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Digitalization as a facilitator of open innovation: Are family firms different?

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ABSTRACT

This study analyzes the effect that a firm's level of digitalization has on its open innovation activities. Specifically, we argue that digitalization facilitates collaboration with a wider set of technology partners in the innovation process (i.e., breadth of technological collaboration). In addition, our arguments contend that certain socioemotional factors in the particular context of family firms may diminish this facilitating aspect. We test our ideas using panel data from a representative sample of Spanish manufacturing firms over the period 2007–2017. We find support for the positive association hypothesized between digitalization and the breadth of technological collaboration. Contrary to our expectations, however, the positive effect of digitalization is more pronounced among family firms. We discuss the implications for the open innovation and family business literatures.

1. Introduction

The pervasive effects and rapid development of digitalization have meant that most company boards have placed it high on their strategic agenda. Digitalization is also one of today's macrolevel megatrends, with an impact on diverse social and economic activities (Ciarli et al., 2021; European Commission, 2021). It has gone from a technological opportunity to a necessity (Bammens and Hünermund, 2021; Kraus et al., 2021). The advent of digital technologies has led many researchers to argue that firm boundaries and corporate strategies are set to undergo drastic changes (Foss and Klein, 2022). While digitalization is generally acknowledged to be important for value creation and capture, more research is needed to determine the effect it has on firms' strategic choices, including innovation (Rachinger et al., 2019). Digital transformation is evolving in step with innovation routines and processes, altering organizations in terms of learning and knowledge management, readjusting their resource use (Cepa, 2021) and shaping innovation results (Radicic and Petković, 2023). As innovation activities are affected by the digital transformation, many new questions have emerged around innovation strategies and, particularly, approaches to open innovation in the digital age (Dahlander et al., 2021).

There is an increasing rate of digitalization supporting business ventures, such as alliances, by reducing the costs of managing them (Gomes-Casseres, 2015). However, relatively little is known about the extent to which a firm's digitalization is associated with its openness to external technology partners in the innovation process. Accordingly, we seek to extend our understanding of the concept of open innovation by focusing on digitalization and its link to hard forms of openness (i.e., technological collaboration). Our research responds to the call for a better understanding of the relationship between digitalization and innovation (Ciarli et al., 2021) and the need to update frameworks such as open innovation in the digital era (Enkel et al., 2020; Appio et al., 2021; Dahlander et al., 2021). Although some studies provide anecdotal evidence of the role of digital technologies in open innovation (Dodgson et al., 2006; Natalicchio et al., 2014), this managerial issue remains underresearched, and the gap is even more pronounced as a growing number of digital technologies shape the corporate innovation process. Further theoretical and empirical research is therefore required to gain a structured view of the use and implementation of digital technologies in the innovation process (Agostini et al., 2020), and particularly in open innovation strategies (Del Vecchio et al., 2018).

We advance our understanding of the drivers of technological collaboration and its diversity by exploring the role of digitalization in the firm's decision to be open to a broad set of external actors in the context of innovation. We join an emerging literature stream that studies how digital technologies affect organizational capabilities (Kuusisto, 2017) and innovation processes, with an emphasis on open innovation (Urbinati et al., 2020). Our first research question therefore reads as follows: what effect does the digitalization of a firm's processes have on its use of external technology partners in the innovation process? More

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specifically, are firms characterized by higher levels of digitalization better able to establish collaboration relationships with a diverse set of innovation partners?

Additionally, we consider the distinct innovation behavior of family firms (Calabrò et al., 2019; Nieto et al., 2015) – specifically towards open innovation (Belitski and Rejeb, 2022; Del Vecchio et al., 2020)) – to explore these relationships within this particular setting. Despite the importance of digitalization for these firms, few studies have thus far addressed this topic (Batt et al., 2020). Nevertheless, research in this area is gaining momentum (e.g., Soluk and Kammerlander, 2021; Soluk et al., 2021). As Batt et al. (2020) posit, more research is needed to establish whether the specific characteristics of family firms affect their ability to exploit digitalization, or even whether some of its challenges are unique to this type of firm. Various characteristics of family firms, such as the role of socioemotional dynamics, informal processes, and tacit knowledge (Berrone et al., 2012; Lee et al., 2003; Miller et al., 2013), may complicate the use of digitalization for firm-level innovation processes. Our second research question therefore addresses whether the positive relationship expected between a firm's level of digitalization and its breadth of technological collaboration differs between family firms and their non-family counterparts.

Based on arguments from transaction cost economics (Williamson, 1979, 2010) and the knowledge-based view of the firm (Grant, 1996), we develop our first hypothesis relating the scope of a firm's digitalization to the diversity of its technological partners (i.e., the breadth of technological collaboration). We then complement this with insights from the socioemotional wealth perspective (Gómez-Mejía et al., 2007) to formulate our second hypothesis on how the above relationship is moderated by family firm status. The results of the empirical analysis, which is based on a large and representative sample of Spanish manufacturing firms for the period 2007–2017, support our first hypothesis. Interestingly, however, the result for the sampled family firms is contrary to our expectations, namely, that digitalization seems to contribute more to the breadth of technological collaboration among family firms than non-family ones.

Our study makes two main contributions to academic literature. On the one hand, it adds to the literature on innovation and the open innovation framework and, on the other, to family business literature. First, we contribute to an emerging research stream analyzing the role of digitalization in innovation management (e.g., Nambisan et al., 2018; Rachinger et al., 2019), and investigate the implications that firm-level digitalization has for strategic choices on the breadth of technological collaboration in its innovation operations. We thus provide insight on the topic of open innovation in the digital era by revealing how such activities are affected by digital transformation, which is an important line of inquiry, as noted by Enkel et al. (2020). In particular, we shed light on the role of digital technologies in enabling a greater diversity of partners in technological collaboration strategies, which may be attributed to the possibilities these technologies provide in managing different sources of knowledge.

Second, this study furthers new insights for the family business literature by shedding light on the impact of digitalization in this type of firm, whose characteristics and behaviors are expected to differ from their non-family counterparts. In so doing, our paper contributes to a more nuanced understanding of the consequences of digitalization for a decision such as technological collaboration. Collaborative innovation may solve the innovation dilemma in family firms (Feranita et al., 2017). The literature, however, has reported a lower propensity among family firms to seek external sources to innovate, such as technological collaboration (Cassia et al., 2012; Nieto et al., 2015; Pittino and Visintin, 2011), as well as a narrower search breadth than non-family firms (Alberti et al., 2014; Classen et al., 2012). Recent research raises the need to clarify the open innovation model in the setting of family firms (Belitski and Rejeb, 2022). In this line, our findings reveal that digitalization allows family firms to narrow the open innovation gap with non-family firms. As such, our results and conclusions advance knowledge on the topic of technological collaboration and innovation in the particular setting of family firms.

Besides its academic contribution, our research questions are also relevant for practitioners. The advance of digital transformation is unstoppable, so it is essential for managers to understand the consequences this may have on corporate strategies. We aim to stimulate the interest of practitioners by highlighting the impact of the degree of digitalization on open innovation activities. Given the challenges involved in the implementation and management of open innovation approaches at firm level, we believe the managerial audience would benefit from this research, as it highlights how digitalization can help to cope with a greater number of external knowledge channels. Given the potential of the breadth of technological collaboration for innovation, understanding that increased digitalization facilitates the management of greater breadth is a relevant implication for managers. The work may also be of particular interest to family firms, insofar as digitalization can help to open up to a wider range of technological partners, and thus reduce the gap in technological collaboration with non-family firms.

2. Literature review and hypotheses development

2.1. Conceptual and theoretical underpinnings

2.1.1. Digitalization

Digitalization involves the adoption of digital technologies and their interfacing with diverse operational and decisional functions within a firm (Ardito et al., 2021; Björkdahl, 2020). These technologies have drastically reduced the costs of searching for, analyzing, storing, and exchanging information (Foss, 2005), thereby increasing firms' processing capabilities and enabling more timely coordination and control of interorganizational processes (Cepa, 2021).

We understand the use of digital technologies and their infrastructure as combinations of computing and ICT, which facilitate employees' tasks, transforming internal business processes and capabilities, and helping to engage more closely with clients and strengthen interfirm relationships (Warner and Wäger, 2019; Westerman et al., 2014). In terms of information sourcing, sharing, and processing, digital technologies help to improve connectivity and the disclosure of information both inside and outside the firm (Radicic and Petković, 2023). The different digital technologies featuring in back-end operations, involving accounting software, CRM, and marketing tools, among many others, may help a firm to be more efficient supporting customers and organizational processes (Coreynen et al., 2017), handle data, and improve communication (Ardito et al., 2021) and access to data sources or enhanced analytical and collaborative capabilities (Del Río Castro et al., 2021).

2.1.2. Open innovation paradigm

Since Chesbrough coined the term in 2003, the concept of open innovation has gained enormous popularity among academics and practitioners. It is well established that companies use inflows of knowledge to accelerate internal innovation and outflows of knowledge to expand the markets for external use of innovation (Chesbrough, 2006). The benefits of open innovation and the shift in recent decades from closed to open innovation systems have been explained elsewhere (e.g., Chesbrough, 2003; Weiblen and Chesbrough, 2015). The last two decades have witnessed an exponential growth in publications on the open innovation paradigm (e.g. Dahlander and Gann 2010; Chesbrough and Bogers 2014; Lopez-Vega et al., 2016; Obradović et al., 2021; van de Vrande et al., 2009), which has been playing a crucial role in the management of business innovation.

Open innovation has been researched from a number of perspectives and explored in diverse contexts. The role of open innovation has been analysed based on the firms' characteristics and the sector in which they are involved (Chaudhary et al., 2022; Marzi et al., 2023); its impact on firm performance (West and Bogers, 2014); its relation to

appropriability (West et al., 2014); its contribution to the generation of dynamic capabilities (Hutton et al., 2021); its limiting factors (Abhari and McGuckin, 2023) and, as a recent challenge, its management in a pandemic context (Radziwon et al., 2022).

Despite these advances and the growing understanding of the term open innovation, there are still challenges to be addressed. Given the essential role of digitalization nowadays, there are increasing calls to analyze its role on firms' openness decision making (Enkel et al., 2020; Appio et al., 2021; Dahlander et al., 2021; Urbinati et al., 2020). Several scholars have observed that digital technologies reduce the cost of information, and can thereby mitigate cooperation and coordination problems in joint innovation efforts among interdependent firms (Adner, 2017; Altman et al., 2022; Foss et al., 2023). Digital technologies can thus facilitate the management of open innovation processes by enabling better access to and sharing and using of knowledge and information flows in innovation partnerships (Chen et al., 2012). In particular, in this paper we will analyze the role of firm's digitalization in relation to the breadth of its technological collaboration.

2.1.3. Open innovation challenges

Setting up open innovation activities in which a firm draws on knowledge from a variety of external partners is not without its challenges. While these challenges are manifold, in this article we will build on *transaction cost economics* (TCE; Williamson, 1979) and the *knowledge-based view* (KBV; Grant, 1996), as the main theoretic underpinnings to provide an organizing framework for our conceptual analysis. We use TCE and KBV in a complementary manner, whereby TCE offers insights into the costs of organizing exchanges in general, and KBV sheds further light on the specific challenges related to exchanges of knowledge as the key resource in open innovation collaborations.

TCE stems from organizational economics and deals with the fundamental question on how best to organize economic activity (Williamson, 1979, 1991). The TCE lens has focused primarily on the strategic issue of vertical integration (make or buy decision), but its premises have wider applicability beyond traditional value chain transactions. Compared to organizing activities inside a firm under hierarchical control (with its own set of internal transaction costs[1]), organizing exchanges with parties outside the firm's boundaries involve external transaction costs (Williamson, 2010). These external transaction costs (hereafter simply referred to as transaction costs) can be divided into two broad categories, namely, search costs and cooperation costs. *Transaction search costs* refer to those costs, such as time and effort, related to finding suitable exchange partners with the required skills or assets (Crook et al., 2013); these include scanning the horizon for possible collaboration partners, screening them, and selecting the most suitable ones. *Transaction cooperation costs* are related to aligning interests among the involved (self-interested) parties through a negotiated agreement, ensuring that they observe the agreement reached, and renegotiating the agreement when conditions change (Crook et al., 2013; Williamson, 1991). For instance, when licensing external technology as part of its open innovation activities, a firm first needs to search for the most suitable partner in that particular field, enter into a licensing agreement that satisfies both parties, monitor compliance (e.g., exclusivity provisions), and review the contract when needed – such activities involve monetary and non-monetary transaction costs.

The KBV is a theoretic framework from the strategic management literature, which has its roots in the resource-based view (Barney, 1991) and focuses on knowledge in competitive firms as their most strategically important resource (Felin and Hesterly, 2007). As stated by Grant (1996: p. 120) "imperfect congruence between firms' product and knowledge domains creates opportunities for knowledge trading to achieve fuller utilization of knowledge" – with such knowledge trading typically taking place through formal or informal alliances. Conditional upon the type of knowledge and how it is being used, transferring and integrating knowledge can be a complex and costly process (Grant, 1996). Even in the absence of transaction costs, sharing knowledge is not without friction and bears nontrivial costs. *Knowledge transfer costs* reflect the difficulty of communication, which depends on the type of knowledge involved. Explicit knowledge (i.e., knowing about) can be codified and exchanged relatively easily between partners, whereas tacit knowledge (i.e., knowing how) cannot be easily codified and is more costly to transfer because it generally requires personal interaction and learning from experience (Grant, 1996; Kogut and Zander, 1992). *Knowledge integration costs* capture the problems involved in internalizing external knowledge and aggregating it with the firm's existing knowledge base (i.e., absorption costs), as well as the difficulties in coordinating one another's contributions to a joint innovation project (i.e., coordination costs) (Cohen and Levinthal, 1990; Ryu et al., 2018).[2]

Despite the possible benefits of open innovation, engaging in such activities is challenging for many firms due to significant transaction costs (i.e., search and cooperation) and knowledge-based costs (i.e., transfer and integration) (Grant, 1996; Williamson, 2010). An increase in the range of outside innovation partners – also referred to as the breadth of technological collaboration – typically incurs higher transaction and knowledge-based costs. Indeed, together with greater upside potential, the need to seek and arrange (implicit or explicit) agreements with multiple partner types, as well as transfer and integrate knowledge from across diverse domains, complicates the innovation management process and increases its associated costs (Crook et al., 2013; Cuypers et al., 2021; Grant, 1996; Laursen and Salter, 2006).

In this research, we explore how firm digitalization can help reduce these transaction and knowledge-based costs, and thus enable firms to organize open innovation activities. The concept of open innovation encompasses a wide range of mechanisms and activities, but we focus on its formal side, such as technological collaboration (Laursen and Salter, 2014). In particular, we analyze the breadth of technological collaboration (i.e., the diversity of collaborating partners), which is a powerful strategy that enables firms to build competitive advantages and increase value by exchanging and sharing their resources (Van Beers and Zand, 2014).

2.2. Digitalization and the breadth of technological collaboration

For our research purpose, we concentrate on two key capabilities of digital technologies: namely supporting *information exchange* and *information processing* (Cepa, 2021; Menz et al., 2021).

First, as stated above, digital technologies increase the efficiency of codifying, storing, sharing, and collecting data, thereby optimizing information exchanges between parties with more precise and timely communications and greater overall digital transparency (Brynjolfsson et al., 2023; Cepa, 2021). An obstacle to technological collaboration, related to the organization of transactions, involves the search for and monitoring of partners, which is particularly challenging when the firm is looking for diverse types of partners. Indeed, as per transaction cost economics, the firm needs to assume the costs incurred by the search for

[1] Internal transaction costs are closely related to adverse selection and moral hazard problems in shareholder-manager and manager-employee relationships as per agency theory, which is another well-documented theory from organizational economics (Eisenhardt, 1989; Jensen and Meckling, 1976).

[2] When a focal firm sources external knowledge for producing inhouse innovation by itself, the need for knowledge absorption is very high and the need for coordination relatively low. When multiple parties jointly produce the innovation (e.g., co-development projects, innovation ecosystems), the need for mutual knowledge absorption and coordination is positively related to the level of task interdependence (pooled, sequential, reciprocal, or team) in the joint innovation effort; when the need for knowledge absorption is low (e.g., joint innovation project with pooled interdependence), the required interparty knowledge transfers are also reduced (see Grant, 1996; Ryu et al., 2018).

appropriate partners, negotiating and securing agreements, monitoring and resolving disputes, and even haggling when partners review agreements to meet changing conditions, as well as maladaptation costs (Crook et al., 2013; Williamson, 2010). We argue that digital technologies reduce information asymmetries thanks to the increased scope and richness of the information available among users (BarNir et al., 2003). Digitalization also impacts on the blurring of firm boundaries, facilitating the relationships with external agents and providing coordination mechanisms like those used internally (Menz et al., 2021). To the extent that digital technologies facilitate relations with third parties and make information sharing more fluid, information asymmetries are reduced and the control over shared activities increased. As such, digital technologies facilitate the search for suitable partners, enhance insight into partners' characteristics and activities, improve coordination, facilitate contracting and control, and so reduce transaction costs in collaborative relationships – thereby facilitating the shift from closed to more open innovation approaches.

Second, digital technologies strengthen a firm's information processing capabilities, rendering the information received more productive and fostering greater learning from and with a variety of partners (Brynjolfsson et al., 2023; Cepa, 2021). Thus, advances in the digital tools applied to a firm's operational and decisional functions are expected to benefit learning through knowledge sharing and assimilation, being facilitated by enhanced data codification and analysis capabilities (Kuusisto, 2017).

Relying on multiple partners and knowledge sources for innovation may have certain benefits initially, although the returns turn negative due to over-searching (Laursen and Salter, 2006). Following Koput (1997), there are three potential causes of over-search. First, firms may benefit from multiple knowledge sources until their absorptive capacity is exhausted (Ardito and Petruzzelli, 2017; Chen et al., 2011; Radicic and Pugh, 2017; Radicic and Balavac, 2019), whereupon firms experience decreasing returns on external knowledge. Additionally, there is a timing issue, whereby innovative ideas are not fully exploited because they come at the wrong time (Ardito and Petruzzelli, 2017). Lastly, an attention allocation problem might arise (Ocasio, 1997) when managers and creative employees have limited time and cognitive capacity to dedicate to too many innovative ideas (Ardito and Petruzzelli, 2017; Chen et al., 2011; Laursen and Salter, 2006). Stronger analytical processing capabilities can help firms overcome the limitations in their absorptive capacity and play a fundamental role in the integration of internal and external knowledge (Cohen and Levinthal, 1990).

The greater digitalization of a firm's internal and interface processes (e.g., by using more computer-based and internet-enabled IT systems) thus reinforces its competencies in the transmission and analysis of information, which, in turn, should reduce the aforementioned transaction and knowledge-based costs of open innovation. Specifically, digital technologies may facilitate partner searches and remote monitoring for verifying compliance with agreements, ease knowledge transfer and absorption processes, and enable more effective multiparty coordination (Brynjolfsson et al., 2023; Cepa, 2021; Kastelli et al., 2022; Menz et al., 2021). To the extent that firm-level digitalization, with its benefits in data codification and data analysis, enhances the process of sharing and assimilating knowledge and alleviates over-search problems, the firm's ability to engage in technological collaboration with diverse partners will be augmented. Based on the above discussion, we propose that a greater variety of partner types in a firm's open innovation activities is associated with higher costs in search, cooperation, transfer, absorption, and coordination – and that a wider adoption of digital technologies reduces these costs thanks to the performance gains involved in exchanging and processing relevant information and knowledge. Fig. 1 summarizes our conceptual logic, which results in our first hypothesis.

Hypothesis 1. A firm's level of digitalization is positively associated with the breadth of its technological collaborations.

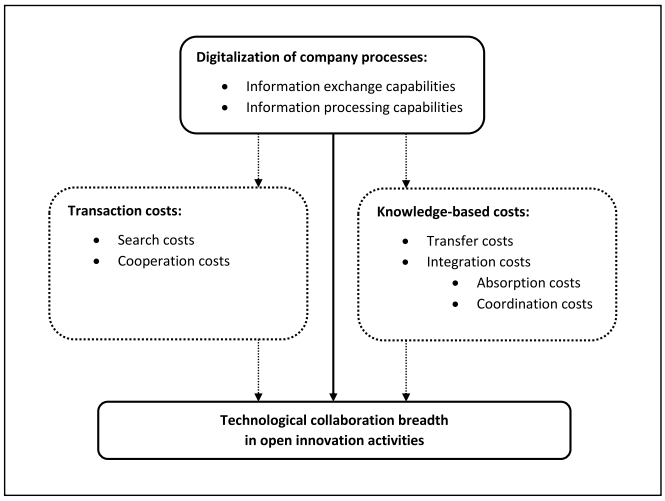

Fig. 1. Digitalization and open innovation efficiencies.

2.3. The family business context and its moderating role

2.3.1. Open innovation and family firms

Not all companies have the same approach to open innovation; such is the case for family firms, whose different innovative behavior has been highlighted in the literature (Calabrò et al., 2019; Nieto et al., 2015). In particular, open innovation behavior is affected by the specific characteristics of family firms, related to their governance structure, goals, and resources (Gjergji et al., 2019; Del Vecchio et al., 2020; Belitski and Rejeb, 2022). On one hand, drawing on the socio-emotional wealth approach, it is expected that family firms have more limitations in their cooperative behavior and are less open compared to non-family ones (Classen et al., 2012; Kotlar et al., 2013). On the other hand, their strong social capital (Llach and Nordqvist, 2010) and stewardship characteristics increase their inclination to build connections with external stakeholders (Brinkerink et al., 2017).

This controversy can explain why we find studies that show how family firms are more open to collaborate (e.g., De Massis et al., 2015; Llach and Nordqvist, 2010), while others find that they are less open to external partnerships or have lower search breadth than non-family firms (e.g., Classen et al., 2012; Kotlar et al., 2013; Nieto et al., 2015). Bigliardi and Galati (2017) highlight the importance of family firms' ability, absorptive capacity, resource orchestration, and willingness to join collaborations with external partners. In any case, an important decision will be the diversity of partners and the breadth in the collaboration. The higher the partner diversity, the more spread and divided the resources of the family firm become across different collaboration partners. The effect of partner diversity on collaboration performance can be detrimental when the family firm has reached its capacity to manage multiple collaborative relationships (Feranita et al., 2017).

Considering the importance of the particular context of family firms, it is valuable to develop a better understanding of how family-specific characteristics affect open innovation behavior (Bigliardi and Galati, 2017), especially in an increasingly digitized economy. Therefore, we advance this line of research by examining the relationship between digitalization and open innovation strategies in this setting. In particular, we will assess how the idiosyncratic nature of family firms moderates the relationship between digitalization and the breadth of technological collaboration.

2.3.2. Subjectivity and tacitness at family firms

Numerous studies have explained why family firms behave differently from non-family ones, due largely to the socioemotional objectives of family owners (Gómez-Mejía et al., 2007; 2011). Besides standard financial efficiency considerations, subjective socioemotional elements

enter the utility function of family owners, shaping the company value function. Research has shown that this affects the strategic behavior of family firms, including innovation-related choices (Brinkerink and Bammens, 2018; Gómez-Mejia et al., 2011). Not only are family firms different from non-family firms, but there is also substantial variance within them as different business families place different emphasis on distinct socioemotional considerations (Bammens and Hünermund, 2020; Bammens et al., 2022). Possible socioemotional objectives include preserving family control over company affairs, upholding family traditions and family values in corporate processes, building a favorable family reputation in the community, and passing on the business to the next generation (Berrone et al., 2012; Gómez-Mejía et al., 2007). These socioemotional aspects also reflect the greater tacitness of much of the knowledge embedded in a particular family firm context ("how we do things around here"); indeed, tacit idiosyncratic firm knowledge plays a major role in family firms (Le Breton-Miller and Miller, 2015; Lee et al., 2003). For instance, De Massis et al. (2016) explain how innovation activities in family firms often leverage the tacit knowledge encapsulated in family traditions.

These subjective socioemotional considerations, which often involve complex trade-offs, and tacit knowledge influence family firms' decisions and actions in open innovation (Brinkerink et al., 2017; Classen et al., 2012). Socioemotional aspects play an important role when family firms search for suitable innovation partners, reach agreements, and monitor compliance, (Gómez-Mejia et al., 2011). Likewise, as task interdependence increases (Grant, 1996),[3] transferring and integrating knowledge flows is likely to include more socioemotional and tacit elements in family firm open innovation activities. Given their subjective and implicit nature, these elements cannot be effectively digitalized, which should generally diminish the transaction and knowledge-related efficiency gains prompted by digital technologies in a family firm open innovation management process (Brynjolfsson et al., 2023; Menz et al., 2021). In contrast, more objective and explicit techno-economic factors prevail in non-family firms' open innovation interactions (Brinkerink et al., 2017; Gómez-Mejia et al., 2011), and digital technologies are more capable of reducing transaction and knowledge-based costs (Brynjolfsson et al., 2023).

On the knowledge side, furthermore, family firms have specific traits and preferences that influence knowledge management and transfer (De Massis et al., 2016; Zapata-Cantu et al., 2022). The most valuable knowledge family firms possess is often held by the founder or by a limited number of family associates (Lee et al., 2003; Letonja and Duh, 2016). Close and personal relationships constitute an important basis for sharing more tacit forms of knowledge (Zahra et al., 2007). The family system shapes knowledge sharing within family firms through their organizational culture, family commitment, and intergenerational relationships, thereby creating advantages in storing and retrieving tacit knowledge (Botero et al., 2021; Gedajlovic and Carney, 2010). The impact of digital technology is expected to vary between explicit and tacit forms of knowledge (Enkel et al., 2020; Grant, 1996). As said, while explicit knowledge lends itself well to digitalization, tacit knowledge is difficult to codify and process, and instead tends to be transferred through socialization (Johannessen et al., 2001). In other words, more experiential or tacit knowledge arising from sustained personal interactions will not benefit from digitalization nearly as much (Enkel et al., 2020). Family businesses thus have advantages in maintaining and preserving tacit knowledge, yet the greater degree of tacitness managed by family firms may be an obstacle to its digital transmission and limit the potential digitalization has to facilitate external knowledge sourcing strategies.

[3] The higher the task interdependence in open innovation projects, the greater the need for mutual knowledge sharing, joint problem solving, and two-way coordination (Ryu et al., 2018), whereby the socioemotional makeup of the focal firm is likely to have a stronger bearing on collaborative processes.

We expect that the combination of family firms' reliance on subjective socioemotional decision criteria and tacit forms of knowledge may limit the beneficial effect of digitalization on transaction costs and knowledge exchanges. This logic suggests that family firm status will mitigate the expected positive effect of digitalization on the breadth of technological collaboration. This leads to our second hypothesis.

Hypothesis 2. The positive association between a firm's level of digitalization and the breadth of its technological collaborations is negatively moderated by family firm status.

3. Empirical analysis

3.1. Data and sample

The database used for our empirical analysis is the Survey on Business Strategies in Spain (SBSS), covering the period from 2007 to 2017. This is an annual panel of firm-level data compiled by the Spanish Ministry of Industry and the Public Enterprise Foundation. The resulting sample is representative of the population of Spanish firms operating in all manufacturing industries within the NACE-Rev. 1 classification. For the population of companies with between ten and two hundred employees, firms are selected by stratified random sampling (considering size and sector). Firms with more than two hundred employees are surveyed on a census basis (Huergo, 2006). Our empirical analysis is based on an unbalanced panel of firms from 2007 to 2017. Our final sample consists of 14,596 firm-year observations, from around 1500 firms that responded to the survey during different years in that period.

The database contains extensive information on the performance of Spanish firms and the many different strategies they employ, along with details on an interesting and broad set of variables related to innovation activities and digitalization. For this reason, the database has been used by many innovation scholars (e.g., Cassiman et al., 2010; Huergo, 2006). In particular, numerous studies have used it to study technological collaboration and open innovation strategies (e.g., Radicic and Balavac, 2019; Santamaria et al., 2009), and the strategies of family firms (Nieto et al., 2015).

3.2. Variables

3.2.1. Dependent variable

Breadth of collaboration. This variable is inspired by previous work in which the diversity of types of partners in the firm's collaboration network renders it possible to capture the degree of search breadth (Alberti et al., 2014; Laursen and Salter, 2006; Nieto and Santamaria, 2007; Classen et al., 2012). The variable takes integer values from 0 (if the firm does not collaborate with any type of technological partner) to 4 (depending on the number of types of technological partners the firm collaborates with in period t: suppliers; customers; competitors; and research organizations) (Radicic and Balavac, 2019). Value 1 indicates that the firm collaborates with only one type of partner, while values 2 and 3 indicate that the firm collaborates with two or three types of partners, respectively. The maximum value 4 indicates that the firm collaborates with all types of partners.

3.2.2. Independent variables

Degree of digitalization. Digitalization is measured by a scale (*Digital*) that allows us to capture different dimensions related to the use of the firm's digital technologies and infrastructure, viewed as combinations of information, computing, and communication technologies that allow transforming business strategies, processes, capabilities, and interfirm relationships (Warner and Wäger, 2019). Specifically, the measure incorporates details related to digitalization in three areas/blocks: (i) Digital technologies in the manufacturing process, including information on the use of numerical control machine tools, robotics, Computer-Aided Design (CAD), flexible manufacturing systems and

Computer-Aided Manufacturing (CAM) technologies, and local area network manufacturing activities; (ii) Internet-based technologies, including information on firm ownership of the internet domain, the website hosted on the firm's servers, online purchases of goods and services (suppliers), online sales to end users (B2C), online sales to other firms (B2B); and (iii) Use of software applied to organizational and industrial processes. Depending on the firm's responses in these three areas, the digitalization scale takes integer values between 0 and 19. The minimum value (0) indicates that the firm has not introduced any digital technology into its production, sales, or organizational processes. For its part, the maximum value (19) indicates that the firm declares that it has introduced digital technologies in all the dimensions of each of the three areas mentioned above. To account for sectoral differences that may exist regarding needs and the average degree of digitalization, we also consider the sector average for the level of digitalization among competitors in the industry. Thus, the independent variable (*Degree of digitalization)* included in the models is a relative measure of digitalization, as the firm's degree of digitalization is divided by the industry average.

Moderator variable. The status of family firm is measured via a dichotomous variable (*Family Firm*) that takes value 1 when one or more members of the owner family occupy managerial positions, and 0 otherwise. This particular measure is drawn from our database and has been used previously by other family business scholars (Diéguez-Soto et al., 2016; Feranita et al., 2017; Kotlar et al., 2014; Fernández & Nieto, 2005). This measure enables us to identify both family ownership and involvement in firm management, like other family firm-oriented studies (Belitski and Rejeb, 2022; Sirmon et al., 2008; among many others).

3.2.3. Control variables

Size. Given that large firms tend to be engaged in more innovation activities, and therefore need to collaborate with different types of partners (Belderbos et al., 2018), firm size is a frequently used control variable in studies of innovation behavior and collaboration strategies. Firm size is also typically controlled for in analyses of digitalization, particularly in studies of family firms (Soluk et al., 2021). We control for the impact of firm size on collaboration decisions by including a variable calculated via the natural logarithm of total sales (Alberti et al., 2014).

R&D effort. We also capture the firm's R&D effort, as this is a critical input for innovation processes as well as a source of absorptive capacity (Cohen and Levinthal, 1990) that typically boosts technological collaboration (Belderbos et al., 2018). Specifically, we calculate *R&D effort* via the natural logarithm of the firm's R&D expenditure (Santamaria et al., 2012).

Committee. The existence of an internal committee/department for technology and innovation processes may support the acquisition and assimilation of external knowledge (Guo et al., 2019). The literature indicates that the existence of a person (gatekeeper) or team that systematically monitors the external information may favor technological collaborations (Fritsch and Lukas, 2001). *Committee* is a dichotomous variable that takes value 1 if the firm has a technology committee, and 0 otherwise.

Export. We control for the relationship between internationalization and innovation activities by calculating *Export* as export sales divided by total sales (Cassiman and Veugelers, 2002; Santamaria and Surroca, 2011).

Foreign capital. The presence of a foreign company in the firm's capital may influence its innovation activity (Becheikh et al., 2006) and its degree of openness (Santamaria and Surroca, 2011). Foreign capital is measured as a percentage of the firm's capital.

Public funding. We include a variable that captures the public funding received by the firm, as this funding often conditions collaboration strategies (Miotti and Sachwald, 2003). *Public* funding is a dichotomous variable that takes value 1 if the firm has received public funding, and 0 otherwise.

Age. Age is typically used to measure levels of experience, a factor that may affect firm behavior (Kumar and Saqib, 1996; Soluk et al., 2021). Firm age is calculated as the number of years since its foundation.

Lastly, we account for each sector's distinct characteristics by controlling for industry effects (via sectoral dummy variables) and for time effects (via year dummy variables) in all the models.

3.3. Preliminary descriptive analysis

Table 1 reports the statistics and correlations of the study's independent and control variables (except for sectoral and year dummy variables). We also include the variance inflation factor (VIF) analysis to test for multicollinearity. All the individual VIFs show values below 3, which suggests that there are no multicollinearity problems in our estimations (O'brien, 2007; Soluk et al., 2021). In line with Belsley et al. (1980), another indication of collinearity is a condition number with values of 30 or higher (in our case, 7.57). In sum, given the results of these diagnostic tests, there is no evidence of collinearity problems.

3.4. Model specification

As our dependent variable (*Breadth of collaboration*) is a count variable that only takes discrete non-negative integer values (from 0 to 4), and given the panel structure of our database, we estimate negative binomial regression models for panel data. This model accounts for observed heterogeneity and is consistent for estimating discrete count outcomes. Poisson regression is a frequently used alternative to estimate count variables. Poisson regression models, however, assume that the mean and variance of the dependent variable are equal and are not efficient estimators of over-dispersed data. Negative binomial regression can be used for over-dispersed count data, which occur when the conditional variance exceeds the conditional mean—as in our case. General Estimating Equation (GEE) is another method for analyzing over-dispersed count data when there are potential problems of autocorrelation and unobserved heterogeneity (Greene, 2012). Although the Arellano-Bond test does not indicate autocorrelation problems, we have estimated GEE models as a robustness check to account for unobserved heterogeneity.

In addition, we control for potential reverse causality from collaboration to digitalization by lagging our explanatory variable by one year; we do the same for the R&D effort of the firm. Other studies also adopt this approach to deal with endogeneity problems (e.g., D'Angelo et al., 2016).

4. Results

The empirical models for testing our hypotheses are reported in Table 2. Model 1 includes the independent variable *Degree of Digitalization* as the explanatory variable. We test the moderating effect of H2 by including the dummy variable *Family firm,* as well as the interaction term between this variable and the *Degree of Digitalization* (Model 3). The estimation of marginal effects is shown in Model 4.

The coefficient of our independent variable—*Degree of digitalization*—in Model 1 is positive and significant ($p < 0.01$). This first result confirms that a higher degree of digitalization is positively related to the breadth of collaboration, thus supporting Hypothesis 1.

Contrary to our expectations, the coefficient of the interaction term (*Degree of Digitalization*Family firm*) in Model 3 (and Model 4, estimating the marginal effects) is also positive and significant ($p < 0.01$). This result indicates that digitalization has a positive effect on the breadth of collaboration, particularly higher in the case of family firms. This finding, then, does not provide empirical support for Hypothesis 2.

In turn, the coefficient of *Family firm* is negative and significant, indicating that being a family firm is negatively related to the extent of collaboration.

Concerning the control variables across the different models, we find that firm size, R&D effort, the existence of an internal committee/

Table 1
Descriptive statistics, correlations, and collinearity diagnostics.

Variables	Mean	Std.Dev	Digital	Family firm	Size	R&D effort	Export	ForeignCap	PubFin	Commitee	Age	VIF
Digital	1.000011	.7,192,937	1.000									1.30
Family Firm	.5,285,451	.499,196	−0.145	1.000								1.32
Size	15.91844	1.965418	0.448	−0.427	1.000							2.22
R&D effort	4.29163	6.067582	0.370	−0.272	0.565	1.000						2.45
Export	.2,292,224	.296,523	0.217	−0.217	0.425	0.363	1.000					1.30
Foreign Cap	13.71105	33.64623	0.162	−0.382	0.440	0.268	0.290	1.000				1.36
Public fun	.1,440,749	.3,511,739	0.227	−0.144	0.363	0.543	0.251	0.096	1.000			1.53
Committee	.2,126,039	.4,091,591	0.306	−0.196	0.440	0.679	0.292	0.193	0.517	1.000		2.03
Age	29.92394	19.4616	0.177	−0.099	0.285	0.206	0.171	0.137	0.115	0.190	1.000	1.10
Mean VIF												1.62

Table 2
Empirical models. Dependent variable: *Breadth of collaboration.*

Variables	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
				(marginal effects)
Digital	0.1260***	0.1250***	0.0930**	0.0594**
	(0.0840)	(0.0838)	(0.0621)	(0.0237)
Family Firm		−0.0477	−0.1550**	−0.9890**
		(-0.0227)	(-0.0739)	(0.0482)
Digital*Family Firm			0.0861*	0.0550*
			(0.0545)	(0.0311)
Size	0.1630***	0.1590***	0.1580***	0.1012***
	(0.3140)	(0.3070)	(0.3050)	(0.0137)
R&D effort	0.0717***	0.0715***	0.0716***	0.0457***
	(0.4200)	(0.4190)	(0.4190)	(0.0032)
Export	0.1810**	0.1810**	0.1800**	0.1148**
	(0.0515)	(0.0514)	(0.0511)	(0.0526)
Foreign Cap	−0.0003	−0.0004	−0.0004	−0.0003
	(-0.0100)	(-0.0133)	(-0.0131)	(0.0004)
Public fun	0.4310***	0.4330***	0.4320***	0.2757***
	(0.1450)	(0.1460)	(0.1450)	(0.0276)
Committee	0.8630***	0.8620***	0.8620***	0.5506***
	(0.3420)	(0.3410)	(0.3410)	(0.0350)
Age	0.0003	0.0003	0.0003	0.0002
	(0.0047)	(0.0054)	(0.0048)	(0.0008)
Constant	−4.959***	−4.866***	−4.801***	
Observations	14,596	14,595	14,595	14,595
Chi-squared model fit statistic	2458,91	2458.10	2456.93	

Normalized beta coefficients in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

department to oversee technology and innovation processes, and public funding are positively related to the diversity of the partners in the collaboration. Internationalized firms also have more open attitudes towards collaboration. In contrast, the presence of foreign capital is not related to the breadth of collaboration. Similarly, the age of the firm is not a significant factor for explaining the breadth of collaboration. The sectoral and time variables are included in the different models.

As previously mentioned, several robustness checks have been performed to confirm the consistency of the results. Specifically, we have estimated GEE models for panel data as an alternative empirical method. The results are consistent with those obtained in our main models. Additionally, we have performed other analyses to corroborate the results to test hypothesis 2. To do so, we have divided the sample into two subsamples (for family and non-family firms), albeit estimating a single model. This model specification allows us to observe the effect of digitalization for family and non-family firms in the same model and compare the coefficient of digitalization in both groups. The test performed on the difference between coefficients confirms the stronger positive effect of digitalization for family firms. We have also estimated other empirical models including different variables/measures of the degree of digitalization, once again obtaining similar results. This additional empirical evidence supports the conclusions previously reached.[4]

5. Discussion and conclusions

Our study indicates that firm-level digitalization helps to increase the diversity of partners the firm involves in its innovation network. It illustrates how digitalization processes are useful to search, process and share information with technological partners, and this makes firms more likely to increase their search for external sources of knowledge.

This study draws on two existing theories – transaction cost economics and the knowledge-based view – to better understand the open innovation implications of a relatively new and increasingly pervasive phenomenon, namely, digitalization. The digital transformation is one of the ongoing megatrends that companies need to navigate (European Commission, 2021), and employing "old" theories in "new" settings provides valuable insight into the usefulness and potential limits of these theories (cf. Cuypers et al., 2021). To address our research question, we have employed the knowledge-based view and transaction cost economics in a complementary manner, as both offer unique insight into different facets of the topic at hand. As noted by Menz et al. (2021), a better understanding of the effect of digitalization on transaction costs is an interesting line of inquiry. Specifically, our study sheds light on how digitalization may affect the governance of transactions through the analysis of the breadth of collaboration. We complement this view using the knowledge-based perspective on the nature of the central asset being shared in technology collaborations, namely, knowledge (Grant, 1996; Williamson, 1979). By applying both theories in a complementary way, our study extends each one, and thereby provides an enriched theoretical perspective on the open innovation implications of ongoing digitalization processes.

As such, our study also addresses the broader research stream dealing with ecosystems, and in particular innovation ecosystems (e.g., Altman et al., 2022; Foss et al., 2023; Leten et al., 2013). Due to the number and speed of technological developments in the present-day business environment, it is no longer possible for most firms to organize their innovation activities entirely in-house. At the same time, buying technological know-how and intellectual property in the open market is limited to relatively standardized tech components (Williamson, 1979, 2010). We are thus witnessing a trend toward the increased use of hybrid forms of organization – i.e., ones that fall between hierarchies and spot markets – which nowadays often take the form of a coordinated network of collaborative interdependencies (Adner, 2017; Altman et al., 2022; Jacobides et al., 2018). We contribute to the burgeoning literature on innovation ecosystems by outlining how digitalization facilitates the productive use of an ever-wider web of technological collaboration partners, and by theoretically anchoring this in the knowledge-based view and transaction cost economics.

[4] Results are available from the authors upon request.

Our findings also contribute to family business literature. The ambiguous findings on open innovation strategies in family firms urge the need for more studies to explain and better understand open innovation in this particular context (Calabrò et al., 2019; Gjergji et al., 2019). By analyzing the relationship between digitalization and the breadth of technological collaboration, we shed more light on collaborative innovation initiatives in family firms, especially when they decide to expand the breadth of its technological collaboration. Open innovation can be beneficial for family firms if they are able to mitigate risks and manage relationships with external collaborative partners (Brinkerink et al., 2017). Our empirical results corroborate this, as, contrary to our theoretical expectations, they show that the effect of digitalization on the breadth of technological collaboration is stronger among family firms. We hypothesized a negative moderation effect because the socioemotional decision criteria and tacit knowledge, which are so characteristic of this organizational form (e.g., Gómez-Mejia et al., 2011; De Massis et al., 2016), could complicate and thus undermine the effectiveness of digitalization as an enabler of open innovation. A possible explanation for the observed positive moderation is that digitalization has a more beneficial impact among family firms because they have inherent social capital benefits. That is, prior research describes how family firms tend toward the development of more enduring and relational social networks and associations (e.g., Miller et al., 2008; Berrone et al., 2012), and this trust-based relational orientation and proficiency in building networks, rather than arms-length transactional ones, may complement and help unleash the full potential of digitalization in stimulating technology partnerships. As pointed by Su and Daspit (2022), relationships are vehicles of knowledge exchange, and in the family firm, they are important for both internal and external knowledge transfer. Our results suggest that family-based social capital capabilities and digital technology may complement each other in open innovation activities, where enduring and trust-based relationships form a strong basis for digitally enabled information flows.

Likewise, Bruque and Moyano (2007) have reported that high levels of employee engagement and participation during the implementation of IT in family firms may lead to enhanced technology adoption. This might explain the better performance and results of family businesses in implementing and driving the changes induced by digital technology. Alternatively, the subset of sampled family firms scoring higher on digitalization may de facto place less emphasis on socioemotional considerations, and instead – much like non-family firms – be more concerned with techno-efficiency aspects, whereby digitalization serves as a positive contingency in the association between family firm status and the breadth of technological collaboration. The aforementioned explanations for our surprising finding are conjecture at this point and require follow-up research, possibly in the form of qualitative studies, to gain a deeper insight into the underlying mechanisms.

Our contributions and findings may also be useful for practitioners. Keeping in mind the usual disclaimers regarding causality in non-experimental research designs like ours, our theory and results suggest that firm-level digitalization is a central strategic activity allowing firms to thrive in the ongoing shift toward innovation ecosystems characterized by a complex web of technological partnerships. Greater levels of digitalization of internal and interface processes facilitate the search for and monitoring of partners, as well as the flow of technological knowledge between them. This seems to be especially true for family firms, which may thus invest in digitalization to close the (open) innovation gap with their non-family counterparts (cf. Block et al., 2013; Classen et al., 2012; Nieto et al., 2015). The digital transformation is changing the very nature of business organizations and innovation strategies, and company managers are well-advised to remain at the forefront by continuing to adopt digital technology throughout their processes in this digital age (Bammens and Hünermund, 2021).

Our study is not without its limitations, which open avenues for future research. First, our study focuses on the breadth of technological collaboration (i.e., hard path to open innovation), which we have considered to be an important dimension of open innovation strategies. Future research may analyze other dimensions of openness, such as an external search without entering into technological collaboration (i.e., soft path to open innovation), for which digitalization can also be a very powerful tool. Thus, for example, digitalization can enhance the management of information that a firm may obtain from interacting with its consumers through various events (e.g., contests, innovation showcases …). Within this context, another interesting line would be to analyze for which of the two paths of open innovation, soft or hard, digitalization can be more beneficial. Moreover, our measure of the breadth of technological collaboration is related to suppliers, customers, competitors, and research organizations (including universities). Future studies could also analyze partnerships with startups that are neither formal suppliers nor direct competitors. As corporate-startup collaboration is gaining in importance in the open innovation field (Weiblen and Chesbrough, 2015), future work may delve deeper into this type of technology collaboration and the corresponding role of digitalization and family firm status.

Second, further studies could include other more complex dimensions and metrics related to other recent advances in digital technologies, such as machine learning, the Internet of Things (IoT), and blockchain, which are not well covered in the survey used. Likewise, although the family firm measure used captures both of the main dimensions related with family involvement (ownership and management), it is somewhat simplistic (being dichotomous). Future studies could include more sophisticated measures of family firm that more accurately describe the percentage of equity and the presence of family members on the board or other positions, as well as gender aspects or more detailed information about the owner family.

Finally, our sampled firms belong to manufacturing sectors prior to the COVID pandemic and within the Spanish institutional context. Future work should test the extrapolation of our findings to other settings, including the service sector, which has widely digitalized in recent years and gained in prominence. Regarding the COVID pandemic, recent work is calling for further research on how it has pushed the culture of digitalization (Kraus et al., 2020) and the impact of digital tools in family firms (De Massis and Rondi, 2020; Firfiray and Gomez-Mejia, 2021), facilitating greater flexibility (Soluk et al., 2021) and changing the organization of routines and coordination mechanisms (De Massis and Rondi, 2020). While the level of digitalization has intensified during the COVID years, we assume this has not substantially affected the nature of our tested relationships. In any case, studies using information from the pandemic and post-pandemic periods will contribute to our understanding of how family businesses are dealing with the challenges in a more digitalized post-COVID world (Zapata-Cantu et al., 2022).

To conclude, we trust that our study on digitalization and open innovation practices in a family business context inspires more research on this significant topic and that future studies will address some of our limitations. As we move from traditional business models to increasingly digital and networking ones, with even more pronounced movements in the aftermath of the COVID-19 pandemic, more academic research will be needed to guide practitioners and policymakers and help turn threats into opportunities.

Data availability

The authors do not have permission to share data.

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