267)		(0.187)		(0.383)	
spill_tech	0.07513	***	0.02924	***	0.03256	**	0.02465	***	0.06271	***	0.04446	***
	(0.409)		(0.681)		(0.228)		(0.333)		(0.297)		(0.469)	
spill_dissem	0.00954		0.01421	*	0.01257		0.00904	+	0.00364		0.01212	
	(0.345)		(0.595)		(0.228)		(0.395)		(0.307)		(0.471)	
spill_valuechcompet	0.04243	***	0.00731		0.02869	***	−0.00070		0.03456	**	0.00289	
	(0.236)		(0.467)		(0.144)		(0.292)		(0.194)		(0.379)	
h_comp_diff	−0.00212		−0.00327		0.01622	*	0.00655	+	0.00663		0.00339	
	(0.229)		(0.482)		(0.135)		(0.255)		(0.188)		(0.377)	
h_mark_diff	−0.01688		0.00188		−0.05380	+	0.00183		−0.07674		0.00000	
	(0.613)		(1.655)		(0.552)		(0.849)		(0.899)		(.)	
i_fund_EU	0.16999	***	0.04029	***	0.09963	***	0.02787	***	0.14329	***	0.05378	***
	(0.443)		(0.598)		(0.249)		(0.331)		(0.313)		(0.473)	
State-owned	0.13845	**	0.04822	+	0.10729	**	0.03640	*	0.07048		0.03395	+
	(0.728)		(1.261)		(0.456)		(0.787)		(0.581)		(0.863)	
Unaffil	−0.06718	***	−0.00861		−0.07663	***	−0.01358	**	−0.06050	***	−0.01199	+
	(0.287)		(0.558)		(0.186)		(0.382)		(0.215)		(0.454)	

Table 4 (continued)

	Boom (2004–2007)				Crisis (2008–2013)				Recovery (2014–2016)			
	All partners		Universities		All partners		Universities		All partners		Universities	
	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)	Margins (se)	Sig. (1)
Multinational	0.03738	+	0.00045		0.01955		−0.00222		0.02965	+	−0.00370	
	(0.319)		(0.676)		(0.208)		(0.453)		(0.242)		(0.561)	
Dynamic (dynamic and RTA)	0.03318	*	−0.00161		−0.03064	*	−0.00818		−0.04660	**	−0.01758	*
	(0.321)		(0.679)		(0.218)		(0.478)		(0.263)		(0.676)	
Withdrawal (non-dynamic & non-RTA)	0.04762		−0.00367		−0.04047	+	−0.01952	+	−0.04646	+	−0.02263	
	(0.566)		(1.414)		(0.403)		(1.359)		(0.496)		(1.665)	
KIBS	0.00317		0.02621	*	−0.01364		0.02716	**	−0.00515		0.03454	**
	(0.394)		(0.730)		(0.250)		(0.451)		(0.284)		(0.525)	
other_services	−0.04788	**	−0.00661		−0.04753	**	0.00101		−0.03575	+	0.00558	
	(0.468)		(0.985)		(0.281)		(0.566)		(0.333)		(0.675)	
lnsig2u	1.99442	***	2.43428	***	1.20657	***	2.00134	***	1.11588	***	1.99666	***
	(0.190)		(0.311)		(0.138)		(0.172)		(0.190)		(0.223)	
Prob > chi²	0.000		0.000		0.000		0.000		0.000		0.000	
N. of cases	5287		5287		10542		10542		4911		4796	
sigma_u	2.71071		3.37751		1.82811		2.72010		1.74707		2.71374	
Rho	0.69074		0.77616		0.50393		0.69221		0.48127		0.69122	

Variables mk_local/regional, i_own_fundRD, h_knowl_diff, h_eco_diff, challenge (dynamic but non-RTA) do not have statistically significant effect

(1) +p < 0.10, *p < 0.05, **p < 0.01, ***p < 0.001

5 and 6, respectively, for all partnerships and for partnerships with universities. The econometric models are robust and possess significant explanatory power.

We start by analysing all types of partnerships. During the crisis and the entire period, unaffiliated domestic firms (*unanaffil*) were systematically less likely to participate in CIEP than DBG (Table 4, columns 1, 3 and 5). Being an unaffiliated domestic firm reduced the probability of cooperating with European partners by 7% during the boom, by 8% during the crisis, and by 6% during the recovery period. This result is in line with Arvanitis & Bolli (2013) who discovered compelling evidence of the positive impact of group membership on a company's likelihood of engaging in international cooperation across all five Western European countries examined in their study. Our results may be explained by two reasons that do not contradict each other. International cooperation necessitates substantial search expenditures; which unaffiliated firms may struggle to afford, especially during a downturn. On the other hand, our unaffiliated firms may be part of extensive networks and may establish indirect connections with European partners (Saglietto et al., 2020). In the context of Spain, unaffiliated firms are able to engage in local cooperation for innovation, particularly during periods of economic prosperity (García-Sánchez & Rama, 2022). As a result, the larger firms with which they collaborate locally, including DBG, SOEs, and FS, could potentially engage in European partnerships and reap the benefits of bridging structural holes between unaffiliated Spanish firms and their European counterparts. This view is consistent with evidence provided by case studies on Spanish industries with a national pyramidal structure and substantial international projection, such as automobiles, telecommunications, and aeronautical engineering (Badillo et al., 2017; Rama & Ferguson, 2007; Sanz Menéndez et al., 1999). An organisation consisting of extended national/supranational networks of innovators is also prevalent in the Spanish defence industry in the framework of integrated EU projects (Callado-Muñoz et al., 2022; Ortega, 2016). Nevertheless, this speculative interpretation cannot be tested with the available data.

The coefficient for *multinational* is marginally significant at the 10% level during both the boom and recovery phases. This suggests that FS have a slightly higher likelihood of engaging in CIEP during prosperous times. However, during crises, their behaviour aligns more closely with that of DBG. In our perspective, the resemblance of their behaviour to that of DBG does not stem from an imitative strategy. Instead, it results from a complex interplay of different strategies within FS and their conflicting impacts on CIEP. On one hand, their significant interest in local cooperation (Fernández-Sastre, 2012; Holl & Rama, 2014), might suggest a reduced inclination toward CIEP. Undisclosed estimations suggest that in dynamic sectors where Spain holds technological advantages *(dynamic)*, FS demonstrate reluctance to engage in CIEP, often preferring to collaborate with efficient local partners (i.e., Spanish partners or other FS located in Spain) (available upon request). Our interpretation appears to be validated by García-Sánchez et al. (2017), who note that FS active in Spain indeed form stronger cooperative connections with local counterparts in those sectors.

On the other hand, easier access of FS to international credit suggests a potential facilitation for engaging in CIEP, even during a crisis. Additionally, their strong involvement in exports implies a propensity for participating in

international cooperation to adapt their products to the needs of foreign customers (subsection 2.1). Álvarez et al. (2011) observed that by 2008, approximately 30% of FS operating in Spain directed over 50% of their sales toward international markets. The effects of these two strategies may potentially offset each other.

State-ownership (*state-owned*) increased the probability that a company was engaged in CIEP by 14% during the boom and by 11% during the crisis (Table 4, columns 1 and 3). Our results contradict those of Clò et al. (2023), who argue that reformed SOEs align with POEs in their internationalization patterns and strategies. However, we do not find such similarity, at least in terms of the internationalization formula involving international cooperation. In our sample, SOEs are more inclined than POEs, whether national or multinational, to participate in CIEP during times of crisis. After *Eu_persistence*, *state-owned* constitutes the strongest driver of CIEP during that period and displays an effect as robust as that of obtaining above-average EU funding for innovation.

Several reasons may explain this result. Over the years, Spanish SOEs have accumulated substantial social capital through exports, FDI, and inter-firm linkages. They have been exporters since the 1950s, when barely 12% of Spanish companies had any export activity (Binda, 2012). When the crisis erupted, SOEs were particularly well-positioned to capitalize on these early linkages to counteract the fall of the domestic demand. For instance, Indra, a large high-tech company that returned to state ownership during the 2008 crisis, increased its exports from 30 to 40% of its sales before the 2008 crisis to 60% after the crisis inception (Álvarez Cuiñas, 2015). Moreover, numerous Spanish SOEs internationalized through FDI (Cuervo-Cazurra, 2018). These circumstances may have played a role in fostering international linkages and nurturing the growth of their social capital over the years. Moreover, their ability to engage with foreign partners has probably expanded through reform, owing to the significant participation of international institutional investors, including pension funds, among their new stakeholders (Etchemendy, 2004). Such investors can aid reformed SOEs in securing international financing and tapping into global knowledge networks (He et al., 2016; Panicker et al., 2022). Interlocking directorates may have indirectly facilitated SOEs in leveraging the international experience of other companies (Yildiz et al., 2023). Spanish SOEs, in particular, have frequently engaged in such practices (Aguilera, 1998; Calvo, 2019).

Furthermore, it is plausible that SOEs are viewed as particularly suitable partners by specific foreign organizations. For instance, German firms engaged in cooperation with competitors in Europe tend to favour partnerships with public sector clients, governments, and research institutions, rather than partnerships with private firms (Navío-Marco et al., 2019). The collaboration with competitors is perceived as a risky strategy due to the potential for involuntary spillovers. In their review of the cooperation literature, Freire & Gonçalves (2022, p. 3395) find that "partnerships with government-funded or related organizations usually have a positive effect" on innovative performance. Finally, SOEs may also elicit more trust from prospective partners since they are financially backed by the state, a crucial consideration during a financial crisis. In this scenario, being an "institutional exception" probably worked to the advantage of SOEs.

During the recovery, however, the cooperative behaviour of the sample SOEs was similar to that of DBG and FS. One plausible explanation resides in the negative impact of austerity measures on budgets and jobs in Spanish SOEs during the 2008 crisis. With such a disadvantage, these measures probably lessened their capacity to interact with other European innovators during the recovery.

In summary, ownership plays a role in influencing a firm's capacity to sustain cooperation during a crisis, even when considering factors like firm size and other relevant variables. However, Hypothesis 2 only garners partial support. While there is some backing concerning group ownership (H2.a) and state-ownership (H2.c), it is not complete, as the hypothesis related to foreign ownership (H2.b) is not substantiated. In fact, foreign ownership does not positively influence a firm's ability to maintain cooperation during a crisis.

We turn now to partnerships with European universities. The *state-owned* variable has a positive and significant coefficient during the boom, the recovery and the crisis (at 10%). During these phases of the business cycle, being a SOE increases by 5%, 4% and 3%, respectively, the probability that a company cooperates with European universities (Table 4, columns 2, 4 and 6). The coefficient for *multinational* is not statistically significant during the boom and is negative during the crisis and recovery. This indicates that these firms are less likely to cooperate with European universities compared to DBG. This interpretation is supported by the findings of Rõigas et al. (2018) for the case of Spain. Finally, the coefficient for the *unaffil* variable is consistently negative and statistically significant throughout the business cycle. To summarize, SOEs are the companies more prone to cooperating with European universities. Probably, owing to their "patient capital" (Landoni, 2020) they are more willing than are POEs, domestic or foreign, to invest in projects that take time to bear fruits or in joint basic R&D. Ownership is certainly associated to the probability that a firm cooperates with European universities.

4.2.3 Other drivers of cooperation

We begin by analysing the drivers of all types of partnerships. Certain variables exhibited a stable behaviour throughout the business cycle. *r_turn* (above average size) was always positively associated to *CooperaEu,* while *i_ownfundRD* was never associated to this variable (Table 4, columns 1, 3 and 5). At the same time, the coefficient of *h_eco_diff*, the variable denoting difficulties in innovation due to high innovation costs, consistently fails to achieve statistical significance. Sharing R&D costs is probably not a significant motive for cooperation. Our findings do not align with those of Abramovsky et al. (2009), who, in their analysis of a 2001 sample from the CIS, observed that Spanish firms engage in collaboration to address financial constraints. Discrepancies between the two studies could be attributed to their study combining both domestic and international cooperation, along with the potentially higher prevalence of SMEs in the domestic sphere, which may encounter more pronounced financial limitations.

In contrast, other drivers of cooperation became increasingly important. *Eu_persistence* increased the probability that a firm was engaged in CIEP by 5% during the boom, 12% during the crisis, and 15% during the recovery period (columns 1, 3,

and 5). Our results confirm those of previous studies in that experience is a crucial factor towards cooperation (Belderbos et al., 2015; García-Sánchez & Rama, 2022). Furthermore, its positive effects multiplied more than twofold and threefold, respectively, during the crisis and the recovery. Previous experience with local partnerships (*Local_persistence*) and US partnerships (*US_persistence*) are also systematically associated to *CooperaEu*, although the association is weaker. There are several reasons that underscore the significance of persistence as a driving force for CIEP, especially during times of crisis. Managers with a wealth of international experience are probably better equipped to handle uncertainties and conflicting perspectives in the international arena. During turbulent periods, repeated collaborations tend to be more effective in navigating the challenges, as they promote mutual adaptation and strengthen interpersonal relationships (Friedberg & Neuville, 1999). In most business relationships, partner changes are often avoided, particularly in times of uncertainty, to minimize the escalation of ambiguity (Vahlne & Johanson, 2019).

i_RDemployees gained importance only once the crisis exploded (Table 4, column 3). Not enduring barriers to innovate attributable to the presence of incumbents in the market or demand uncertainty (*h_comp_diff*) was insignificant in the pre-crisis. However, this favourable situation became a predictor of CIEP during the crisis. The positive coefficient indicates that firms facing these obstacles less intensely than the industry average are more inclined to engage in collaboration with European partners.

Results run counter an argument that firms facing difficulties will tend to cooperate, as preconised by the RBV theory. Instead, it may well be that, during the crisis, Spanish innovators with a formal R&D department and/or enjoying market potential were more valued by prospective partners than they had been in the pre-crisis period. Both innovation-related characteristics and often forgotten structural factors influence the probability of cooperation (García-Sánchez et al., 2017), and this seems to be especially true during a crisis.

Exporting to European markets (*mk_Eu*) was only marginally associated to *CooperaEu* before the crisis, but increased the probability of CIEP by 5% when the crisis exploded. Additionally, the influence of exporting experience in markets beyond European markets grew. Given the contraction of the domestic demand, many Spanish firms resorted to the international market, especially to that of the Eurozone, during the crisis. Exports increased by around 9% in 2009, only one year after its inception.[8] At the same time, an effort to diversify the export base was made by promoting sectors, such as renewable energy, technology and KIBS. These changes may explain our results since high-tech firms are more prone to cooperating (Freire & Gonçalvez, 2022; Miotti & Sachwald, 2003; Vega-Jurado et al., 2009).

Finally, other variables were always positively associated to *CooperaEu* throughout the business cycle despite the fluctuation in the strength of the association. While firms enjoying technological spillovers had 8%–6% more probability of being engaged in CIEP during the boom and the recovery period, they had only 3% more probability during harsh economic times (column 3). During the

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[8] https://www.icex.es/es/todos-nuestros-servicios/informacion-de-mercados/estadisticas May 2023.

downturn, Spanish universities and research centres, the most proximate sources of knowledge for many of the sample firms, suffered severe cuts in their budgets (Cruz-Castro et al., 2018) and this circumstance certainly reduced their influence on the Spanish economy. Despite this limitation, even in times of crisis and particularly during periods of economic prosperity, the impact of *spill_tech* on the propensity to cooperate is more pronounced than the impact of *spill_int*, which gauges the influence of internal knowledge.

Obtaining above-average funding for innovation from EU programmes (*i_fund_EU)* always stimulated CIEP: the likelihood that a firm cooperated increased by 17% during the boom and by 14% during the recovery period. Even during the in-crisis period, EU funding constituted a substantial stimulus by increasing the likelihood of CIEP by 10%. The results confirm that firms using external funding to finance innovation are more prone to cooperating (Aristei et al., 2016; Arranz & Fernández de Arroyabe, 2008; Bianchi et al., 2019; Rõigas et al., 2018). They also show that the funding helped receivers to remain cooperative even during a crisis as severe and prolonged as the Spanish 2008 crisis. In summary, the results indicate that certain drivers of intra-European cooperation for innovation undergo changes or, at the very least, a shift in intensity throughout the business cycle, with conditions becoming more challenging for firms when the crisis erupted. Hypothesis 3 is supported.

We now turn to the drivers of collaboration with European universities (*CooperaEu_uni*). An above average size and, especially, the availability of EU funding remain determinant of this specific type of partnership (Table 4, columns 2, 4 and 6). Our results support those of Rõigas et al. (2018) for the case of Spain and are also in accordance with those of a study conducted by Aristei et al. (2016). In analysing seven EU countries between 2007 and 2009, they found that larger firms and those receiving public R&D funding tend to conduct a significant portion of their research in collaboration with universities. Rõigas et al. (2018), drawing upon empirical literature and their own estimations for several EU countries, also assert that large firms possess more resources and better awareness of university activities. In contrast, we find that market-related applications of innovation lose importance in this case. Above-average "other" innovation expenditures, such as those for marketing a new product *(i_other Innov_Exp)*, show only a weak association with cooperation with European universities (*CooperaEu_uni*) during the boom and no association since the onset of the crisis. Additionally, the share of turnover from products new to the market *(i_newmar)* shows no association with *CooperaEu_uni*. This suggests that the commercialization of new ideas holds relatively less significance for universities in their cooperation endeavours. These results align with a previous study conducted by Bianchi et al. (2019), which have reported similar findings. Moreover, firms that cooperate with all types of European partners and those that cooperate specifically with universities benefit from different incoming spillovers. Throughout the business cycle, the former tend to value information sources for innovation from the value chain (clients and suppliers), while the latter do not. Similarly, an above average capacity to absorb spillovers from dissemination sources, such as technical and scientific journals, and scientific events, is a predictor of cooperation with European universities during the boom and the crisis, although its practical effects are small.

The *spill_dissem* variable, in contrast, is not associated with the probability that a firm cooperating with all types of partners.

Throughout the business cycle, KIBS exhibited 3% more probability of partnering with European universities than their counterparts, a result in line with those of Segarra-Blasco and Arauzo-Carod (2008) and Trigo and Vence (2012). Note that the sample KIBS are prone to cooperating specifically with European universities but not necessarily with all types of European partners. They probably fear interactions with potential competitors and prefer industry-university collaborations, which are less risky in terms of involuntary spillovers (Cassiman & Veugelers, 2000). A speculative explanation is that the sample KIBS mainly consist of companies active in the highly competitive Spanish engineering consulting-services, an industry whose exports accounted for approximately 40% of Spain's exports of services during the crisis (Álvaro-Moya, 2022). The aforementioned author observes that external networks, such as those generated in engineering professional associations and in both national and international meetings played a decisive role in fostering the resilience and the worldwide expansion of Spanish engineering firms. In turn, research institutions foster international connections by enabling their inventors to establish personal relationships with selected scientists and technicians worldwide (Perri et al., 2017). In this context, international social networks connecting European academics with Spanish technicians and scientists may have played a crucial role in preparing cooperative agreements between the sample KIBS and European universities.

Our results suggest that drivers of cooperation for innovation are quite specific in the case of partnerships with European universities. This supports Hypothesis 4.

5 Conclusions

Panel data from a statistically representative sample of innovative firms located in Spain was examined, focusing on their collaborative innovation efforts with European partners between 2004 and 2016. The analysis revealed that the 2008 economic crisis, on its own, had a discouraging effect on firms seeking cooperation with European partners for innovation. However, this negative impact was counterbalanced by the firms' increasing experience in collaboration. Moreover, the number of partner types per firm increased when the crisis unfolded. Additionally, we tested the influence of ownership on firms' ability to maintain cooperation for innovation with European partners during the crisis. Foreign ownership does not enhance a firm's ability to maintain cooperation during a crisis, despite the easier access to international credit available to foreign subsidiaries. In fact, foreign firms exhibit pro-cyclical behaviour in their cooperation efforts.

Unaffiliated domestic firms are the least inclined to participate in such partnerships, both during the crisis and throughout the entire period. Finally, state-owned enterprises exhibited superior performance compared to both domestically owned private enterprises and foreign subsidiaries during the downturn.

We also ascertain whether drivers of cooperation with European partners remain stable throughout the business cycle. Although certain determinants, such as a large size, are always associated to the probability that a firm engages in such

collaboration, there is support for the idea that other drivers of cooperation for innovation modify, or at least augment, their intensity when the crisis erupts. Experience in cooperative activities, export business, an above-average number of R&D employees, and market potential become vital for the firms to cooperate when the crisis erupts. Without denying the clear relevance of the Resource-Based View of the Firm, our results do not confirm the assumption that firms facing difficulties in terms of knowledge, finance, and/or the presence of incumbents in their market are prone to cooperating. In contrast, the data provides verification of the importance of opportunities in cooperation agreements (Ahuja, 2000): the appeal of prospective partners in terms of knowledge, money or market potential is undeniable, especially during a crisis. Drivers of cooperation with European universities display specific characteristics. Our findings suggest that universities may prioritize technological proficiency and research capabilities when forming collaborative partnerships.

Our results have policy and management implications. EU funding for innovation is instrumental for companies staying connected to European networks of innovation, even when the country in which they locate endures a recession as severe and long-lasting as the Spanish crisis in 2008. Both managers and policy-makers need to encourage cooperation during expansive periods since previous experience helps firms to stay innovative when new crises break out. To start by stimulating domestic cooperation for innovation is a worthy strategy to prepare conditions for future collaboration with European partners. State-owned enterprises are particularly well-suited to effectively navigate challenges in times of crisis, thereby maintaining and strengthening the linkages between the National Innovation System and European networks of innovators in difficult times. During the crisis, these firms strongly contributed towards stabilising the presence of Spanish firms in European innovation networks. The stability of partnerships is desirable as it facilitates finding solutions to technical and commercial problems. Our study also has academic implications since it shows the interest of a dynamic approach to cooperation for innovation, beyond the mere consideration of "normal" phases of the business cycle that prevail in the literature. Furthermore, it shows that persistent disparities in cooperative innovation performance distinguish state ownership from other ownership structures. Therefore, the inclusion of institutional theory in the analysis becomes imperative for predicting the cooperative behaviour of different types of ownership structure.

A limitation of our study is that the empirical evidence available to analyse cooperation for innovation consists of a dummy variable. This type of variable may obscure the varied characteristics and nuances of these cooperative arrangements. To illustrate the potential differences in these arrangements, we specifically analysed collaborations with European universities. Despite these limitations, our study contributes to the analysis of international cooperation for innovation by being the first to provide a dynamic view of intra-European partnerships and by improving our understanding of the critical role of state-owned enterprises during crises.

Appendix

See Table 5 here.

Table 5 Description of variables and main descriptive statistics. Source: Authors' own from PITEC data

Variables			Descriptive statistics
Name	Type	Description	(Relative frequencies in parenthesis for dummy and categorical variables)
cooperaLoc	Dummy	Cooperates with local partners (in spain), business group excluded	1 = yes (36.6%) 0 = no N = 22,412; n = 2044
cooperaEu	Dummy	Cooperates with european partners (eu and efta), business group excluded	1 = yes (13.4%) 0 = no N = 22,412; n = 2044
cooperaUS	Dummy	Cooperates with usa partners, business group excluded	1 = yes (3%) 0 = no N = 22,412; n = 2044
cooperaEu_uni	Dummy	Cooperates with european universities (eu and efta)	1 = yes (3.6%) 0 = no N = 22,412; n = 2044
Local_persistence	Dummy	Persistence in local cooperation (continuously cooperating for at least the last two years)	1 = yes (26.2%) 0 = no N = 22,412; n = 2044
Eu_persistence	Dummy	Persistence in european cooperation (continuously cooperating for at least the last two years)	1 = yes (8.8%) 0 = no N = 22,412; n = 2044
US_persistence	Dummy	Persistence in us cooperation (continuously cooperating for at least the last two years)	1 = yes (1.9%) 0 = no N = 22,412; n = 2044
i_newmar	Dummy	The share of "new to the market" products in turnover exceeds the average for firms in the same two-digit industry	1 = yes (17.1%) 0 = no N = 29,094; n = 2238
i_newent	Dummy	The share of "new to the firm" products in turnover exceeds the average for firms in the same two-digit industry	1 = yes (21.5%) 0 = no N = 29,094; n = 2238

Table 5 (continued)

Variables		Description	Descriptive statistics
Name	Type		(Relative frequencies in parenthesis for dummy and categorical variables)
i_intRDexp	Dummy	Internal r&d expenditures above the two-digit industry average	1 = yes (36.3%) 0 = no N = 29,092; n = 2238
i_extRDexp	Dummy	External r&d expenditures above the two-digit industry average	1 = yes (16.9%) 0 = no N = 29,092; n = 2238
i_other_innov_exp	Dummy	Expenditures in other innovative activities above the two-digit industry average	1 = yes (19.4%) 0 = no N = 29,092; n = 2238
i_RDemployees	Dummy	Number of r&d employees per 1,000 employees above the two-digit industry average	1 = yes (39.3%) 0 = no N = 29,094; n = 2238
i_owm_fund_RD	Dummy	Share of own funds used for internal r&d above the two-digit industry average	1 = yes (41.7%) 0 = no N = 29,094; n = 2238
i_fund_EU	Dummy	Share of eu funds used for internal r&d above the two-digit industry average	1 = yes (2.7%) 0 = no N = 29,094; n = 2238
spill_int	Dummy	High importance of internal information for innovation	1 = yes (61.8%) 0 = no N = 22,411; n = 2044
spill_tech	Dummy	High importance of knowledge institutions information for innovation	1 = yes (4.8%) 0 = no N = 22,411; n = 2044

Table 5 (continued)

Variables			Descriptive statistics
Name	Type	Description	(Relative frequencies in parenthesis for dummy and categorical variables)
spill_dissem	Dummy	High importance of dissemination channels for innovation	1 = yes (5.9%) 0 = no N = 22,411; n = 2044
spill_valuechcompet	Dummy	High importance of client, supplier, and competitor information for innovation	1 = yes (15.6%) 0 = no N = 22,411; n = 2044
h_knowl_diff	Dummy	High hindrance from knowledge access barriers in innovation	1 = yes (5.4%) 0 = no N = 29,094; n = 2238
h_eco_diff	Dummy	Economic difficulties hinder innovative activities	1 = yes (23.9%) 0 = no N = 29,094; n = 2238
h_comp_diff	Dummy	Competitive difficulties hinder innovative activities	1 = yes (21.8%) 0 = no N = 29,094; n = 2238
h_mark_diff	Dummy	Market access barriers hinder innovative activities	1 = yes (4%) 0 = no N = 29,094; n = 2238
mksize	Categorical	Declared market breadth by firm (local–regional/national/europe (eu, efta and associated countries)/rest of the world)	1 = local/regional: 8.56% 2 = national: 20.37% 3 = Europe: 14.57% 4 = other international (outside Europe): 56.5% N = 29,094; n = 2238

Table 5 (continued)

Variables			Descriptive statistics
Name	Type	Description	(Relative frequencies in parenthesis for dummy and categorical variables)
Sectors	Categorical	Molero and García (2008) taxonomy for manufacturing, and eurostat for services	3 = dynamic (Fast growth in worldwide patenting and RTA * in Spain): 15.1% 4 = stationary (Slow growth in worldwide patenting and RTA * in Spain): 25.4% 5 = withdrawal (Slow growth in worldwide patenting and non-RTA*): 3.7% 6 = challenge (Fast growth in worldwide patenting and non-RTA* in Spain): 16.6% 9 = KIBS Knowledge Intensive Business Services: 11.5% 10 = Other services: 27.7% N = 29,094; n = 2238
Crisis	Categorical	Business cycle phase based on the spanish gdp path	0 = boom (2004–2007): 8.56% 1 = crisis (2008–2013): 20.37% 2 = recovery (2014–2017): 14.57% N = 29,094; n = 2238
r_turn	Continuous	Base 100 index of firm's turnover vs. Two-digit industry average	Mean: 167.75 ǁ min: 0 ǁ Max. 8363.32 Std. dev.: 466.52 (overall) 440.75 (between) 153.15 (within) N = 29,094; n = 2238

*The abbreviation RTA stands for Revealed Technological Advantages

RTA revealed technological advantages

Declarations

Conflict of interest None.

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