The moderating role of technological collaboration in the relationship between absorptive capacity and servitization: open innovation approach in high-tech industries

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Abstract

Purpose. Absorptive capacity, technological collaboration and servitization are analyzed to establish ways to overcome the balance between products and services in manufacturing companies. A fresh perspective is introduced by presenting a framework for innovation strategy, moving beyond product-based R&D.

Design/methodology/approach. The hypotheses are tested using data on Spanish firms in the high-tech chemical and pharmaceutical industries through ordinary least squares regression analysis. The sample consists of 112 manufacturing firms included in the Spanish Survey of Business Strategies.

Findings. The results show that absorptive capacity facilitates servitization and that technological collaboration moderates the relationship between absorptive capacity and servitization. The synergies between absorptive capacity and technological collaboration for servitization are recognized from the perspective of open innovation as a way of resolving the trade-off between products and services.

Research limitations/implications. Future research should introduce more sources of collaboration by broadening the value chain perspective. Other approaches to innovation may also be considered, including relationships to process innovation.

Practical implications. The results can provide meaningful guidance for companies to determine the key opportunities of servitization driven by absorptive capacity, and the best ways to leverage open innovation and collaboration strategies to exploit such approaches.

Originality. This research enriches theories on servitization, open innovation, and innovative behavior. Open innovation strategy should be linked to greater servitization activity and should support an open service strategy. This approach is crucial for building innovation capabilities through technological collaboration.

Keywords: servitization, absorptive capacity, technological collaboration, open innovation, service innovation.

Paper type. Research paper

Quick Value Overview

Interesting because: The shift towards servitization in manufacturing firms, integrating services into the value chain, introduces a trade-off between service and product-based R&D investments. Absorptive capacity, identified as a driver for product innovation, may not automatically apply to service innovation. Furthermore, the concept of open innovation, crucial for services, is underexplored in the context of servitization, despite the reliance on external knowledge for innovative services. This study extends the analysis of the relationship between absorptive capacity and servitization from an open innovation approach.

Theoretical value: There is a positive relationship between absorptive capacity and servitization. Customer collaboration, supplier collaboration and technological collaboration along the supply chain moderate this positive relationship. Although all associations have a causal origin, the most relevant and clear cause-effect relationship appears when absorptive capacity occurs together with supplier collaboration, forming an interaction that positively influences the level of servitization.

Practical value: Managers must adapt to evolving business models and embrace servitization for a well-rounded innovation strategy encompassing both products and services. Developing innovation capability via absorptive capacity is crucial for a competitive edge through product-service innovations. Managers should combine internal and external R&D as this will lead to more innovation activities.

1. Introduction

The rise of intense global competition has driven manufacturing companies to seek tailored solutions by integrating services into their offerings. This phenomenon is commonly referred to as servitization (Vandermerwe and Rada, 1988). Servitization enables a transformative approach within an organization, involving innovation in capabilities and processes, aimed at fostering mutual value creation. This shift includes transitioning from the mere sale of products to offering comprehensive product-service systems (Cusumano et al., 2015). Building upon this foundational concept, Bustinza et al. (2019) conceptualize servitization as a continuum related to the innovation level.

Innovation is recognized as the main source of competitiveness and growth (Cirera and Muzi, 2020). Companies need continuous technological innovation and the incorporation of various sources of innovation. The Oslo Manual (OECD) considers product and process innovation as technological innovation, whereas Vendrell et al. (2023) also include service innovation. Product and process innovation is usually pursued by research and development (R&D) activities (Berchicci, 2013), and the literature links it to service innovation (Chang et al., 2014). Cohen and Levinthal (1990) argue that R&D investment not only generates new knowledge but also enhances a firm's ability to identify, assimilate, and exploit knowledge from the environment, referring to this ability as absorptive capacity. In this context, innovative capacity is at the core of innovative behavior, and it is manifested in firms through their absorptive capacity.

Many innovation studies focused on products rather than services and most of research manufacturing firm innovation has focused on technological innovation (Toivonen and Tuominen, 2009), largely ignoring service innovation and its inherent opportunities. Service innovation adds a new dimension to the balancing effort in innovation in manufacturing firms and requires particular attention when integrated into the company's innovation strategy (Benedettini and Kowalkowski, 2022). The research in service innovation in manufacturing firms has yet to be fully uncovered (Shin et al., 2022). So, servitization has emerged as a viable alternative to a product-based R&D strategy (Eggert et al., 2015), with servitized firms pushing the limits for manufacturers by integrating services into the value chain. This introduction of services can shift product-based R&D investment toward service innovation. However, this shift in innovation strategy can become a problem for firms (Hwang and Hsu, 2019), creating a trade-off between servitization and investment in product-based R&D (Benedettini and Kowalkowski,

2022). Product innovation and the provision of services compete for the limited resources of the firm. And there is a gap in literature about how to manage this trade-off.

Prior studies have confirmed that absorptive capacity plays a pivotal role in driving product innovation (Chang et al., 2014). But the factors contributing to successful product and service innovation differ significantly. Consequently, it is incorrect to assume that absorptive capacity automatically drives service innovation. The meta-analysis of Storey et al. (2016) marked the initial indication of a potential connection between absorptive capacity and service innovation. In addition, Mennens et al. (2018) only facilitated empirical evidence for Dutch manufacturing SMEs. Therefore, it remains of utmost importance to develop theoretical frameworks and deepen our comprehension of how absorptive capacity influences service innovation.

Furthermore, given the complexity of the innovation process, scholars have analyzed forms of collaboration between a focal firm and other actors for the sake of innovation, giving rise to the concept of open innovation (Chesbrough, 2003). The open innovation approach incorporates knowledge from other organizations in the value chain (Dabić et al., 2023). This seems to be particularly important for services compared to products (Storey et al., 2016). Scholars investigate customer and supplier collaborations in manufacturing firms (Chesbrough, 2011) and service firms (Mina et al., 2014) but barely consider such collaborations in the case of servitization because many firms still servitize through internal development (Bustinza et al., 2013). However, to develop innovative services, manufacturers must rely on external knowledge. Although servitization is often presented as a way of strengthening buyer-supplier relations, it is rarely addressed from an explicit open innovation perspective or linked to it and there is an absence of open innovation processes (Keupp and Gassman, 2009). One exception is the study by Bustinza et al. (2019), although it focuses on very large companies and interactions between manufacturing firms and knowledge-intensive business services only. Polova and Thomas (2020) also enquired into collaborative servitization projects, but in an exploratory manner, studying a small set of cases. 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). Martín-Peña et al. (2023) clarify the cause-effect relationship between technological collaboration and servitization, using time-lagged models. So, one important gap is to determine how a dynamic and collaborative approach impacts the development of novel servitization within open innovation dynamics (Polova and Thomas, 2020).

In this context, there are research opportunities to further understand the role of innovation activities (through absorptive capacity and open innovation) as antecedents in service innovation in manufacturing firms (Bustinza et al., 2019; Martín-Peña et al., 2023). The identified gaps could then be addressed. The following research questions are raised:

QR1: How can the trade-off between product and service investment in manufacturing firms be managed?

QR2: What is the relationship between absorption capacity and servitization in manufacturing firms? How does open innovation affect that relationship?

The present study aims to extend the analysis of the relationship between absorptive capacity and servitization from an open innovation approach. Therefore, this paper addresses an integrative perspective. A theoretical model based on the literature review is proposed to describe the interactions.

Because an innovative attitude is a complex and dynamic phenomenon influenced by the technological conditions, the influence of the scientific and technological characteristics of the sector on innovation activity is relevant (Zawislak et al., 2018). Storey et al. (2016) demonstrate through their meta-analysis that the antecedents of service innovation are contingent in the sector´s context, which varies across different industries, making it clear that a one size fits all approach to service innovation is no longer applicable. So, this research is based on the analysis of the chemical and pharmaceutical sectors (such as high-tech industries), which are characterized by intense innovative activity and the implementation of servitization (Ruiz-Alba et al., 2016). Chemical and pharmaceutical firms have traditionally made extensive use of technological collaborations to support their new product and process development (Das and Brunet, 2015).

The formal cause-effect relationships that arise at a theoretical level in social sciences are difficult to demonstrate at an empirical level. Association and causation are different but related concepts. In the paper, distinction between association and cause-effect is achieved. The results show that there is a significant, positive, and direct interaction between absorptive capacity and servitization. In addition, technological collaboration moderates the relationship between absorptive capacity and servitization. If absorptive capacity (supported by technological collaboration) positively influences servitization, then the trade-off between product and service investment can be managed. In fact, as proposed by Benedettini and Kowalkowski (2022), R&D strength would be a critical asset for servitized firms.

This paper thus offers a novel approach. Drawing on the servitization and innovation management research as the theoretical lens, a framework for the innovation strategy in the manufacturing firms which goes beyond the orientation of product-based R&D is provided. This study contributes to the understanding of the role of absorptive capacity and technological collaboration in turning internal and external knowledge into product-service systems in manufacturing and enhances understanding of absorptive capacity not only as a process that transfers intangible knowledge but also as a vehicle that has the potential to change service offers. The theory on service innovation is thus further developed. It also addresses the need for more theoretical and empirical work on the interaction between absorptive capacity, service innovation and open innovation, and it extend product to the service innovation theory. Furthermore, analyzing these interactions provides useful insight for managers who need a framework to evaluate their decisions regarding the innovation policies of their firms and to balance their innovation efforts.

The paper outlines as follows: the next section reviews literature linking absorptive capacity, open innovation, and servitization, theorizing their relationships, leading to hypotheses and a model. Section 3 presents sample data and operationalizes key variables. Section 4 shows results, and Section 5 discusses findings. Finally, Section 6 concludes with insights, managerial implications, and future research suggestions.

2. Background, hypotheses, and research model

This study builds on the intersection between different areas of the existing literature, namely *servitization* (Vandermewe and Rada, 1988), *absorptive capacity* (Cohen and Levinthal, 1990), and *technological collaboration* along the value chain based on *open innovation* (Chesbrough, 2006). These areas are developed in the general environment of innovation and innovative behavior.

Scholars challenge the closed innovation model, advocating a shift from sole reliance on internal resources for innovation. Alongside utilizing internal assets, organizations should seek external knowledge and ideas (Chesbrough, 2006). This involves technological collaboration through open innovation and leveraging competencies under absorptive capacity. Viewing servitization as an innovative capacity promotes interaction among these three aspects.

In fact, the introduction of services in manufacturing presents a new way of competing to adapt more effectively to customers, which is also considered a type of innovation (Cusumano et al., 2015). A service-focused

servitization strategy has the goal of providing related services or products at the right time (Kamal et al., 2020). Hence, the servitization strategy is linked to innovation management.

The innovation literature examines the innovation processes of firms and explores how organizations create and capture value (Chesbrough et al., 2018). Organizations can build an internal capability to identify and acquire new knowledge from the environment. This capability is known as *absorptive capacity* (Cohen and Levinthal, 1990). This ability of firms to recognize and assimilate new knowledge and then apply it in relevant contexts is the key factor in the diffusion of any innovation (Moretz et al., 2021). The complexity of the innovation process demands a search for external knowledge in an open innovation context (Chesbrough, 2003). Technological collaboration along the value chain is particularly crucial for building innovation capabilities.

The role of open innovation in the transformation toward servitization is twofold. First, it can help firms at the start of the transformation. Second, it can contribute at a later stage when the transformation has already taken place and when the focus is on the continuous development and innovation of the value creation process in services (Consiglio, 2020).

The literature analyzes some relationships between the three topics, such as the linkages between absorptive capacity and open innovation (Dabić et al., 2023), as well as between servitization and open innovation (Kroh et al., 2018). The aim is to extend these relationships by linking absorptive capacity with servitization and by considering the interaction in this relationship of technological collaboration with customers and suppliers (i.e., open innovation). Hypotheses H1, H2a, H2b and H2ab are thus proposed.

2.1 Absorptive capacity and servitization in manufacturing

The construct of absorptive capacity has been developed with a focus on product innovation in the manufacturing firms. However, some of the assumptions behind this development also seem to apply to the service and open innovation domains.

Absorptive capacity improves a firm's information processing and enhances operational resilience (Zhang et al., 2022). Chang et al. (2014) find it positively influences new product development in manufacturing and service innovation in services. Ukpabio et al. (2016) distinguish its impact in manufacturing and services. However, the link between absorptive capacity and servitized firms, rooted in the product-service system innovation approach,

remains underexplored. Unique aspects of this approach might yield variations in understanding absorptive capacity as a driver of servitization.

The improvements that result from services primarily involve acquiring product and market knowledge from new external sources, and decision-makers are faced with situations of lack of internal and external information (Dahmani et al., 2016). Firms must be appropriately equipped to exploit the new opportunities made available by offering services. To do so, firms must have absorptive capacity. Depending on the extent to which a firm has that capacity, it can successfully add more services, which would further increase the firm's access to external knowledge sources and the opportunity to create additional value, as long as the firm knows how to identify, assimilate, and exploit those business opportunities. Absorptive capacity enables a firm to interact effectively with the environment and promotes learning inside the firm. Therefore, manufacturers with high levels of absorptive capacity can easily detect new opportunities and create value by improving servitized offers (Abou-Foul et al., 2023). Some scholars suggest that product-service innovation leads to higher innovation levels (Visnjic et al., 2018). It may thus be inferred that higher innovation levels are related to absorptive capacity.

The literature shows that for successful servitization, organizations must have a suitable degree of readiness and absorptive capacity (Hong et al., 2015). Xing et al. (2017) suggest that absorptive capacity can significantly influence the development of service capability, and Benedettini and Kowalkowski (2022) note the trade-off between service-based differentiation and product R&D strength. All in all, absorptive capacity helps an organization to achieve the potential innovation benefits made available through services. Storey et al. (2016) identified for the first time that absorptive capacity as a key antecedent of service innovation performance in service firms. They suggest for these firms, "the idea of working with entities outside of the firm to develop and deliver innovations is crucial in today's economy. Contrasting with this is the finding that, for products, dedicated innovation resources (traditionally R&D resources) are particularly important. It seems that product firms succeed by creating knowledge internally whereas service firms succeed more often by utilizing external knowledge and capabilities" (pp, 541). Mennens et al. (2018) investigate the effect of absorptive capacity on service innovation in a sample of Dutch servitizing manufacturing SMEs. As an extension, this paper analyses the case of high-tech manufacturing firms that incorporate services, considering absorptive capacity as an antecedent of servitization. The following hypothesis can be formulated:

H1. Absorptive capacity positively influences the level of servitization.

2.2. Absorptive capacity, technological collaboration in the value chain, and servitization

The absorptive capacity interacts with the technological capability of firms. The literature recognizes the importance of internal research to create technological capabilities, which can be complemented, but never replaced, by cooperation and other external knowledge sources. Absorption and diffusion in periods of major technological uncertainty essentially depend on the ability of firms to understand and apply novel technologies from the market, which they can access through a range of partnerships. For example, to facilitate digital servitization, manufacturers implement scans and collaborative procurement mechanisms by obtaining expertise and resources from proprietary data specialists, collaborating with other product providers and accessing independent data knowledge and experience (Momeni et al., 2023).

An open innovation context boosts collaboration along the value chain. Supply chain scholars highlight the fact that collaborating with supply chain partners is critical for successfully developing new products, obtaining a competitive advantage (Minguela-Rata et al., 2014) and enhancing innovation performance (Villena et al., 2011). Nonetheless, that stream of literature primarily considers operational outcomes or applications to product innovations. However, collaboration with supply chain partners can also be applied to the service-related activities of manufacturing firms, although it might work differently (Chesbrough, 2011). Mina et al. (2014) argue that collaborating with external sources is associated with the adoption of a service-inclusive business model by manufacturing firms. Knowledge-intensive servitized manufacturers find formal methods effective but only with no or minimal collaboration (Yacoub et al., 2020).

Agarwal and Selen (2013) provide empirical evidence that innovation in services is enabled through not only technical capabilities but also the contribution of soft skills such as collaboration and relationship management, which enable the realization of such innovation. Chesbrough (2003) affirms that successful service innovation promotes better inter-organizational collaboration to stimulate knowledge sharing. Hongda et al. (2023) affirm that the manufacturing, service and innovation relationships formed in the industrial chain should be analyzed by studying the supply chain, the service chain and the innovation chain. The introduction of new services in manufacturing firms can therefore be achieved through collaboration with customers, suppliers, and other stakeholders in the value chain. Each type of external source has a different knowledge base that results in a different knowledge recombination when combined with the firm's own knowledge base. External sources also differ in terms of how easily that knowledge can be accessed and in the strength of this interaction (Brunswicker

and Vanhaverbeke, 2015). Martín-Peña et al., (2023) study technological collaboration and servitization through time-lagged models. The research identifies technological collaboration as a previous moderator of the relationship between technological innovation and servitization.

However, firms cannot benefit from external knowledge flows merely by being exposed to them; instead, they must integrate that knowledge inside the firm. For this purpose, organizations require absorptive capacity. Building on the open innovation literature, Vanhaverbeke et al. (2008) argue that open innovation is impossible without considering the theoretical angle of absorptive capacity as an internal capability of innovative companies and that the understanding of absorptive capacity can be enriched by tying it to open innovation. The combination of external sources with absorptive capacity also leads to an improvement in servitization capability.

H2ab. Technological collaboration along the value chain positively moderates the relationship between absorptive capacity and servitization.

2.2.1 Downstream collaboration. Regarding downstream collaboration, literature shows that collaboration with customers has a marked effect on the achievement of service innovation by manufacturing firms (Baines et al., 2009). The involvement of customers in the servitization process helps resolve customer problems and anticipate customer needs (Chesbrough, 2011). Customer involvement means that customers provide the information from the demand side, which is crucial for developing new services. Therefore, interactions with customers throughout the product life cycle are very important and this implies the definition of the extent of information sharing (Adrodegari and Saccani, 2020). Customers provide new insight into new business opportunities for technological development beyond existing products and markets (Brunswicker and Vanhaverbeke, 2015), contributing to the creation of unique and original customized products (Bonfanti et al., 2018). In addition, customers also share insights of the market, such as the advantages and disadvantages of competitors' products (Fredberg and Piller, 2011), thereby complementing firms' understanding of market conditions to develop new product-services.

Bustinza et al. (2013) describe the idea of an effective link channel with customers, where value is generated because such links are mechanisms that articulate the proposition of a value chain and display value offerings through customer needs. They explain that the traditional manufacturing supply chain is broken when services are introduced, so it is necessary to focus on demand chain management. Extending that approach, the demand and supply chains can be effectively integrated through the inclusion of customer input in the firm's knowledge base,

not only by adopting a customer focus but also by drawing on customer collaboration. According to the customer co-created servitization literature, value in use is derived through the mutual integration of both firm and customer resources (Green et al., 2017). Absorptive capacity has been widely recognized as a crucial element of an organization's ability to transfer knowledge and utilize it in their customer relationships (Winkelbach and Walter, 2015). For a successful integration of customer knowledge and resources, firms must absorb such knowledge and integrate it with the internal knowledge of the firm (Scaringella et al., 2017). The collaboration with customers helps transform a firm's absorptive capacity of customer input into value-added service offerings.

H2a. Technological collaboration with customers positively moderates the relationship between absorptive capacity and servitization.

2.2.2 Upstream collaboration. Collaboration along the upstream value chain also contributes to the servitization innovation process. Suppliers are usually considered the most valuable knowledge sources to develop new products and services and to improve existing ones because they are more experienced and have specialized knowledge about components and parts of production processes (Brunswicker and Vanhaverbeke, 2015). Baines and Lightfoot (2014) reveal that vertical integration and supplier relationships are key strategies. They argue that collaboration with suppliers reduces stockholding delays and costs of remanufacturing components, aids the redesign of components, and enables a route for transferring good practices developed in production into service operations. Markovic et al. (2020) report that cooperating with suppliers helps focal firms create new or significantly improved services.

Collaboration with suppliers also helps transform a firm's absorptive capacity of customer input into value-added service offerings. Huikkola and Kohtamäki (2017) present a conceptual model of the strategic capabilities of servitization. Among these capabilities, they identify the supplier network management capability. This capability relates to creating, maintaining, and developing supplier networks to foster flexible delivery while ensuring the firm's competitiveness, innovativeness, and cost efficiency. In other words, the effective management of supplier collaborations is seen as a strategic capability of servitization. Consequently, this collaboration enhances the relationship between the firm's absorptive capacity and the value added for customers through servitization. In addition, developing a relationship with a supplier with a high degree of related technological skills may help the firm learn about the process, thereby developing joint absorptive learning (Jean et al., 2016). Accordingly, it has been argued that collaboration with suppliers can help firms develop learning capabilities and new routines that

support the introduction of product-service offerings. An operational capability acquisition mechanism requires a manufacturer to utilize the capabilities of other actors, particularly in the upstream value chain (Momeni et al., 2023). Therefore, the following hypothesis is proposed:

H2b. Technological collaboration with suppliers positively moderates the relationship between absorptive capacity and servitization.

In short, open innovation scholars stress the importance of collaborating with customers and suppliers to enhance product-service value offerings. If distinctive capabilities for servitization are sought, product-service offerings require companies to collaborate with customers as well as partners such as distribution and logistics service providers (Kimita et al., 2022). Building on an open innovation approach, external knowledge should be integrated within a firm's knowledge base. As a result, collaborating downstream and upstream all along the value chain should enhance the relationship between absorptive capacity and servitization. Figure 1 provides a graphical representation of the cause-effect relationships proposed in the hypotheses.

Figure 1. Theoretical model

3. Data and variables

3.1 Sample

The Spanish chemical and pharmaceutical sectors were selected to provide the study context. Chemical and pharmaceutical companies are among the top investors in R&D worldwide (Bauer and Leker, 2013). In both industries, there is a strong link between technological innovation and servitization (Gonzalo-Hevia and Martín-Peña, 2021). In these industries, greater complexity, new technologies, the availability of highly qualified experts outside traditional companies, and greater time and cost pressure have advanced the development of open innovation (Das and Brunet, 2015).

The sample comprised Spanish manufacturing companies covered by the Spanish Survey of Business Strategies, which is conducted by the SEPI Foundation in collaboration with the Spanish Ministry of Industry. This study considered data from companies in the chemical and pharmaceutical sectors. The data used corresponds to the year 2017. The final sample consisted of 112 firms. The sample is considered representative of the total population. The sample characteristics are shown in Table I.

Table I. Sample characteristics

3.2 Variables and Measures

Level of *servitization* was measured as the proportion of the firm's sales accounted for by service offerings (Crozet and Milet, 2017). It corresponds to the conceptual foundations of servitization. So, this variable can take values from 0 to 100.

Absorptive capacity was conceptualized as a firm's knowledge base (Lane et al., 2006). Many scholars have used R&D intensity as a proxy for absorptive capacity (Zhang et al, 2022); internal R&D investment not only generates new knowledge but also enhances a firm's ability to identify, assimilate, and exploit knowledge from the environment. This proxy was used in the present study.

The variable for *technological collaboration* was constructed from dummy variables reflecting technological collaboration in the value chain (i.e., with suppliers and customers). The independent effect of each type of partner in the value chain was considered, as well as the combined effect.

To rule out alternative explanations to the formal hypotheses, several control variables were included in the model. We controlled firm size and firm age, as larger firms could possess more resources and capabilities (Bortoluzzi et al., 2022). Firm age was measured as the number of years between the foundation of the firm and the observation year (Vendrell-Herrero et al., 2017). Firm size was measured as total liabilities (Crozet and Milet, 2017). Descriptive statistics and correlations of all variables are shown in Table II.

Table II. Descriptive statistics and correlations

4. Analysis and Results

The proposed model and hypotheses were tested using ordinary least squares regression analysis. The assumptions of normality of the distribution of the error terms and of the individual variables were confirmed. The variables and equations associated with the hypotheses are shown in Table III.

Table III. Variables and equations

The results for the different regression models are shown in Table IV. In all equations, servitization was the dependent variable. Table IV shows unstandardized coefficients and standardized coefficients. Unstandardized

regression coefficients are useful to interpret the individual effect of predictor variables on servitization and have an intuitive interpretation. Standardized regression coefficients allow you to compare the effect that different predictor variables have on the response variable.

Interactions between variables were captured through moderating effects. The moderating effect of collaboration with customers was introduced in Equation 2; the moderating effect of collaboration with suppliers was introduced in Equation 3; and the moderating effects of collaboration with suppliers and customers (two moderators) were introduced in Equation 4. The control variables were included in all models. In addition, a variance inflation factor (VIF) test was used to evaluate the effect of multicollinearity. No multicollinearity was observed because the VIFs for the variables were small.

Table IV. Regressions associated with the hypotheses

Equation 1 was used to test Hypothesis 1. A positive relationship was observed between absorptive capacity and servitization. The explanatory power of the model did not increase when the control variables were introduced. Only the absorptive capacity variable is significant. The non-standardized coefficient relates each million units with a 0.3321 increase in the percentage of servitization. The standardized coefficient is 0.226. It may be concluded that a firm's absorptive capacity partially explains servitization, thereby confirming Hypothesis 1.

In Equation 2, the moderating effect of collaboration with customers was included in isolation. The interaction variable (IC) improved the explanatory power with respect to Equation 1. However, the explanatory power was not high (low adjusted R-squared), and the interaction variable did not render absorptive capacity non-significant in Equation 2. Comparing these significant explanatory variables through their standardized coefficients, the greater importance of the interaction is confirmed in this model (0.333 vs. 0.208). Because the interaction variable was significant, partial moderation exists. This finding supports Hypothesis 2a.

Using Equation 3, the isolated moderating effect of collaboration with suppliers was analyzed. The interaction variable (IS) improved the explanatory power with respect to Equation 1. The interaction variable rendered absorptive capacity non-significant in Equation 3. The standardized coefficient of the interaction with suppliers in this Equation 3 (0.370) is greater than the standardized coefficient of the interaction with customers in this Equation 2 (0.333). Because the interaction variable was significant, moderation exists. This finding supports Hypothesis 2b.

In Equation 4, the two moderators (customers and suppliers) were introduced simultaneously. The simultaneous use of both interaction variables improved the explanatory power with respect to Equation 1 (no moderation), Equation 2 (moderation by collaboration with customers only), and Equation 3 (moderation by collaboration with suppliers only). The interaction variable (IS) associated with suppliers (with standardized coefficient of 0.305) was significant and had greater explanatory power than the interaction variable (IC) associated with customers (with standardized coefficient of 0.239). This finding supports Hypothesis 2ab.

Because a moderating effect was found, follow-up analysis was conducted with extended simple slopes. This analysis was implemented using PROCESS (Hayes, 2017). This analysis studied the relationship between the predictor and the outcome. Table V shows the increase in R-squared due to the interaction effects.

Table V. Increase in R-squared due to interaction

The results are consistent with the regression analysis. The conditional effects of the focal predictor were also analyzed at different values of the moderator. These effects can be found in Table VI.

Table VI. Conditional effects of the focal predictor at different values of the moderator

Table VI shows different values of the moderator and computes the coefficient (effect) for each value, as well as its significance for the relationship between the absorptive capacity and servitization. We implement and interpret marginal effects approach depicting the nature of main effect (absorptive capacity) in the presence of a moderator (technological collaboration). When the moderator "Supplier collaboration" is 0, the effect or coefficient of absorptive capacity is not significant, that is, it has no influence on servitization. The added effect of the customers and suppliers' moderators stands out in H2ab (when both take the value 1, the non-standardized coefficient is 3.5098).

So, distinction between association and cause-effect is achieved by analyzing strength (standard coefficients, R-squared and conditional effects in regressions), consistency/specificity (control variables and conditional process analysis), temporality (exposure precedes outcome), plausibility (theoretical and empirical literature review), and coherence/analogy (theoretical literature review). Although all associations have a causal origin, the most relevant and clear cause-effect relationship appears when absorptive capacity occurs together with supplier collaboration, forming an interaction that positively influences the level of servitization.

5. Discussion

This study examines the links between absorptive capacity, servitization in manufacturing, and technological collaboration with suppliers and customers along the value chain from an open innovation perspective. From the innovation management perspective, cause-effect relationships between the three items are proposed to fill the gaps detected in the literature in relation to the trade-off between product-based R&D and services, as well as the effect of open innovation on servitization.

The need to evaluate and build knowledge capabilities in the firm is critical in open innovation. The combination of internal and external capabilities, as explained in the theoretical foundations of innovation, might facilitate the development of knowledge that is critical to the service innovation process (Freiling and Dressel, 2015) and, by extension, to servitization. The difference with respect to the findings reported in the servitization literature may result from overlooking the role of different types of collaborative partnerships and absorptive capacity in service capability (Xing et al., 2017). This study provides findings to address these issues. In addition, following Storey et al. (2016), service innovation processes must be open, driven by customer engagement and systems must be in place to manage the knowledge that open innovation generates.

The first hypothesis states that a firm's absorptive capacity positively influences servitization. Results reveal that if manufacturing firms develop absorptive capacity and can recognize, assimilate, and use external knowledge for their own knowledge base, the introduction of services in their market offerings will be enhanced. Therefore, this paper extends the findings of Hong et al. (2015), who report that the possession of innovative capacity through absorptive capacity is critical for a manufacturing firm to achieve successful servitization. Hence, a firm's absorptive capacity is a facilitator of servitization, as noted by Storey et al. (2016) and Mennens et al. (2018). These findings are consistent with the idea that absorptive capacity influences the effectiveness of organizations' technological and innovation-related activities such as research productivity in pharmaceutical firms (Rezai and Ray, 2022).

Firms embarking on a journey toward servitization must consider how to develop the necessary capabilities (Jovanovic et al., 2019). The positive relationship between absorptive capacity and servitization suggests a significant influence on firms' development of service capability (Xing et al., 2017). This development leads to the optimization of innovation through product-service systems. The study therefore shows that the trade-off

between product-based R&D and service innovation can be resolved. If absorptive capacity positively influences servitization, the firm can plan an innovation strategy that seeks a balance between product and service innovation.

As noted at the theoretical level, servitization emerges in a context of open innovation, in which external and internal knowledge must be combined. As shown by the second hypothesis, firms that combine both internal and external R&D will benefit more from their innovation activities. Recently, research has shed light on the synergies between internal and external R&D (Mina et al., 2014; Bustinza et al., 2019), but it lacks a deep understanding of the mechanisms behind those synergies. Open innovation should be understood from the theoretical angle of absorptive capacity as an internal capability of innovative companies (Vanhaverbeke et al., 2008), which is what is observed in the empirical analysis. This article extends this research stream and shows how technological collaboration along the supply chain moderates the relationship between absorptive capacity and servitization. So, when there is no collaboration with customers or with suppliers, the relationship between absorptive capacity and servitization is weaker. Furthermore, there is evidence of the moderating effect of technological collaboration upstream and downstream in the relationship between absorptive capacity and servitization. This effect is significant and positive when the two moderators (collaboration with customers and collaboration with suppliers) are introduced simultaneously.

Cooperation with business partners is essential to develop servitization, as reported in literature (Visnijc et al., 2018). Although servitization is rooted in service innovation, it has its own features, so analysis of the role of technological collaboration requires a different approach, as presented in this article. Firms do not just incorporate services but rather change their strategies in such a way that servitization creates a new role in the value chain. Partnerships are widely considered fundamental for servitization to occur (Consiglio, 2020).

In particular, the effective management of downstream collaboration and upstream collaboration can be understood as a strategic capacity for servitization. The analysis of technological collaboration as a moderator of the relationship between absorptive capacity and servitization supports previous research that suggests that manufacturers with a customer orientation can benefit from the diversity of external knowledge flows (Mina et al., 2014) and that the effective management of collaboration with suppliers is a strategic capability of servitization (Huikkola and Kohtamäki, 2017). The study shows that the relationship with suppliers has a positive effect on the success of manufacturing firms because suppliers provide new knowledge, capabilities, and work methods.

Following analysis of open service innovation, Chesbrough (2011) suggests the following: (1) think of the business as a service business (which is consistent with the foundations of servitization); (2) consider customers to co-create innovation (i.e., downstream collaboration); (3) use open innovation logics to streamline service innovation through the integration of competencies, capabilities, and internal and external solutions (i.e., considering absorptive capacity and upstream and downstream collaboration); (4) transform the business model by delivering and capturing value through the platform (which acknowledges the moderating role of collaboration).

Overall, this paper advances open service innovation research by showing that technological collaboration with suppliers moderates the relationship between a firm's absorptive capacity and servitization, as does collaboration with customers. These relationships are evaluated through the conditional effects of the focal predictor at different values of the moderator. This analysis detects and evaluates the specific effects of technological collaboration, both differentiating between and combining customer collaboration and supplier collaboration. The reason could be that the benefits of the knowledge complementarities of the downstream and upstream partners are greater than the costs of knowledge integration or isolated innovation. This finding highlights the need to integrate the entire value chain.

In the pharmaceutical and chemical sector, which was the focus of this study, servitization and collaboration along the value chain is a key aspect for managers. As Dachs et al. (2012) indicate, highly innovative sectors reveal the highest share of firms that offer services and the highest turnover generated with services. After studying a set of pharmaceutical firms, Martínez-Grau and Alvim-Gastón (2019) report that, for these firms to be competitive, they must reduce the time and cost of product development and streamline the design process, hence developing their R&D capacity given that a closed innovation model is incapable of resolving emerging problems. To succeed in the new scenario, pharmaceutical companies must invest in collaborative models where different partners create innovation (Orlova, 2019).

Nowadays, less than half of the value chain in the pharmaceutical sector is outsourced, and a growing focus on contract manufacturing can be expected to drive the need for more advanced cooperation models (Alicke et al., 2016). The external collaboration models for pharmaceutical companies encompass supplier collaboration and customer collaboration as the principal choices. Ruiz-Alba et al. (2016) report that when the level of co-creation of service design with customers is high in the pharmaceutical sector, there are significant effects of servitization

on firm performance. If, as shown, collaboration with customers moderates the relationship between a firm's absorptive capacity and servitization, new opportunities are created in the sector.

6. Conclusions

Absorptive capacity and servitization in manufacturing are two topics that have received much scholarly attention and are relevant for innovation strategy. Literature describes the trade-off between product and service investment given the limited resources of firms. This trade-off can potentially lead to negative consequences for the firm. In this context, open service innovation represents a key strategy for manufacturing firms. In a joint framework, this paper has analyzed the positive relationship between absorptive capacity and servitization, as well as the moderating effect of technological collaboration along the value chain. The theoretical basis found in the literature and the statistical analysis of the data studied provide a solid foundation for the cause-effect relationships proposed.

This study reveals that development of absorptive capacity and collaboration along the value chain for servitization offer major opportunities for companies in a context characterized by global competition and growing demand for customization. Therefore, the study shows how to overcome the aforementioned trade-off. Open innovation strategy should be linked to greater servitization activity and should support an open service strategy. This idea is crucial for building innovation capabilities and creating a competitive advantage through technological collaboration. The conclusion is that the innovative capacity that determines absorptive capacity is crucial in the development of servitization. Open innovation positively moderates the influence of this capacity. As a whole, it determines the innovative behavior of the firm. The empirical analysis of the role of technological collaboration along the value chain in the relationship between absorptive capacity and servitization enhances existing knowledge about the complex interaction between these variables. It can also help lead to the right decisions to improve the situations of firms. For manufacturing firms that add services, this implies a reconsideration of their innovation setup, toward an integrated approach for product and service innovation activities (Kindström and Kowalkowski, 2014).

6.1 Theoretical Contributions

This research contributes to the existing literature in several ways, and the theories of innovative behavior, servitization, and open innovation are enriched by these results. First, this study advances scholars' understanding of the relationship between firm's absorptive capacity and servitization. So, it advances the theory on service innovation by investigating whether absorptive capacity is an antecedent of service innovation. And it contributes

to the studies related to service development by using absorptive capacity as a process underlying their inception (Leposky et al., 2022). In particular, it is argued that a firm's absorptive capacity is a facilitator of servitization. The trade-off between investment in product-based R&D and services would be managed. The innovation and innovative behavior research are extended by explaining how absorptive capacity is developed in firms to understand the external environment and, in particular, customers.

This study also extends the open service innovation research by further investigating the relationships between a firm's absorptive capacity and servitization from an open innovation perspective. In fact, the open innovation perspective is relatively underexplored. It opens new horizons for research on the impact of partnership practices in the transformation of firms and, more specifically, in transitions toward product-service systems (Consiglio, 2020). This study shows that the relationship between a firm's absorptive capacity and servitization is moderated by technological collaboration and is even more beneficial when it involves the entire value chain, strengthening the importance of an open innovation strategy that involves a range of partners (Kafouros et al., 2020). As previously reported by Mennens et al. (2018), this study provides evidence that, even though servitization requires a shift in the mindset of the firm, the importance of building a knowledge base is as important for service innovations as it is for product innovations.

In addition, the open innovation literature highlights the idea that internal knowledge must be combined with external knowledge to enhance firms' innovation performance (Berchicci, 2013). This study provides evidence of the interaction between external and internal knowledge by examining the positive effect of the moderating role of technological collaboration on the relationship between a firm's absorptive capacity and servitization.

Finally, by investigating how high-tech manufacturing firms can boost service innovation, we further develop servitization literature.

6.2 Practical contributions

Managers in manufacturing companies should be aware of changes in business models and should start to introduce servitization to deploy a balanced innovation strategy between products and services. In addition, building innovation capability through absorptive capacity is a key method to gain a competitive advantage through the introduction of product-service innovations. The results highlight the importance of technological collaboration with other agents. This open innovation strategy should be linked to an increase in servitization activities. New opportunities can emerge from an open service innovation approach.

6.3 Limitations and future research

First, the analysis of secondary data prevented the inclusion of observations other than those included in the pre-established external questionnaire. Generalizations based on these secondary data always have limitations due to the use of proxy variables and the differences between the target and sample populations. Second, although most studies use multiple sources to measure the breadth of external relationships, in this study, technological collaboration was operationalized in terms of breadth but only through the sum of two technological partners (customers and suppliers), due to the focus of the study being on the value chain. Third, this study focused on the Spanish high-tech industry. This focus was well suited to the study´s aims, but it limits the scope for generalizing the results to other sectors and other country contexts. Fourth, these fin dings could be extended using qualitative research methods such as multiple case studies or direct interviews with managers.

It would be of interest to introduce more sources of collaboration by broadening the perspective of the value chain. In addition, to understand the dynamics of servitization and open service innovation more deeply, it would be of interest to consider other approaches to innovation. Moreover, there is a need to understand the links between all concepts and their influence on firm performance.

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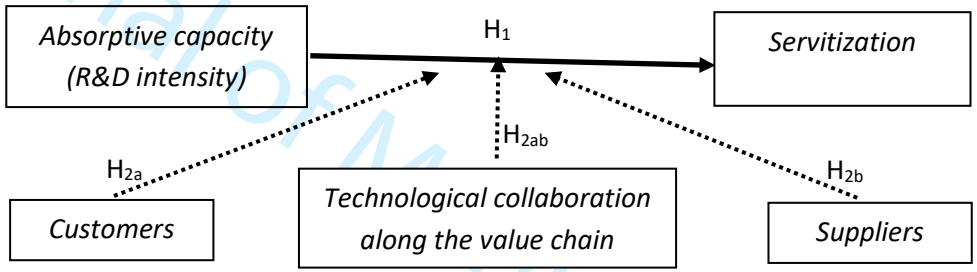
Figure 1. Theoretical model



Source(s): Authors' own elaboration

Table I. Sample characteristics

Model Variables	Percentage	Model Variables	Percentage
Level of servitization		Firm age	
Less than 2 percent	48.2%	Less than 20 years	20.5%
More than 2 and up to 35 percent	41.1%	Between 20 and 40 years	42.0%
More than 35 percent	10.7%	More than 40 years	37.5%
Absortive capacity (Internal R&D investment) €		Size (Total liabilities) €	
Less than 70,000	34.8%	Less than 7,000,000	14.3%
Between 70,001 and 3,500,000	55.4%	Between 7,000,001 and 40,000,000	44.6%
More than 3,500,000	9.8%	Between 40,000,001 and 110,000,000	21.4%
		More than 110,000,000	19.7%
Technological collaboration			
Without	55.4%	Size (Employees number)	
With customers	35.7%	Less than 50	29.5%
With supliers	33.0%	Between 51 and 200	37.5%
Both	24.1%	Between 201 and 500	21.4%
		More than 500	11.6%

Values grouped into intervals and relative frequencies

Table II. Descriptive statistics and correlations

	Level of servitization	Absorptive capacity	Tech. collaboration	Firm size	Firm age
Level of servitization	1	0.22*	-0.05	0.04	0.16
Absorptive capacity		1	-0.04	0.33**	0.28**
Tech. collaboration			1	0.10	0.04
Firm size				1	0.16
Firm age					1
Mean	11.08	2.8701	0.6875	101.7676	39.3929
Standard deviation	18.06	12.0593	0.8386	248.8766	20.7170

** Significance level ($p < 0.01$)
* Significance level ($p < 0.05$)
Absorptive capacity and firm size in millions of euros.

Table III. Variables and equations

Item	**ID**	**Role**
Level of servitization	LS	Dependent variable (according to services offered)
Absorptive capacity	AC	Independent variable (firm's knowledge base)
Tech. collaboration	TC	Main moderator (technological collaboration in the value chain)
Customer collaboration	CC	Secondary moderator (independent effect due to customers)
Supplier collaboration	SC	Secondary moderator (independent effect due to suppliers)
Interaction AC-CC	IC	Secondary interaction (effect due to customers)
Interaction AC-SC	IS	Secondary interaction (effect due to suppliers)
Firm size	FS	Control variable
Firm age	FA	Control variable
Hypothesis/Equation	**Mathematical model**	
H1 => Equation 1	$LS=\beta1_0+\beta1_1*AC+\beta1_2*FA+\beta1_3*FS$	
H2a => Equation 2	$LS=\beta3_0+\beta3_1*AC+\beta3_2*CC+\beta3_3*IC+\beta3_4*FA+\beta3_5*FS$	
H2b => Equation 3	$LS=\beta4_0+\beta4_1*AC+\beta4_2*SC+\beta4_3*IS+\beta4_4*FA+\beta4_5*FS$	
H2ab => Equation 4	$LS=\beta5_0+\beta5_1*AC+\beta5_2*CC+\beta5_3*IC+\beta5_4*SC+\beta5_5*IS+\beta5_6*FA+\beta5_7*FS$	

Table IV. Regressions associated with the hypotheses

Independent variables	Equation 1 (H1): LS: Servitization	Equation 2 (H2a): LS: Servitization	Equation 3 (H2b): LS: Servitization	Equation 4 (H2ab): LS: Servitization
AC: absorptive capacity	0.3321 *0.226* (0.02)	0.3066 *0.208* (0.04)	0.1539 *0.105* (0.32)	0.1818 0.124 (0.24)
CC: customer collaboration		-7.0173 *-0.188* (0.07)		-4.952 *-0.132* (0.25)
IC: AC * CC		3.0283 *0.333* (0.01)		2.1773 *0.239* (0.05)
SC: supplier collaboration			-3.9197 *-0.102* (0.29)	-3.234 *-0.084* (0.47)
IS: AC * SC			1.3956 *0.370* (0.00)	1.1507 *0.305* (0.01)
FA: firm age	0.1103 *0.126* (0.21)	0.1125 *0.130* (0.18)	0.0881 *0.102* (0.29)	0.0940 *0.109* (0.26)
FS: firm size	-0.0044 *-0.052* (0.61)	-0.0157 *-0.214* (0.07)	-0.0084 *-0.114* (0.25)	-0.0161 *-0.220* (0.05)
Adjusted R-squared	0.042	0.097	0.128	0.147
F value	5.573 (0,02)	3.261 (0.01)	4.087 (0.00)	3.589 (0.00)

The table shows unstandardized coefficients, *standard coefficients,* and significance in parentheses
Absorptive capacity and firm size in millions of euros.

Table V. Increase in R-squared due to interactions

Equation	R2 change	F	p
H2a (Equation 2)	0.04006761	4.78	0.03
H2b (Equation 3)	0.09143838	11.48	0.00
H2ab (Equation 4) Int_IC	0.00973232	1.22	0.27
H2ab (Equation 4) Int_IS	0.05999504	7.54	0.01

Table VI. Conditional effects of the focal predictor at different values of the moderator

Moderator	Value	Effects (dy/dx)	p	LLCI	ULCI
H2a (Customer collaboration)	0	0.3066	0.04	0.0042	0.6090
H2a (Customer collaboration)	1	3.3349	0.01	2.2126	4.4572
H2b (Supplier collaboration)	0	0.1539	0.32	-0.3530	0.6608
H2b (Supplier collaboration)	1	1.5495	0.00	0.6384	2.4606
H2ab (Customer, Supplier)	(0,0)	0.1818	0.24	-0.0985	0.4621
H2ab (Customer, Supplier)	(0,1)	1.3325	0.01	0.9671	1.6979
H2ab (Customer, Supplier)	(1,0)	2.3591	0.05	0.0236	4.6946
H2ab (Customer, Supplier)	(1,1)	3.5098	0.00	2.4867	4.5329

LLCI: Lower Level of the 95% Confidence Interval

ULCI: Upper Level of the 95% Confidence Interval

The table shows effects according to unstandardized coefficients.

Control variables were included for calculations

Absorptive capacity and firm size in millions of euros.