R&D MANAGEMENT

The innovation antecedents behind the servitization–performance relationship

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Servitization allows manufacturing firms to differentiate themselves from rivals and become more competitive. Scholars have studied the service paradox, but analysis of the relationship between servitization and firm performance has provided inconclusive results. In terms of the antecedents that influence this relationship, the literature has tended to focus on firm and product characteristics but not on companies' innovative behavior. This article probes the relationship between servitization and firm performance by focusing on two forms of innovation (technological and open) that may exert an influence. The study draws on the resource-based view literature to explain the role of interactions between technological innovation, service innovation, and open innovation in enhancing firm performance. Longitudinal empirical analysis was conducted with a sample of Spanish industrial firms for the period 2010–2016. Two time-lagged models were built and analyzed. The results show that technological innovation influences servitization. This relationship is moderated by open innovation. Servitization mediates the relationship between technological innovation and firm performance. The findings contribute to the literature on servitization and innovation management. Innovation is posited as an antecedent to the service paradox. Products, services, and open innovation should be considered when firms design innovation strategies to improve their performance. Such innovation strategies should lead to an increase in servitization. Service innovation should be supported by open innovation to strengthen technological innovation potential.

1. Introduction

Manufacturing companies are increasingly adding services to the products they offer as a way to differentiate and improve their value propositions. In a similar fashion, many industrial companies shift from providing standardized products toward offering customized solutions through the incorporation of services (Storbacka et al., 2013). Thus, servitization (Vandermerwe and Rada, 1988; Oliva and Kallenberg, 2003) emerges as a way to compete in the market (Raddats et al., 2019) and improve business performance.

However, studies of the relationship between servitization and firm performance have provided inconclusive results. Some studies seem to confirm the service paradox (Gebauer et al., 2005; Neely, 2008). In contrast, others suggest that servitization positively influences business performance (Crozet and Milet, 2017; Wang et al., 2018). Feng et al. (2021) recently provided an inventory of studies of the relationship between servitization and firm performance. This inventory summarizes the findings of these studies and indicates whether they considered any intervening variables. Interestingly, Feng et al. (2021) found factors that influence the relationship between servitization and firm performance ex ante (i.e., antecedents) and included firm and product characteristics, but not firm behavior in terms of, for example, innovation.

Innovation is recognized as a key source of competitiveness (Cirera and Muzi, 2020). According to the Oslo Manual (OECD, 2018), product and process innovation counts as technological innovation. Most research on innovation in manufacturing firms has focused on technological innovation (Toivonen and Tuominen, 2009; Vilkas et al., 2022). It has largely ignored service innovation and the opportunities it offers. Although product and service innovation are sometimes considered together, arguments are provided to show that service innovation in manufacturing firms deserves attention in its own right (Gebauer et al., 2011). Specific analysis of the innovation strategy adopted by industrial companies is required (Benedettini and Kowalkowski, 2022). According to Shin et al. (2022), this analysis remains an open issue.

To date, research on servitization has tended to focus primarily on business model innovation (Visnjic et al., 2016), and technological innovation, in the broad sense of the term, has largely been disregarded (Vendrell-Herrero et al., 2023). Scholars have even discussed a trade-off between product-based research and development and service innovation (Benedettini and Kowalkowski, 2022). Research on open innovation has examined both manufacturing firms pursuing new product development (Chesbrough, 2011) and service firms trying to produce new services (Mina et al., 2014). However, such research has rarely studied the context of manufacturing firms trying to develop their service business (i.e., servitizing companies). Thus, there are research opportunities to further the understanding of the role of innovation activities as an antecedent in the servitization–performance relationship.

The present study aimed to extend analysis of the relationship between servitization and firm performance by focusing on two forms of innovation that may influence this relationship. The first is technological innovation. According to Eggert et al. (2011) and Zhang and Zhao (2012), this form of innovation may be expected to have a positive influence on servitization and firm performance. The second is open innovation. According to Chesbrough (2011), it may be expected to have a positive influence on servitization. Thus, by analyzing the servitization–performance relationship against the backdrop of the research and development (R&D) literature, the scope of this relationship is broadened, and its visibility is raised.

This study follows a quantitative approach. Specifically, a framework with interactions between variables is used, responding to the call of Feng et al. (2021) to investigate the relationship between servitization and firm performance and explore different moderating and mediating variables. Longitudinal data from 337 Spanish manufacturing firms for the period 2010–2016 were collected. These data gave an unbalanced panel of 2345 firm-year observations. Two time-lag models running in parallel and sharing t-1 and t were examined.

The results show that there is a significant, positive, and direct interaction between technological innovation and servitization and also reveal a significant positive relationship between servitization and firm performance. In addition, servitization mediates the relationship between technological innovation and firm performance. Finally, technological collaboration moderates the relationship between technological innovation and servitization.

To ground the findings in theory, the study draws on the resource-based view (RBV) literature (Wernerfelt, 1984; Peteraf and Barney, 2003) to explain the role of the interaction between technological innovation, service innovation, and open innovation in firm performance. It is argued that manufacturing companies develop innovation strategies based on internal and external resources. At the same time, they combine technological innovation, service innovation through servitization, and technological collaboration through open innovation. This process gives rise to a set of resources dedicated to innovation strategy. The impact of these resources on firm performance leads to RBV-based analysis (Sirmon et al., 2007; Alexy et al., 2018). If open innovation moderates the relationship between technological innovation and servitization, then the study would fill the gap in the literature on how firms solve the apparently paradoxical tensions between open innovation and RBV. In other words, such a finding would show how firms can share knowledge and innovation while protecting essential resources (Alexy et al., 2018; Vendrell-Herrero et al., 2023). The contributions of this paper are based on the development of these ideas.

As a whole, this study was designed to address problematization in relation to the servitization–performance relationship in the context of management science, using the RBV as a theoretical lens. The focus of this research is not merely spotting a gap. It aims to improve knowledge of the antecedents of the relationship between servitization and performance based on innovative behavior. The analysis evaluates how innovation behaves in relation to servitization and performance, differentiating between the role of open innovation and that of technological innovation.

Locke and Golden-Biddle (1997) described how to manage problematization in a scientific context. Researchers 'first must represent and organize existing knowledge so as to configure a context for contribution that reflects the consensus of previous work'. In the field of innovation and servitization, this study presents the existing knowledge and establishes a context of analysis where there is a consensus. Researchers 'second … must in a sense turn on themselves, subverting or problematizing the very literatures that provide locations and *raisons d'être* for the present efforts' (Locke and Golden-Biddle, 1997, p. 1,029). This study identifies the problematization of the servitization–performance relationship and considers the antecedents related to innovative behavior. Through 'the process of problematization, then, a text attempts to signify how much the offered contribution matters. And, in doing so, it seeks to establish the contribution's importance and relevance to readers' (Locke and Golden-Biddle, 1997, p. 1,040). The contributions of this study are presented at the theoretical and managerial levels. In short, phenomenon-driven problematization is adopted, with underlying theoretical assumptions explained and scrutinized in conjunction with novel empirical material.

As a result, this research contributes to the literature on servitization and innovation management. There is a lack of research on the factors that affect the relationship between servitization strategy and firm performance (Kowalkowski et al., 2017). This study researches the factors behind this relationship. It complements the literature on antecedents based on firm and product characteristics incorporating innovative behavior, and it can help solve the service paradox. The understanding of the service paradox can be reinforced through the lens of open innovation. Moreover, the longitudinal nature of this research enabled assessment of the long-term performance of innovation strategies and servitization. Accordingly, this study provides useful insight for managers, who need a framework to evaluate their innovation policy decisions and to balance their innovation endeavors. To the extent that firms invest in R&D, it enhances the introduction of services to the market. Accordingly, the possession of innovation capacity through R&D is critical for manufacturing firms to succeed in servitization.

The rest of the paper is organized as follows. Section 2 reviews the literature that relates technological innovation and open innovation with servitization and theorizes the relationships between these three concepts and firm performance. This background leads to several hypotheses and a framework for analysis (Section 3). Afterward, Section 4 presents the sample data and the operationalization of the variables from the framework for analysis. Next, Section 5 presents the results, while Section 6 discusses the findings. Finally, Section 7 closes with a series of conclusions, theoretical and managerial implications, and future research suggestions.

2. Background on the antecedents of servitization and firm performance: technological innovation and open innovation

Manufacturing companies are transitioning from business models based on standardized products to solution-based models (Storbacka et al., 2013). Hence, servitization in the manufacturing industry is firmly based on a strategic view of the company (Bustinza et al., 2019). Innovation is an important underlying concept given that servitization represents a shift of product firms from developing, manufacturing, and selling products to innovating, selling, and delivering services (Oliva and Kallenberg, 2003). Investigation into the topic of servitization has thus led to a broader view of innovation (Lerch, 2014).

The literature offers extensive analysis of the relationship between servitization and firm performance (Bustinza et al., 2018; Martín-Peña et al., 2020). However, studies of this relationship have failed to reach a consensus. Consequently, scholars continue to reveal facets of the service paradox, which refers to the idea that manufacturing companies' investment in service business does not necessarily generate high returns (Brax et al., 2021). The service paradox is arguably a sign of the complex relationship between servitization and firm performance. This relationship is influenced by many factors inside and outside the firm (Feng et al., 2021). Despite the growing body of research on factors influencing the servitization–performance relationship, business innovation behavior has not received the full attention of scholars.

The improvement of firm performance of manufacturing enterprises is the joint result of internal and external resources (Feng et al., 2021). Therefore, the innovative behavior of firms may be an important factor in the relationship between servitization and firm performance. This idea stems from an innovation-based approach.

According to Vendrell-Herrero et al. (2023), servitization has been acknowledged as an important new form of (business model) innovation for manufacturing organizations (Eloranta and Turunen, 2016; Crozet and Milet, 2017). However, when explaining how innovation affects firm performance, the emphasis has primarily been on product and process innovation. Given that technological innovation and servitization both seem to matter for firms to achieve a competitive advantage, the role of technological innovation in servitization should also be explored. Indeed, technological innovation is cited in the literature as a potential driver of servitization (Vilkas et al., 2022).

Over time, firms continually search for ways to transform and advance their innovation strategies to raise their performance (Zobel, 2013). One way to enhance firm performance is by adding value to products through servitization. The direct relationship between technological innovation and firm performance has been analyzed in the literature (e.g., Hall et al., 2010), as has the direct relationship between servitization and performance. As explained earlier, such research has provided mixed results (i.e., the service paradox). Despite this research, the mechanisms through which the benefits of technological innovation translate into firm performance are not always evident. Servitization might be a mechanism that can unlock the benefits of innovation to enhance firm performance, in part because developing and providing a combined product–service offering can enhance a manufacturer's product innovation and differentiation (Zhang et al., 2016).

Along with technological innovation, open innovation may also support servitization to enhance business performance. As innovation processes become more complex, companies must search more for external knowledge (Tether, 2002). This situation can lead them to embrace open innovation practices (Chesbrough, 2003).

Although open innovation has mainly been studied regarding product innovations, it can also be found in service innovation (Chesbrough, 2011). Servitization transforms manufacturing from a closed, individualistic environment to an open, network-based setting that demands relational and collaborative approaches to innovation (Rabetino et al., 2017; Vendrell-Herrero et al., 2023). New services can be introduced by manufacturing firms following collaboration with customers, suppliers, and other stakeholders throughout the value chain. Such collaborations have rarely been analyzed in the context of manufacturing firms trying to develop their service business (i.e., servitizing companies). One exception is the study by Bustinza et al. (2019). However, it focused on very large companies and interactions between manufacturing firms and knowledge-intensive business services only. Another study by Vendrell-Herrero et al. (2019) is also worth highlighting because of its focus on manufacturing firms that simultaneously engage in product and service innovation. However, it did not explore open innovation processes. Vendrell-Herrero et al. (2023) introduced the idea of the direct effect of open innovation on what they denote treble innovation (product, process, and digital servitization). Finally, Polova and Thomas (2020) also studied collaborative servitization projects. However, they adopted an exploratory approach, studying a small set of cases.

The present study builds on a synthesis approach (Witell et al., 2016). It presents a framework of technological innovation and open innovation within manufacturing firms, using these concepts as antecedents to understand how servitization influences business performance. In line with the discussion in the previous section, open innovation practices in servitization can lead to both new business models (Mina et al., 2014; Chen et al., 2021) and new value propositions (Wilden et al., 2013). Framing this idea in terms of the resource-based view (RBV), the resources and capabilities of different organizations are brought together to offer value to customers (Vanhaverbeke and Cloodt, 2014). It supports a co-evolutionary process of organizational learning and dynamic capability building where organizations can take a variety of competitive actions to achieve service innovation (Wilden et al., 2013).

This study examines not only the effects of servitization on firm performance but also its antecedents in terms of the innovative behavior of firms. The analysis of antecedents draws on the literature on the RBV (Barney, 1991), which suggests that innovative firms that engage in product and process innovation (technological innovation) and open innovation, are more likely to achieve service innovation. As Vendrell-Herrero et al. (2023) found in their analysis of treble innovation, these firms have unique capabilities that defuse the apparently paradoxical tensions between sharing knowledge and protecting essential resources.

3. Hypothesis development

3.1. *Technological innovation and servitization*

The servitization literature is not unanimous on the relationship between technological innovation and servitization. Some literature suggests that the effects of technological innovation on servitization are weak or even negative. For example, Jaw et al. (2010) reported that the development of services is not comparable to the development of new technological products due to special features of services. Hence, synergies between technological innovations and servitization should not be expected (Lerch, 2014). Even some scholars have reported that servitization is an alternative to a product-based R&D strategy for firms aiming to innovate (Eggert et al., 2011). Introducing services can shift product-based R&D investment toward service innovation. However, this shift in innovation strategy can become a problem for firms, creating a trade-off between servitization and investment in product-based R&D (Benedettini and Kowalkowski, 2022). Under the RBV, product innovation and the provision of services compete for the limited resources of the firm.

In contrast, some scholars suggest that product innovation activities lead companies to become better in innovation overall, thus spurring servitization as well (Tongur and Engwall, 2014; Visnjic et al., 2018; Bustinza et al., 2019). Hwang and Hsu (2019) have shown that when company innovativeness is high, technological innovation has a stronger influence on initiating servitization processes. Their explanation for this relationship is based on three arguments. First, from a service innovation perspective, technological product innovation is an enabler of new services because it facilitates the design and introduction of new types of services in manufacturing firms. Second, from a resource-based perspective, innovation capabilities are time-invariant endowments that enable firms to learn. Third, from a production management perspective, servitization might foster the demand (pull) dimension of innovation by intensifying customer relationships. Similarly, Parida et al. (2015) and Eloranta and Turunen (2016) have reported positive relationships between technological innovation and servitization. Benedettini and Kowalkowski (2022) explained that industrial companies should not cut back on technological innovation when pursuing a servitization strategy because doing so would erode their overall competitiveness. Consequently, service businesses could also suffer. Hence, technological innovation should improve servitization opportunities. This argument reflects the idea that servitization often starts with a core product or product technology around which services are created (Tongur and Engwall, 2014).

The growing research on the interrelation between digitalization and servitization (Kohtamäki et al., 2019; Paschou et al., 2020; Tronvoll et al., 2020; Gebauer et al., 2021) supports the idea that technological innovation fosters servitization processes, notably those of digital services. The synergistic relationship between digitalization and servitization can be attributed to endeavors in technological innovation (Kryvinska et al., 2014). Porter and Heppelmann (2014) have certainly voiced this idea, arguing that smart and connected products open the door for more diverse digital (after-sales) services. Thus, it is argued that technological innovation drives servitization, particularly given the synergies that the servitization literature postulates between digitalization and servitization.

H1 Technological innovation at the firm level is positively related to servitization.

3.2. *Servitization and firm performance*

From the perspective of strategic management, the provision of services by manufacturing firms can be interpreted under the RBV. A company that has strategically superior resources and competencies than its competitors can provide hybrid offerings with greater customer value than those of its rivals. Consequently, it can achieve better performance (Wernerfelt, 1984).

Over time, manufacturing firms from different industries have pursued servitization processes to improve their competitive and financial performance (Morris and Davis, 1992; Miller et al., 2002; Davies, 2004; Neu and Brown, 2005). Results on the return on investment from service business development are mixed. Some results suggest that servitization fuels manufacturing firms' chances of making revenue streams more robust and recurrent (Wise and Baumgartner, 1999; Coreynen et al., 2017; Ardolino et al., 2018). Scholars have provided evidence of sales growth (Kohtamäki et al., 2013; Martín-Peña et al., 2020), profitability, business growth (Cusumano et al., 2015; Bustinza et al., 2018; Kohtamäki et al., 2020; Abou-Foul et al., 2021), and market value (Fang et al., 2008) due to servitization. In contrast, scholars have also noted the existence of a service and a digitalization paradox (Gebauer et al., 2005, 2021; Kohtamäki et al., 2019). If the cost of developing and delivering a (digital) service offering exceeds the revenue it produces, then the rollout of this service offering will lead its provider to fall victim to the service or digitalization paradox.

A large-scale study by Neely (2008) of the relationship between servitization and profitability showed that this relationship is not straightforward. This finding has been seconded by Suárez et al. (2013), Visnjic and Van Looy (2013), Eggert et al. (2014), and Zhou et al. (2020), who have also reported complex relationships between servitization and firm performance. To illustrate the former idea, Zhou et al. (2020) found that servitization has a U-shaped relationship with a manufacturer's financial performance. In addition, their research showed that the existence of stronger ties between a manufacturer and major service suppliers intensifies the U-shaped servitization–performance relationship. Bustinza et al. (2018) provided an inventory of relationships between servitization and business performance, showing that these relationships may be linear or non-linear. Although the evidence of the relationship between servitization and firm performance is inconclusive, it can be assumed that servitization is worthwhile from a strategic perspective and that benefits such as differentiation (Kryvinska et al., 2014; Zhang et al., 2016) provides companies with a better basis to compete and survive in the marketplace. Hence, although servitization may not always translate immediately into a return on investment, it seems reasonable to propose the following hypothesis:

H2 Servitization is positively associated with firm performance.

3.3. *Technological innovation, servitization, and firm performance*

The direct effect of a firm's technological innovation on servitization (Hypothesis 1) and the direct effect of servitization on firm performance (Hypothesis 2) have already been discussed. Given the nature of these relationships, servitization is also expected to have a mediating effect on the relationship between a firm's technological innovation and firm performance. Most scholars believe that there is a significant positive correlation between technological innovation and firm performance. The more innovation an enterprise engages in, the more profit it will make (Psomas et al., 2018). However, certain scholars have reached the opposite conclusion regarding the relationship between technological innovation and firm performance. Innovation activities create uncertainty, and firms are susceptible to interference from fluctuations in the external environment, which have a negative impact on their economic development (Wilbon, 2002).

Some authors have cited a long-term indirect effect of R&D expenditures on firm performance through their influence on patents and products or process innovations (Chakrabarti, 1990; Hall and Bagchi-Sen, 2002). Under such a model, R&D is thought to enhance achievements in innovation, which improve firm performance. A firm's technological innovation plays a key role in enabling service innovations (Miles, 2005). It is becoming more important as a key contributor to service productivity and, subsequently, performance.

Geum et al. (2011) cited the notable role of technology in product–service integration. They argued that it plays a crucial role in service development and occupies a pivotal role in offering integrated product–service systems that allow firms to improve their customer performance. Similarly, Visnjic et al. (2012) found a curvilinear relationship of the interaction of servitization and product R&D investment with profit. In a later publication, Visnjic et al. (2016) probed deeper into the relationship between product innovation and service business model innovation. They argued that the complementarity between R&D intensity and servitization occurs in the long term, whereas there might be a substitution effect in the short term.

Similarly, scholars such as De Luca et al. (2010) and Bustinza et al. (2019) have shown that R&D intensity is a key moderator in the context of innovation effects. Service innovation in manufacturing firms characterized by high R&D intensity may thus exert stronger business or economic performance effects than production firms that operate in industries with low or medium R&D intensity. Ariu (2016) explained that high R&D intensity firms continuously develop new complex products. Then, related services that piggyback on such complex products offer more opportunities to generate added value, allowing providers to recover returns on investment more easily. This reasoning supports the idea that technological innovation can not only directly translate into improved business performance but also foster the profitability of servitization processes. Thus, firms with higher technological innovation intensity are expected to have more opportunities to enhance their rents through servitization.

H3 Servitization mediates the relationship between a firm's technological innovation and performance.

3.4. Open innovation, technological innovation, and servitization

Despite efforts to study the intersection of servitization and technological innovation, there is a need for a deeper understanding of the relationships between these variables (Alexiev et al., 2018), as well as the inclusion of other innovation-related variables (Opazo-Basáez et al., 2022).

Under an RBV perspective, open innovation highlights the interdependence of complementary firm resources (Vanhaverbeke and Cloodt, 2014; Alexy et al., 2018). Firms cannot develop the resources they need internally. Instead, they team up with innovation partners to enable resource flows between firms (Vanhaverbeke and Cloodt, 2014). Among these partners, customers, suppliers, competitors, and universities have received the most attention in the literature. For example, Chesbrough (2011) argued that the value chain should be conceived following the approach of Levitt and Drucker as an iterative process that involves the customer and results in a customer experience. Involving customers in servitization journeys in this way makes it easier to resolve customer problems and helps manufacturing firms anticipate customer needs (Chesbrough, 2011). Similarly, from a service logic perspective, Bonfanti et al. (2018) and Sjödin et al. (2020) have stressed the value of customer co-creation processes. They revealed that their participation in (digital) service innovation processes help manufacturers develop customized and original value propositions. In a literature review, Baines et al. (2009) found that collaboration with customers has a marked effect on manufacturing firms' ability to deliver successful service innovations.

Ayala et al. (2018) and Bustinza et al. (2019) examined whether interaction with suppliers helps production firms servitize, finding evidence that it does. Although their supplier base was made up of KIBS and service firms, they showed that upstream collaboration along the supply chain helps product firms servitize. This situation can even lead firms to collaborate with competitors to share the costs and risks of R&D (Huang et al., 2009) or to learn from each other (Tsai and Hsieh, 2009).

Also, digitalization, as a form of technological innovation, encourages the engagement of additional actors and thus facilitates the creation and functioning of an ecosystem (Sklyar et al., 2019). Interestingly, as noted by Chesbrough (2003), synergies of openness can also work the other way round. Successful service innovation promotes better interorganizational collaboration and can thus stimulate knowledge sharing among the partners involved in a joint innovation process.

Open innovation entails the interdependence of complementary resources of firms in developing and launching innovations (Vanhaverbeke and Cloodt, 2014). Therefore, it is necessary to analyze how open innovation could moderate the relationship between technological innovation and servitization. Such analysis fills the research gap on how firms solve the apparently paradoxical tensions between sharing knowledge and innovation and protecting essential resources (Alexy et al., 2018; Vendrell-Herrero et al., 2023). Hence, a positive moderating role of technological collaboration in the relationship between a firm's technological innovation and servitization is hypothesized.

H4 Open innovation positively moderates the relationship between a firm's technological innovation and servitization.

4. Data and variables

4.1. Sample

The hypothesis was tested using data from responses to the Survey on Business Strategies (SBE). This survey collects data from a representative sample of industrial firms in Spain. The period of analysis was 2010–2016 (representative of a stable macroeconomic structure). The survey population consisted of companies that have 10 or more employees (all companies with more than 200 workers and a stratified random sample of companies with 200 workers or fewer) and that are engaged in one of the activities described in Divisions 10 to 32 of the CNAE-2009 classification (i.e., the Spanish official version of NACE rev.2).

Based on their crucial role in innovation in Spain and their advancement in servitization and open innovation practices, the following industries were included in the study: Chemical and pharmaceutical products, non-metallic mineral products, agricultural and industrial machinery, computer, electronic, and optical products, electrical machinery and material, other transport equipment, and other manufacturing. These industries accounted for 43% of total technology expenditure (Mulet, 2021). In all industries, there was servitization (Gonzalo-Hevia and Martín-Peña, 2021) and technological collaboration. The total sample consisted of an unbalanced panel of 2359 firm-year observations covering 337 manufacturing firms across seven manufacturing subindustries between 2010 and 2016. A firm-year unit of analysis was used to form the estimators for the study because they were time series. Specifically, the time series consisted of short panel data. Table 1 gives details of the sample.

4.2. Measures

Several items were used to measure the key constructs. *Level of servitization* was measured as the proportion of a firm's sales accounted for by service offerings (Santamaría et al., 2012; Crozet and Milet, 2017). *Technological innovation* was measured as technological endeavors. It was a categorical variable indicating the intervals for a firm's total R&D expenses and technology imports as a percentage of total sales. The variable had six levels: 0%, 0% to 1%, 1% to 2.5%, 2.5% to 5%, 5% to 10%, and more than 10%. Product innovation is usually triggered by R&D (Lerch, 2014). Also, process innovation is covered by R&D and technology acquisition. *Technological collaboration* was built from dummy variables reflecting technological collaboration with suppliers, customers, competitors, and universities. Following the method of Laursen and Salter (2006), technological collaboration was measured in terms of breadth. It was constructed as the sum of four sources of collaboration. Each of the four sources was coded as a binary variable (*0* = no use of knowledge source; *1* = use of knowledge source). *Firm performance* was measured using added value in millions of euros, calculated as the sum of sales, change in stocks, and other revenues minus purchases and expenses on external services. Added value was suitable for measuring firm performance in this study because it only considers operating incomes and expenditures. This measure includes neither noncash expenses, such as depreciation or amortization, nor taxes or interest from financial investments. The measure therefore gives a reliable performance measure for private firms (Belderbos et al., 2004; George, 2005; De Massis et al., 2018).

Table 1. Sample description

Sample distribution by subindustry	*n*	%
Non-metallic mineral products	553	23.44
Chemical and pharmaceutical products	539	22.85
Agricultural and industrial machinery	434	18.40
Electrical machinery and material	308	13.06
Other manufacturing	210	8.90
Other transport equipment	175	7.42
Computer, electronic, and optical products	140	5.93
Total	2359	100.00

To rule out possible alternative explanations to those formally hypothesized, the model included several control variables. The review by Becheikh et al. (2006) confirms that most studies have shown a significant relationship between sector and innovation. In addition, more than half (55%) of studies consider size an explanatory variable of innovative behavior. Some authors have also found a positive relationship between the age of a firm and innovation due to the accumulation of experience and knowledge (Sørensen and Stuart, 2000). However, others have reported the opposite, arguing that older companies develop established procedures and routines, which create resistance and represent an obstacle to innovation (Freel, 2003). Firm age was measured as the number of years between the foundation of the firm and the observation year (Bikfalvi et al., 2013; Benedettini et al., 2015; Vendrell-Herrero et al., 2017). Firm size was measured as the natural logarithm of total liabilities (Crozet and Milet, 2017). Because business sectors may have distinct levels of each variable, industry effects were controlled (Manzaneque et al., 2020) by including a dummy variable for each subindustry. Finally, to control for potential year effects, a variable for each year was included (as per the estimation method of the models). Table 2 shows descriptive statistics and correlations of all variables.

Finally, to enable causal inference, the hypotheses were tested using a time-lag effect (Tsinopoulos et al., 2018). According to innovation diffusion theory, even if a company makes a technological breakthrough, it takes time to expand the market scale of new products (Turnbull and Meenaghan, 1980). The time it takes for innovation initiatives to influence certain variables differs (Holak et al., 1991; Belderbos et al., 2004). A frequent and widely accepted period used in studies with time-lag effects and a primary focus on performance is 2–5 years (Cheng and Huizingh, 2014; Xu, 2015). There is no reference for impact after introducing new services. It seems reasonable to assume that innovative endeavors in a given period will influence the introduction of new services in at least the following period and performance in at least the following two periods.

5. Results

To test the hypotheses, panel data methodology was used. This technique controls for unobservable

Table 2. Descriptive statistics and correlations

	Mean	SD	1	2	3	4	5	6
1. Firm performance	22.14	73.51	1					
2. Tech. innovation	2.25	1.49	0.306***	1				
3. Tech. collaboration	0.97	1.21	0.119**	0.061	1			
4. Servitization level	10.14	15.41	0.434***	0.501***	0.059	1		
5. Firm age	41.45	19.01	0.164**	0.196***	0.156**	0.090*	1	
6. Firm size	16.61	1.93	0.512***	0.437***	0.507***	0.135**	0.202***	1
VIF (var. inflation factor)				1.687	1.805	1.035	1.037	1.467

***Significant at 0.1%, **Significant at 1%, *Significant at 5%.

heterogeneity, which refers to the specific behavior and features of each sampled firm. Two lagged models were proposed. In the first, the influence of technological innovation and open innovation in t-2 on servitization in t-1 was studied. In the other, the influence of servitization in t-1 on performance in t was studied.

The hypotheses were tested using multiple linear regression analysis based on linear mixed models with maximum likelihood estimation. Random effects were mostly used because the time-invariant nature of the control items (age and industry) precluded the use of fixed effects (González et al., 2013; Diéguez-Soto et al., 2016). The results of the Hausman test, with a *P*-value close to 1, confirmed that the random effects estimator was not inconsistent. Nevertheless, to check the robustness of the estimates, fixed effects estimators were also used. For Models 3 and 6, conditional process analysis using bootstrapping was performed. Table 3 provides details of the models used in the regression analysis.

In Models 1, 2, and 3, servitization was the dependent variable. In Models 4, 5, and 6, performance was the dependent variable. The results for the random effects models appear in Table 4.

The results for the fixed effects models appear in Table 5. These models were least squares dummy variable models. They were used to check the robustness of the estimates. With this approach, the firm age and industry variables were not included. The null hypothesis that the variance of the error of the dependent variable was the same throughout all groups was supported. For all models, Levene's test was significant.

Although the values of the estimates vary, no changes were observed in the key relationships between variables. Hence, the two estimation methods present consistent results when modeling the framework proposed in Figure 1.

Hypothesis 1 is tested with Model 1. There was a positive relationship between technological innovation and servitization. The control variables were significant. Although the model did not have a high adjusted R squared value, it suggests that technological innovation partially explains servitization, confirming Hypothesis 1.

Hypothesis 2 is tested with Model 4. The model was significant and had high explanatory power (R squared = 0.2959). The variable servitization was positive and significant, confirming Hypothesis 2. Control variables were significant.

Hypotheses 3 (mediation) and 4 (moderation) were introduced in Model 6 and Model 3. The use of bootstrapping helped perform a deeper level of

Table 3. Regression models

	ID	Role
Main items		
Servitization level	SL	Dependent variable (Models 1 to 3)/Independent variable (Models 4 to 6)
Firm performance	FP	Dependent variable (Models 4 to 6)
Tech. innovation	TI	Independent variable (technological endeavors)
Tech. collaboration	TC	Moderator (suppliers, customers, competitors, and universities)
Interaction TI-TC	I_IC	Interaction (effect due to technological collaboration)
Control items		
Firm size	FS	Control variable (random and fixed effects models)
Firm age	FA	Control variable (random effects models)
Subindustry	SU	Control variable (random effects models)
Year ‘t’	YE	Control variable (Index/Factor)

Model name	Mathematical model
Model 1	$\mathrm{SL}_{\mathrm{it}} = \beta_{10} + \beta_{11,\mathrm{t-1}} \times \mathrm{TI} + \textit{Control Variables} + \mu_i + \varphi_t + \varepsilon_{it}$
Model 2	$\mathrm{SL}_{\mathrm{it}} = \beta_{20} + \beta_{21,\mathrm{t-1}} \times \mathrm{TI} + \beta_{22,\mathrm{t-1}} \times \mathrm{TC} + \textit{Control Variables} + \mu_i + \varphi_t + \varepsilon_{it}$
Model 3	$\mathrm{SL}_{\mathrm{it}} = \beta_{30} + \beta_{31,\mathrm{t-1}} \times \mathrm{TI} + \beta_{32,\mathrm{t-1}} \times \mathrm{TC} + \beta_{33,\mathrm{t-1}} \times \mathrm{I\_IC} + \textit{Control Variables} + \mu_i + \varphi_t + \varepsilon_{it}$
Model 4	$\mathrm{FP}_{\mathrm{it}} = \beta_{40} + \beta_{41,\mathrm{t-1}} \times \mathrm{SL} + \textit{Control Variables} + \mu_i + \varphi_t + \varepsilon_{it}$
Model 5	$\mathrm{FP}_{\mathrm{it}} = \beta_{50} + \beta_{51,\mathrm{t-2}} \times \mathrm{TI} + \textit{Control Variables} + \mu_i + \varphi_t + \varepsilon_{it}$
Model 6	$\mathrm{FP}_{\mathrm{it}} = \beta_{60} + \beta_{61,\mathrm{t-1}} \times \mathrm{SL} + \beta_{62,\mathrm{t-2}} \times \mathrm{TI} + \textit{Control Variables} + \mu_i + \varphi_t + \varepsilon_{it}$

analysis in the conditional process analysis. It also enabled checking of the robustness of the estimates. The models are summarized in Table 6.

To test Hypothesis 3, Models 4, 5, and 6 were considered. The random effects models were used to test the four conditions of mediation (Baron and Kenny, 1986; Field, 2013). In Model 5, the predictor variable (technological innovation) predicted the outcome (performance). In Model 1, the predictor variable (technological innovation) predicted the mediator (servitization). In Model 4, the mediator (servitization) predicted the outcome (performance). The relationship between a firm’s technological innovation and performance was smaller when servitization was included in the model (Model 6) than when it was not (Model 5). Hence, the mediator variable (servitization) displaced the predictor in explaining the performance. Hypothesis 3 was confirmed by the Sobel test in Table 7.

The analysis was complemented by direct and indirect effects of technological innovation on performance to establish whether mediation was significant (PROCESS Hayes, 2017). Table 8 displays the two effects: the direct effect of technological innovation on performance when servitization was included as a predictor; the indirect effect of technological innovation on performance. The confidence interval did not contain 0, so there was an indirect effect. Thus, servitization mediated the relationship between technological innovation and performance.

To test Hypothesis 4, Models 2 and 3 were used. To test for the moderating effect, Model 3 included the independent effect of technological collaboration and the interaction variable (technological innovation × technological collaboration). The introduction of the new interaction variable improved the explanatory power with respect to Model 1 (adjusted R squared increased from 0.1435 to 0.1903 in the

Table 4. Estimated models (random effects models)

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Dependent variable	SL (t-1)		SL (t-1)		SL (t-1)		FP (t)		FP (t)		FP (t)	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Independent variables												
TI (t-2)	1.0502***	0.2835	1.3539***	0.3118	−0.0036	0.3976			4.1988**	1.3171	2.9459*	1.3211
SL (t-1)							0.5499***	0.1069			0.5202***	0.1070
TC (t-2)			−0.5049	0.3900	−1.1924	0.7173						
I_IC (t-2)					1.1157***	0.2050						
Controls												
FA (t-2)	0.0388*	0.0190	0.0400*	0.0189	0.0437*	0.0189	0.2901**	0.0886	0.2760**	0.0887	0.2665**	0.0887
FS (t-2)	0.7752***	0.2188	0.9423***	0.2300	1.1171***	0.2305	19.2120***	0.9362	18.1097***	1.0215	17.9659***	1.0226
SU	dummies		dummies		dummies		dummies		dummies		dummies	
YE	Index/factor		index/factor		index/factor		index/factor		index/factor		index/factor	
R^2	0.1435***		0.1492***		0.1903***		0.2959***		0.2911***		0.3002***	

***Significant at 0.1%, **Significant at 1%, *Significant at 5%.

Table 5. Estimated models (fixed effects models)

Dependent variable	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	SL (t-1)		SL (t-1)		SL (t-1)		FP (t)		FP (t)		FP (t)	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Independent variables												
TI (t-2)	1.1182***	0.2596	1.5112***	0.2982	0.2670	0.3830			5.4904***	1.2141	3.1921**	1.2195
SL (t-1)							0.5926***	0.1080			0.5425***	0.1081
TC (t-2)			−0.4383	0.3817	−0.8658	0.7018						
I_IC (t-2)					1.0275***	0.2005						
Controls												
FS (t-2)	0.6825**	0.2033	0.9030***	0.2131	1.0792***	0.2145	19.4898***	0.8598	17.8725***	0.9501	17.7142***	0.9513
YE	Dummy/ factor		Dummy/ factor		Dummy/ factor		Dummy/ factor		Dummy/ factor		Dummy/ factor	
R^2	0.1333***		0.1355***		0.1801***		0.2863***		0.2811***		0.2846***	

***Significant at 0.1%, **Significant at 1%.

random effects models). The interaction variable was significant, so there had moderation, supporting Hypothesis 4. Technological collaboration influenced the magnitude of the causal effect of technological innovation on servitization.

Because a moderation effect was found, simple slopes analysis was also performed (PROCESS, Hayes, 2017). This analysis examined the relationship between a predictor and outcome at different values of the moderator. The conditional effects of the focal predictor at different values of the moderator are reported in Table 9. The value 0 was not significant (P = .7058), meaning that technological collaboration only had a moderating role in firms with technological collaboration. In addition, the greater the technological collaboration, the greater the effect ('Effect' column in Table 9).

6. Discussion

The literature lacks studies of the factors that may influence the relationship between the servitization strategy and firm performance. The lack of such studies hinders the understanding of how servitization and firm performance interact. In addition, it suggests a need for further studies of the direct and indirect relationships between servitization and business performance (Feng et al., 2021).

This study addresses this problematization in the literature, introducing innovation as an antecedent and using models with direct effects, a moderator effect, and a mediator effect. The models include lagged variables to capture the effects of the independent variables on the dependent variables more effectively.

The first part of the discussion centers on the relationship between technological innovation and servitization. It was hypothesized that technological innovation positively influences servitization (H1). The literature shows evidence of opposite approaches, and it has received the attention of scholars (Alexy et al., 2018). The data used for the analysis confirm Hypothesis 1. These results reveal that to the extent that firms invest in R&D, it enhances the introduction of services to the market. Accordingly, the possession of innovation capacity through R&D is critical for manufacturing firms to succeed in servitization. The results are in line with previous studies, such as those of Santamaría et al. (2012), Hong et al. (2015), Rabetino et al. (2018), and Hwang and Hsu (2019). Those authors found that product innovation capacity promotes servitization by enabling a company to innovate and design product–service systems through

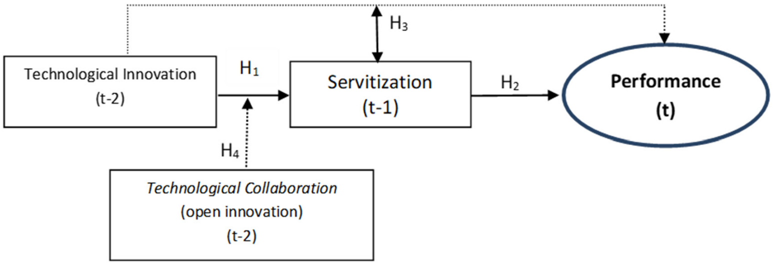

Figure 1. Analysis framework.

Table 6. Estimated models (Hayes process)

	Model 3		Model 6	
Dependent variable	Servitization (t-1)		Firm performance (t)	
	Coef.	SE	Coef.	SE
Independent variables				
TI (t-2)	0.1618	0.4285	2.8061*	1.1158
SL (t-1)			0.6319***	0.1078
TC (t-2)	−1.7744	0.8731		
I_IC (t-2)	1.0415***	0.2189		
Controls				
FA (t-2)	0.0517*	0.0204	0.2862**	0.0891
FS (t-2)	0.8045***	0.2426	17.1365***	0.9955
SU	dummies		dummies	
YE	dummies		dummies	
R^2	0.1987***		0.3134***	

Estimated models from conditional process analysis (Hayes). ***Significant at 0.1%, **Significant at 1%, *Significant at 5%.

Table 7. Mediation model test statistics

Firm performance	***c***	***a***	SE_***a***	***b***	SE_***b***	***z***
Servitization level	2.9459	1.0502	0.2835	0.5202	0.1070	2.9465**

Data from random effects models z (Sobel test) = $ab/\text{sqrt}(a^2 \cdot SE\_b^2 + b^2 \cdot SE\_a^2)$.
**Significant at 1%.

Table 8. Direct and indirect effects

Type of effect	Effect	SE	LLCI	ULCI	***P***
Direct effect of X on Y	2.8061	1.1158	0.7431	4.8691	.0188

Effect (servitization level)	Effect	Boot SE	Boot LLCI	Boot ULCI
Indirect effect of X on Y	1.0876	0.3378	0.4933	1.6819

Data from conditional process analysis (Hayes).

Table 9. Conditional effects of focal predictor at values of the moderator

TC (t-2)	Effect	SE	***t***	***P***	LLCI	ULCI
0.0000	0.1618	0.4285	0.3775	.7058	−0.6787	1.0022
1.0000	1.2033	0.3372	3.5687	.0004	0.5419	1.8646
2.0000	2.2448	0.3736	6.0078	.0000	1.5119	2.9777
3.0000	3.2863	0.5112	6.4281	.0000	2.2835	4.2890
4.0000	4.3278	0.6921	6.2536	.0000	2.9704	5.6852

Data from conditional process analysis (Hayes).

the integration of services into customer-oriented solutions. Similarly, Qi et al. (2020) showed that product innovation capacity is an important antecedent for servitization because it helps manufacturers develop integrated packages of products and services to fulfill customers' needs. Firms embarking on a journey toward servitization must consider how to develop the necessary capabilities (Jovanovic et al., 2019). The positive relationship between technological innovation and servitization suggests a significant influence on firms' development of service capability.

Moreover, the findings are also aligned with the observation that digital technologies are increasingly important for servitization. Because these technologies are often first embedded into products, they function as catalyzers for manufacturers to develop product–service systems and thus enhance levels of servitization (Kohtamäki et al., 2019; Martín-Peña et al., 2020; Paschou et al., 2020; Tronvoll et al., 2020; Gebauer et al., 2021).

The data also reveal a positive relationship between the level of servitization and firm performance. Hence, Hypothesis 2 is supported. The study is consistent with others that have shown the direct effect of servitization on firm performance. Introducing services in manufacturing companies contributes to creating and capturing added value (Cusumano et al., 2015; Kohtamäki et al., 2020; Abou-Foul et al., 2021). This finding supports the idea that offering (a wider set of) services can, in itself, generate new revenue streams in addition to the traditional product business, and the overall margins benefit from this situation. It is also in line with the findings of Bustinza et al. (2015), who confirmed the relationship between servitization and competitive advantage through differentiation, linking servitization and organizational performance. Interestingly, this finding counters the findings of studies that show a service paradox (Gebauer et al., 2005; Neely, 2008).

Indeed, as proposed in this paper, the direct relationship between servitization and firm performance needs to be probed and analyzed from the perspective of its antecedents. This study examined firm behavior through innovation, an antecedent of the servitization–firm performance relationship. Hypothesis 3 proposed a mediating role of servitization between a firm's technological innovation and performance. This hypothesis is supported by the data. The results are in line with those of Visnjic et al. (2016) in pairing servitization with product innovation processes to enhance long-term profitability. They are also aligned with the findings of Vendrell-Herrero et al. (2019), who reported that firms with an extensive, varied innovation portfolio achieve greater financial returns. Similarly, the results are aligned with those of Visnjic et al. (2012), who found that the interaction between servitization and product R&D investment ultimately leads to an improvement in profit ratios at the firm level.

This research is also in line with the study of Liao and Rice (2010), whose findings are very revealing. They analyzed Australian manufacturing firms and found that the impact of R&D intensity on firm performance was mediated by two variables. The first was the firm's market engagement. However, the primary mediator was the firm's transformation strategy. This strategy was defined as changes in the range of products or services, changes in the distribution of products or services, and changes in target markets. In this scenario, servitization is a key element of this transformation strategy.

Hence, validation of the mediation hypothesis can be interpreted as evidence that service provision raises a firm's understanding of customer needs, while increasing the number of contact points. It thereby provides further inputs for product improvement and innovation (García-Martin et al., 2019). This function is an important part of servitization, both for the overall performance of firms (Hypothesis 2) and for product and process innovation purposes. This insight also provides them with clues to redesign products or offer new products (Kindström and Kowalkowski, 2014; Parida et al., 2015). The former could also imply possible reverse causality between servitization and technological innovation (i.e., an interdependent relationship between the two variables).

Following the rationale behind this study, open innovation is presented as an antecedent of servitization. Few studies have linked open innovation to the success of servitization strategies (Abu Farha et al., 2022). The study identifies technological collaboration (open innovation) as a moderator of the relationship between technological innovation and servitization (H4). This finding is in line with previous research that shows that customer-oriented manufacturers can benefit from the diversity of external knowledge flows (e.g., Mina et al., 2014). Moreover, the results strengthen the idea that service innovation and servitization are *per se* more interactive (user-supplier) than product development (Edwards et al., 2015). This finding also resonates with the idea of value-in-use (Lusch and Vargo, 2014). It therefore implies that open innovation for servitization can center on co-creation with customers, not necessarily formal research partners. The value of customer co-creation for service innovation is categorically endorsed by many studies (e.g., Ordanini and Parasuraman, 2011; Gustafsson et al., 2012).

Furthermore, the moderating role of open innovation enhances the theoretical lens of the RBV by adding an argument to reduce tensions around the protection of internal company resources by incorporating other external resources. Firms can share knowledge and innovation while protecting essential resources (Alexy et al., 2018).

7. Conclusions

The relationship between servitization and firm performance has been extensively analyzed in the literature. However, there is a lack of consensus on the meaning and scope of this relationship. The service paradox is still recognized as a topic that is open to debate (Brax et al., 2021). Understanding the effect of offering services on firm performance and the factors that condition this effect should be high on the servitization research agenda. 'Establishing where the service growth strategy works and under what conditions is a fundamental first step to justify its effectiveness and will be instrumental in building the credibility for research to influence practice' (Kowalkowski et al., 2017, p. 86).

Feng et al. (2021) reviewed the studies that have examined the relationship between servitization and firm performance. This review explored their findings and whether they considered any intervening variables. Interestingly, when considering the possible antecedents that may influence the relationship between servitization and firm performance, they focused on firm and product characteristics but not on business behavior. Innovative behavior increases the number and variety of products and services on offer (Kamran and Ganjinia, 2017). It also provides a basis for innovative actions by firms. Technological innovation and open innovation shape innovative behavior and can act as antecedents of the servitization–firm performance relationship. The problematization in the literature due to a lack of research on these antecedents is addressed by the present study. Accordingly, through technological innovation and open innovation, the scope of the servitization–performance relationship is broadened.

This study examined the interactions between technological innovation, open innovation, and servitization, and their separate or joint impact on firm performance. The results reveal that technological innovation and collaboration, together with servitization, present a promising opportunity for companies in a context of global competition and increasing demand for customized solutions. Accordingly, it addresses the need for more theoretical and empirical research on the interplay between technological innovation, service innovation, open innovation, and firm performance.

7.1. Theoretical implications

The theoretical implications of this research are worth noting. Several contributions are made. First, the study helps continue unpacking the relationship between servitization and firm performance by focusing on two antecedents (i.e., innovative behavior) that may influence this relationship. Accordingly, this analysis can help solve the service paradox based on business behavior. And, it complements the literature on antecedents based on firm and product characteristics (Feng et al., 2021).

Second, this study contributes to the servitization and innovation management literature by linking open innovation (Chesbrough, 2003) to the RBV (Barney, 1991). The interactions examined in this study show that technological innovation in manufacturing firms leveraged by open technological innovation drives service innovation. By engaging with external sources of innovation (i.e., open innovation), firms can improve service innovation, without stretching their internal resources. Hence, innovative firms can complement value from product and process innovation with value from service innovation, increasing firm performance (Cassiman and Veugelers, 2006). As reported by Vendrell-Herrero et al. (2023), the importance of the RBV to a firm's innovation strategy is well documented (Chahal et al., 2020). However, it can be strengthened by including open innovation, given the tensions that arise when external resources are absorbed by the firm. In this context, open innovation moderates the relationship between technological innovation and servitization. It answers the question of how firms can solve the apparently paradoxical tensions between open innovation and the RBV. Specifically, it illustrates how firms can share knowledge and innovation while protecting essential resources (Vendrell-Herrero et al., 2023).

Third, the analysis of the service paradox in the literature has provided mixed results (Brax et al., 2021; Feng et al., 2021). This study opens the black box of the complex interrelations between servitization and firm performance. It contributes to the literature by clarifying the aforementioned mixed results on the relationship between servitization and firm performance. Although other studies indicate that the relationship between servitization and firm performance is not always positive, this paper provides evidence of just such a positive relationship.

To understand the service paradox more fully, this study examined a mediating relationship. This study sheds light on this interrelation and explains how servitization mediates the relationship between a technological innovation and performance. Thus, the paradox can be overcome by considering it as an antecedent of the relationship discussed earlier. The study also shows how servitization subsequently influences firms' innovation performance. In sum, this study clarifies the service paradox by examining antecedents and outcomes. The results suggest that antecedents such as technological innovation and open innovation increase the probability that firms implement service innovation, thus achieving a positive influence on firm performance.

Finally, this study shows that technological innovation drives servitization. Servitization requires firms to change by making innovation-oriented decisions. Service innovation in manufacturing firms is strengthened by these decisions. Thus, this finding extends product to service innovation theory. Accordingly, the results contribute to service innovation theory building for manufacturing firms. The expansion of R&D is valuable because most research on innovation in manufacturing firms has focused on technological innovation, largely ignoring service innovation and the opportunities it offers. As reported by Gebauer et al. (2011), service innovation in manufacturing firms deserves attention in its own right. Thus, the present study also responds to calls for more research on the innovation strategy of industrial companies (Benedettini and Kowalkowski, 2022).

7.2. *Managerial implications*

The results of this study have several implications for managers. It gives them a comprehensive overview of the innovation landscape in their organizations. The results strongly suggest that managers of manufacturing firms should consider service innovation for the general benefit of technological innovation and firm performance. Hence, companies can enhance their performance by considering the interactions between product, process, and service innovation. The study shows the mediating role of servitization in translating innovation into profitability. On this basis, a firm's technological innovation can help overcome the service paradox. Managers should focus on the relationship between the introduction of services and firm performance, also promoting innovative business models that can generate profits by introducing services and product-as-a-service payment.

This study also highlights the importance of collaborating with other agents. Internal and external R&D should be considered when defining a firm's innovation strategy. In the current competitive world, innovation strategy should be linked to an increase in servitization activity, which can also support a firm's pursuit of differentiation. Altogether, if managers aim to increase their firms' performance, an open service innovation strategy seems advisable. In fact, practitioners searching for performance benefits ought to consider openness as a complement to internal R&D rather than a substitutive strategy.

From the perspective of policy implications, viewing servitization as a lever of change in the renaissance of manufacturing, given the steady fall in the percentage of manufacturing within the economy over the last decade, should lead to the inclusion and promotion of servitization in manufacturing empowerment programs. Likewise, innovation strategies that include innovation in services are also recommended. As indicated by Opazo-Basáez et al. (2022) and Bailey et al. (2020), innovation development programs should consider digital service innovation as a fundamental aspect of technological innovation systems in regional policy development. In Spain, industry can be supported by open innovation practices, which allow companies to integrate resources and complementary capabilities to add value and maximize the benefits of innovation.

7.3. *Limitations and future research lines*

Although this study reveals some interesting findings, it also has some limitations, which provide opportunities for future research. First, the analysis of secondary data only enabled the study of observations included in an externally pre-established questionnaire. The use of primary data would allow research based on direct observational methods (Laursen and Salter, 2006). Second, sampling frames other than Spanish firms would be useful to extend the validity of the findings. Third, the way that servitization and technological innovation were measured did not enable analysis of whether digitalization processes contribute to the relationship between technological innovation and servitization (as well as firm performance). However, digital services were implicit in the measures employed in the study, especially in the last few years of the study period. This question could be addressed in future research. Similarly, the way the study measured servitization and firm performance did not enable examination of whether service-oriented business models (e.g., pay-per-use or product-as-a-service value-capturing systems) contribute to correlations between servitization and firm performance. Therefore, this question could also be tackled in future research. Furthermore, there may be reverse causality at play in the relationships with the research framework and hypotheses. One example, highlighted in the discussion, is between servitization and technological innovation. Examining these relationships of reverse causality may also be a promising avenue for future investigation.

Finally, this study leaves some other interesting issues for future research. For instance, the use of absorptive capacity as a measure of assimilation and exploitation of internal and external knowledge would represent an improvement in the measurement of variables for future analysis. Also, other types of performance in addition to financial, such as innovation performance, should be included when analyzing the impact of technological innovation and servitization.

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Ethics statement

Not applicable.

Data availability statement

Shared data are not present.

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