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Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective

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A R T I C L E I N F O

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A B S T R A C T

Servitization and Industry 4.0 are considered two of the most recent trends transforming industrial companies. Servitization is mainly focused on adding value to the customer (demand-pull) while Industry 4.0 is frequently related to adding value to manufacturing process (technology-push). Although some scholars address them as complementary concepts, the literature lacks evidences about what are the interfaces and connection between the two trends. Thus, we aim to develop a conceptual framework that connects Servitization and Industry 4.0 concepts from a business model innovation (BMI) perspective. Our framework is based on three Servitization levels (i.e. smoothing, adapting and substituting) and three levels of digitization (i.e. low, moderate and high levels). We show that matching these levels results in nine possible configurations classified in manual, digital and industry 4.0-related services, which can focus on smoothing, adapting or substituting services. We use reported cases from the literature to support and illustrate these configurations. We also discuss different levels of complexity for the implementation of these configurations. The study hence provides a foundation for the growing research on the interface between Servitization and Industry 4.0.

1. Introduction

Industries have been facing many transformations in the last decade, dramatically changing the way companies are doing business with their customers as well as how products are developed, manufactured and delivered (Gersch and Goeke, 2007). Two recent macro-phenomena and trends are specifically challenging the business models (BMs) of product firms: Servitization and Industry 4.0.

The first phenomenon – Servitization – is predominantly related to the demand-pull innovation trajectory (Dosi, 1982). Since the market has been changing from product consumption to result-oriented demand, customers are expecting to receive additional services to improve the experience they make when getting in touch with such products (Enkel and Gassmann, 2010); or, in some cases, instead of affording the cost of the product itself, customers want to receive only the value inherently offered by the product use, thus consuming it as a service (Tukker, 2004, 2015). This change resulted in the Servitization strategy of product firms, which consists in a transformation journey of product-centered firms towards product-service systems (PSS) (Kowalkowski et al., 2017; Martinez et al., 2017). Such transformation is so deeply rooted in the product firms' value architecture – composed by value creation, delivery and capture mechanisms and complementarities (Teece, 2010), and acting as a manifestation of the firm's business strategy (Cortimiglia et al., 2016) – that is considered a business model innovation (BMI) of product firms themselves (Ayala et al., 2017; Kastalli and Van Looy, 2013), which can happen at different stages of the industry evolution (Cusumano et al., 2015).

A second recent industrial macro-trend affecting product firms is the so-called Industry 4.0 phenomenon (Liao et al., 2017; Reischauer, 2018; Yin et al., 2017). It is considered a new industrial scenario in which the convergence of different emerging technologies strengthen by the Internet of things (IoT) results in cyber-physical and intelligent systems that can create value for the industrial activities (Frank et al., 2019; Müller et al., 2018; Liao et al., 2017). Thanks to the connectivity platforms offered by the industrial Internet, mature industries are now facing a transformation towards a digitalized era, where machines,

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devices and products can be interconnected to adapt themselves and be flexible to quickly attend to market changes (Wei et al., 2017). In this sense, Industry 4.0 trend is mainly based on the technology-push innovation approach, since it comes from the direct competitors inside the product firms' own industry (Dosi, 1982; Lasi et al., 2014). Specifically, in the manufacturing industry, developed economies such as Germany and the United States achieved high maturity in automation and are moving towards this new technological stage (Liao et al., 2017). Several scholars have stressed that this technology-push innovation also implies a radical business model innovation of the manufacturing companies (Müller et al., 2018; Wei et al., 2017).

In such a context, product firms need to respond to the demand-pull model of service innovation, while they also need a strong investment in new technologies and connectivity to compete in the technology-push model established by the competitors. Both Servitization and Industry 4.0 were born from different research fields – the first from management and the latter from engineering and computer science (Díaz-Garrido et al., 2018; Liao et al., 2017) – and, therefore, for a long time the literature treated these issues as stand-alone areas, one centered on the customer value and the other centered on the manufacturing process value (Coreynen et al., 2017; Tongur and Engwall, 2014). However, since both these strategic decisions have deep implications for competition, scholars have started to devote attention to the connections between these two fields (e.g. Ardolino et al., 2017; Belvedere et al., 2013; Coreynen et al., 2017; Kamp et al., 2017; Vendrell-Herrero et al., 2017). Nevertheless, the incipient literature that connects Servitization with Industry 4.0 provides little support to the understanding of the interfaces between these innovation trajectories – demand-pull versus technology-push – which generally present tensions for strategic decisions (Brem and Voigt, 2009).

In the light of these considerations, two main questions arise. Firstly, if both industrial trends – Servitization and Industry 4.0 – have business model innovation consequences, *is there a common interface between them*? Some scholars recently assume that, in fact, both concepts are strongly interrelated. For instance, smart products, digital services, mass customization and other new value propositions have been presented as concepts from both streams of literature (e.g., Ardolino et al., 2017; Coreynen et al., 2017; Kamp and Parry, 2017). However, should we assume that one of these trends is a demand-pull and the other a technology push, most of these related concepts could fall in only one of these categories and not in the interface between them. Thus, if there is a real convergence of the concepts, *what kind of services in product firms* (*Servitization*) *can be seen as a part of the real concept of Industry 4.0*? In other words, *in what kind of solutions is there a convergence between both concepts*?

To answer these research questions, we develop a conceptual framework that connects Servitization and Industry 4.0 concepts from the business model innovation perspective, to identify and discuss the interfaces between them. We first provide a conceptualization of both perspectives from a business transformation point of view. Then, we position them according to two dimensions: (i) *levels of digitization*, representing intensities of digital tools usage in the context of Industry 4.0 and (ii) *Servitization types*, showing three ways a company can offer product-service solution. We use these two categories to classify different types of services in product firms by considering the manual services, digital services and those services related, in fact, to the Industry 4.0 concept. We hence show that there are nine types of service configurations in the combination of both perspectives, and that only three of them show a convergence between Industry 4.0 and Servitization. We also show that some types of services sometimes considered as a part of Industry 4.0 are only digital services, but not part of that broader concept. We conclude our study by discussing the challenges for Servitization in the context of Industry 4.0, based on our conceptual framework. In this sense, we introduce six propositions about our conceptual framework implication for business value proposition, strategic decision of the firm's business transformation paths, industry platforms and industry lifecycle. With such results, we provide a new perspective on Servitization in the context of Industry 4.0 which can help strategists to position their company and related business model in these two different though intertwined innovation fields.

2. Theoretical background

2.1. Servitization as a BMI

Several manufacturing companies are innovating their Business Models following a service-driven orientation (Martinez et al., 2017). While Servitization refers to the transformational process from product-centric to service-oriented business models (Kowalkowski et al., 2017), the product-service system (PSS) refers to the output of this process: the PSS is a bundle of integrated products and services that provides functionalities to customers and other stakeholders – as it may also offer environmental benefits (Tukker, 2004, 2015). There is a common understanding that Servitization (and, consequently, PSS) brings strategic and competitive benefits for companies adopting this form of business model innovation (Ayala et al., 2018).

One of the main Servitization challenge is to determine the new value proposition, which has clear impacts on the business model value architecture as a whole (Ayala et al., 2017). The provision of services embedded in the value proposition can vary, thus implying different types of Servitization (Martinez et al., 2017). Concerning this issue, several authors (e.g. Ayala et al., 2017; Park et al., 2012; Tukker, 2004) proposed different classifications of PSS or Servitization types. In this study, we follow Cusumano et al. (2015) who developed a framework to identify types and roles of services in the competitive strategies of product firms. According to the authors, some services complement products and others substitute them. More specifically, services fall into three main groups: (i) Smoothing services facilitate the product sale or usage without significantly altering the product functionality (e.g. financing, maintenance and basic training). They are loosely coupled with the product and can be offered by the company or a partner; (ii) Adapting services, on the other hand, are integrated to the product and expand product functionalities or provide new uses for it (e.g. customizations and consulting about new uses). They require more knowledge exchange between the manufacturing company and its customers; finally, (iii) Substituting services replace the purchase of the product and customers pay primarily for its usage; this category of services is similar to use-oriented PSS and resulted-oriented PSS proposed by Tukker (2004), and advanced services proposed by Baines and Lightfoot (2013).

Besides considering different service types, manufacturing firms deploy appropriate services based on their stages in the industry lifecycle (Cusumano et al., 2015; Lee et al., 2016; Visnjic et al., 2019). Thus, adapting services should be more prevalent in the early phase of industry lifecycle, due to the high level of costs and uncertainties related to the product and the market; as these conditions decrease throughout the transition to maturity, smoothing services gain more relevance in the late phases of industry lifecycle. Although substituting services can emerge in the early phase (in cases of extreme uncertainties), they are more common in the mature phase, when companies seek to expand the market to attract new customers who cannot afford the product purchase (Cusumano et al., 2015). Such options also depend on the type of industry environment of the company. As demonstrated by Visnjic et al. (2019), companies choose for product-oriented services in Schumpeterian industry environments, while customer-oriented services are more pursued in non-Schumpeterian environments. Therefore, product firms do not necessarily follow the product-service continuum. They alternate and offer types of services simultaneously as a response to the challenges and opportunities they face in their industry lifecycle. Moreover, services aim to complement and leverage one another and to expand product sales (Salonen et al., 2017). Consequently, diverse services strategies result in different

Servitization modes and levels, which in turn demand proper business model reconfigurations (Forkmann et al., 2017).

2.2. Industry 4.0 as a BMI

Several concepts related to Industry 4.0 have recently emerged. Some synonyms such as the 'fourth industrial revolution' (Liao et al., 2017; Sung, 2018) or 'smart factory' (Oesterreich and Teuteberg, 2016) have been used to describe a new industrial scenario dominated by information technologies and connectivity. Other concepts such as manufacturing cyber-physical systems (Babiceanu and Seker, 2016), advanced manufacturing (Müller et al., 2018; Reynolds and Uygun, 2018), digitization (Oesterreich and Teuteberg, 2016), industrial Internet of things (Rong et al., 2015), among others, have been strongly related to Industry 4.0 even when some of them may only reflect partially the whole Industry 4.0 concept. Most of these concepts are focused on the establishment of intelligent products and production processes by integrating modern information and communication technologies (Brettel et al., 2014), and they emphasize different faces of the new industrial challenges.

From our business perspective on these different concepts, and based on the aforementioned prior works, Industry 4.0 can be conceptualized as *a new industrial maturity stage of product firms, based on the connectivity provided by the industrial Internet of things, where the companies' products and process are interconnected and integrated to achieve higher value for both customers and the companies' internal processes*. We base our concept on two recent studies from Dalenogare et al. (2018) and Frank et al. (2019). In the first one, Dalenogare et al. (2018) showed the connections between product development and the manufacturing processes in the Industry 4.0 context. As the authors pointed out, both dimensions should be integrated and aligned based on data and information sharing. Furthermore, Frank et al. (2019) proposed a conceptual framework for the understanding of Industry 4.0. According to them, the Industry 4.0 concept comprises many business dimensions (i.e. manufacturing, product development, supply chain and working processes) supported by emerging technologies. As proposed by Frank et al. (2019), these dimensions are supported by what they called "base technologies", which are four: (i) Internet of things, (ii) cloud services, (iii) big data and (iv) analytics. The base technologies allow companies to integrate different processes and activities and to provide artificial intelligence to the company (Frank et al., 2019). In this perspective, the digitization or Digital Transformation of product firms is seen as the transition process companies are facing when moving from previous industrial stages to an interconnected smart enterprise of the Industry 4.0 era supported by these base technologies (Dalenogare et al., 2018; Frank et al., 2019).

Our proposed concept of Industry 4.0 integrates two streams of research: the one concerned with the industrial processes, which has paid significant attention to smart (or advanced) manufacturing (e.g. Babiceanu and Seker, 2016; Ivanov et al., 2016; Yin et al., 2017); and the one related to process and product innovation aiming to add value to customers (e.g. Frank et al., 2019; Wei et al., 2017). In such a wider perspective of Industry 4.0, the digitization of companies implies changes that exceed their own frontiers, requiring product firms to change the way they interact with external actors and customers (Frank et al., 2019; Porter and Heppelmann, 2014). Also, technologies associated to Industry 4.0 are seen here as twofold. On the one hand, they allow firms to better understand what value means for customers by obtaining a significant amount of data associated to their behavior and product usage (e.g. through Internet of things and big data analytics) (Porter and Heppelmann, 2014; Wamba et al., 2015). On the other hand, those advanced technologies allow firms to better deliver value to their customers by rapidly integrating the external information of demand with their internal processes (e.g. by horizontal and vertical systems integration and additive manufacturing) (Bogers et al., 2016) and new customers' needs with more agile product and service development processes (e.g. by additive manufacturing and simulation) (Babiceanu and Seker, 2016; Weller et al., 2015). Consequently, Industry 4.0 reflects a new industrial scenario where the production technology as it is known today changes (Reischauer, 2018). This new scenario demands important transformation and innovation in the current industrial business model, as interoperability, virtualization, decentralization, real time capabilities, service orientation and modularity become imperative (Saldivar et al., 2015).

3. Prior research on the connection between Servitization and Industry 4.0

The literature addressing the connections between Servitization and Industry 4.0 is still emerging. Most of the existing studies relate Servitization only to Digital Transformation in a broader sense, focusing on the value creation for Servitization through the application of IoT solutions (e.g. Rymaszewska et al., 2017; Zancul et al., 2016; Zhu et al., 2012). Some studies have considered the contribution of specific digital tools for Servitization, such as remote monitoring (Grubic, 2014), cloud computing (Wen and Zhou, 2016), big data (Opresnik and Taisch, 2015) and predictive analytics (Ardolino et al., 2017). These papers have been more concerned with the use and contribution of such technologies for the Servitization offering.

Another stream has focused the attention to the business perspective of the Digital Transformation in Servitization. Some works have contributed with the classification of types of digital PSS (Lerch and Gotsch, 2015) and considered the integration of Servitization with other business dimensions through digitization, as supply chain (Vendrell-Herrero et al., 2017), production (Coreynen et al., 2017) and after-sales (Belvedere et al., 2013). These studies consider that the adoption of digital technologies should be accompanied by a redesign of operating processes. In this stream of research, one of the most detailed works on the integration of Servitization with digital technologies using a BMI perspective is the one proposed by Coreynen et al. (2017). They examined how digital technologies can enable different Servitization pathways and, consequently, should be supported by different sets of resources and capabilities. In summary, according to this work, the Industrial Servitization Pathway employs digital technologies, resources and capabilities to make the internal manufacturing operations smarter and provide new hybrid services for the clients. In the Commercial Servitization Pathway, the integration of the client with the supplier increases. Hence, the digital technologies go beyond the domain of production and support intelligence gathering and semantics to capture customer needs. The Value Servitization Pathway encompasses the previous ones and incorporates an additional inter-organizational value creation perspective. Consequently, digital technologies, capabilities and resources allow customers to monitor product usage and performance to accomplish particular outcomes (Coreynen et al., 2017).

In general, the abovementioned studies tend to emphasize only the value that digital technologies can provide for the service value delivery to the customer, while internal manufacturing processes value is not fully addressed. This means that Industry 4.0 base technologies such as IoT, cloud, big data and analytics (Frank et al., 2019) are studied in Servitization disconnected from manufacturing and, thus, disconnected form the Industry 4.0 core concept, which is strongly rooted in manufacturing processes (Dalenogare et al., 2018). In fact, few studies of the Servitization literature address the Industry 4.0 topic, while they limit their scope of discussion to a more generic concept of Digital Transformation.

There is a third and very recent stream of research focused specifically on Industry 4.0. Some works from this stream have addressed PSS and Servitization as a part of Industry 4.0. For instance, Frank et al. (2019) considered digital platforms for service offering in their Industry 4.0 framework. Dalenogare et al. (2018) suggest that digital service may provide feedback for manufacturing processes creating common big data sources for such integration. Jiang et al. (2016) proposed a concept of social manufacturing in which Industry 4.0 comprises customization and adaptation to personal needs of the customer, as a service-oriented process. Nonetheless, these works simply embrace Servitization as a part of Industry 4.0, while the real interface of both is shallowly discussed. In other words, they do not address under which conditions Servitization can be considered as a part of Industry 4.0 and how this affects the company's BM. Our research aims at filling this gap. First, in the following sections we consider how Servitization can be connected to the broader concept of Industry 4.0 and under which conditions. Second, we aim to classify and differentiate the different levels of digital PSS by showing which of them can be considered integrated with the Industry 4.0 concept. Third, we consider a BMI perspective to show how the integration of these two trends can enhance the whole value architecture for manufacturing companies embarking in a Digital Innovation and Transformation journey.

4. A conceptual framework for the convergence of Servitization and Industry 4.0

The theoretical perspective used to build our conceptual framework are introduced in Fig. 1. We consider two different BMI forms. The first one – *Digitization level* – considers the levels of implementation of Industry 4.0-related technologies and, therefore, it follows a technology-push innovation trajectory resulting in value added mainly for the company's internal processes (e.g. cost reduction, flexibility and productivity) (Fig. 1: from Quadrant 1 to 2). The second one – *Servitization level* – considers the relevance of Servitization in the company based on different types of service offerings and levels of service dominance in the product firm BMI. In this case, the BMI follows a demand-pull innovation trajectory, where the value proposition is focused on the customers (e.g. market expansion and customer loyalty) (Fig. 1: from Quadrant 1 to 3). We aim to explore the condition where a convergent innovation trajectory between these two concepts occurs (Industry 4.0 and Servitization), as shown in Quadrant 4 of Fig. 1.

Based on the theoretical perspective presented in Fig. 1, we develop the conceptual framework shown in Fig. 2 with a threefold aim. First, to clarify the differences between types of Servitization when digital technologies are considered. Second, to support strategy makers in understanding the possible combinations they can pursue and the consequences for the company's BMI implementation. Third, to enable a discussion on challenges and implications of these innovation trajectories for the company's strategy and BMI. We first explain the underling concepts of the conceptual framework, and then we describe different situations and cases to provide a better explanation of the interfaces between Servitization and Industry 4.0 as forms of BMI for product firms.

Two dimensions guided the development of the conceptual framework. The first one is the *Servitization type* (along the horizontal axis). We adopted the Servitization types proposed by Cusumano et al. (2015), consisting in *smoothing*, *adapting* and *substituting* services (see Section 2.2) and we assumed these types represent different *Servitization levels* in the product firm based on the service-dominance of their approaches (Fliess and Lexutt, 2017; Sousa and da Silveira, 2017), as described before in Fig. 1. The second dimension considers the level of digital technologies embedded into the service offering, named as *Digitization level* (along the vertical axis). As we explain in Section 2.2, we consider digitization as the transition process companies are facing when they progressively adopt digital technologies to achieve an interconnected smart enterprise as proposed in the Industry 4.0 concept (Frank et al., 2019). We did not use any preordained typology for this axis, since we do not have any evidence from the literature regarding typologies of digital technologies oriented to different service offering features. In line with this, we propose a division in three main categories of digitization intensities based on their purpose for the service offering of product firms. The first level – *manual services* – considers low levels of digital technologies usage for service offering. In this case, digital technologies are used only as a support to create customers

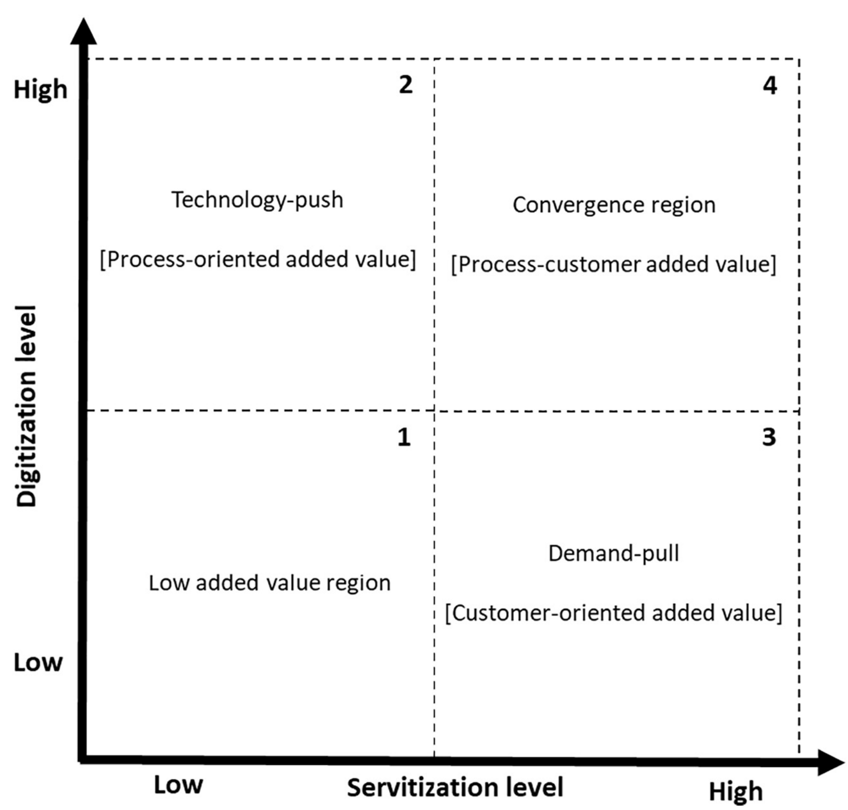

Fig. 1. Innovation trajectories for Industry 4.0 and Servitization.

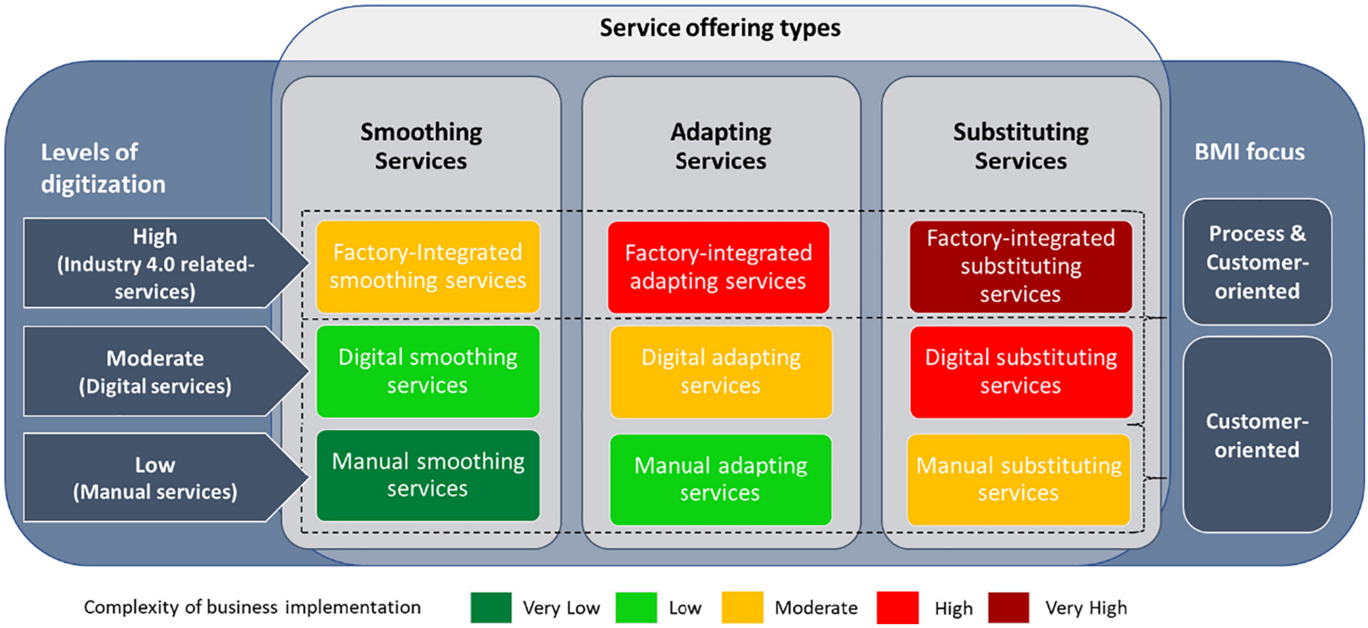

Fig. 2. Conceptual framework for Servitization and Industry 4.0 convergence. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

database, to manage customers with CRM (Customer Relationship Management) software, and so on, but they do not provide the service itself – i.e. services are manually delivered. The second level – *digital services* – considers moderate usage levels of digital technologies. It comprises the use of digital tools enabling manufacturers to deliver distinct service offerings to the customer. In this case, digital technologies such as apps, cloud computing and embedded software are used to provide the service itself, adding value to the service solution that customers are receiving. These two levels – *manual services* and *digital services* – show a BMI focus only on the customer (customer-oriented added value), as portrayed in the right column of Fig. 2. Finally, the highest level of digitization – *Industry 4.0 related-services* – considers high-tech services that can provide value for both customer and the companies' internal processes. This is the only level of digitization for Servitization that complies with the proposed concept of Industry 4.0. As we describe in Section 2.3, Industry 4.0 is as a new industrial maturity stage of product firms, based on the connectivity provided by the industrial Internet of things, where the companies' *products and process are interconnected and integrated* to achieve higher value for *both customers and the companies' internal processes*. In this sense, our framework maps in this highest level of digital services only those services that deliver value to both sides, creating new types of interactions between the customer and the manufacturing process (Coreynen et al., 2017; Opresnik and Taisch, 2015; Rymaszewska et al., 2017; Tukker, 2004; Ulaga and Reinartz, 2011). Therefore, we position this configuration of innovation trajectory of the product firm in the fourth quadrant of Fig. 1, where a convergence between process and customer added value is found.

When considering the different configurations between levels of digitization and types of Servitization (or intensity levels) in the conceptual framework (Fig. 2), we provide nine configurations and different levels of complexity of the twofold BMI implementation (red, yellow and green colors). Next, we discuss all these combinations (Subsection 4.1) and then we discuss the resulting complexity for their implementation (Subsection 4.2). We provide examples from the literature for these configurations, paying specific attention to the unexplored level in the extant literature: Industry 4.0 related services (high digitization level).

4.1. *Configurations in the conceptual framework of Servitization and Industry 4.0*

Drawing from our conceptual framework, we firstly consider the smoothing services configurations: a) Manual smoothing services, b) Digital smoothing services and c) Factory-integrated smoothing services. *Manual smoothing services* are services at the non-digital level, which can be most of the basic services provided in product firms (e.g., technical supports, maintenance/repair, basic training). The extended warrantee contract from Whirlpool dishwasher (Cusumano et al., 2015) or services provided by IT companies to put the new system online, e.g. configuration, logistics and data migration (Ayala et al., 2017), are some examples in this category. In the second digitization level, the *digital smoothing services* are considered. This category includes products' complementary services focused on technical support but provided through digital technologies, such as apps, cloud computing or embedded software. Remote product support as those offered by Hewlett-Packard and Dell computers (Cusumano et al., 2015) are some examples. Finally, the highest level of digitization in smoothing services is what we named *factory-integrated smoothing services*. Differently to the other two categories, here the value of the BM is focused on both customer and internal manufacturing processes. In this case, digital technologies allow smoothing services to deliver the service itself to the customer, right as in the digital smoothing service; but by doing this they gather data to integrate services with manufacturing to enhance activities such as production planning and control, new product launch, inventory management, etc., being thus part of the Industry 4.0 concept. The OnStar® telematic service system provided in the General Motor's cars is an example: customers can use GPS, security, maintenance and other services in this system integrated in the cars, while the data generated as well as the real-time connectivity of the car are used by the company to learn about the product usage for product development improvement purposes (Williams, 2007). Another company, SKF, a manufacturer of bearings, developed a condition monitoring technology to support their Asset Efficiency Optimization concept (Grubic, 2014). Porter and Heppelmann (2014) cites also the examples from Tesla automobiles which are connected to a single manufacturer system that monitors performance and accomplishes remote service and upgrades; and from Diebold automated teller machines that are monitored for early signs of trouble, thus anticipating operational planning. These three possible configurations – manual, digital and factory-integrated smoothing services – can be positioned in Fig. 1 as predominant technology-push BMI (Quadrant 1 and 2) since the progressive addition of technology is on a low level of service dominance in the product firm.

The second type of services considered in the conceptual framework are the adapting services: a) Manual adapting services, b) Digital adapting services and c) Factory-integrated adapting services. The low digitization level considers what we called as *manual adapting services*, which show low or no use of digital technology. For instance, a manufacturer, such as General Electric, might provide adaptations in generators and nuclear reactors for the use in extreme weather conditions (Cusumano et al., 2015). Another example is provided in Ayala et al. (2017) referring to Telecommunication companies that shifted their focus from developing hardware for Telecom Operators, to engineering services for the optimization of the hardware implementation and use. Secondly, the moderate digitization level comprises the *digital adapting services*, where digital technologies provide services for new product applications. Ayala et al. (2017) discuss the case of a German dental care equipment manufacturer who developed integrated software services to adapt the use of this equipment in the Brazilian emerging market, where the target customer is not the same as in Germany and the software service has to bridge this gap. Another case worth mentioning is that of ABB, a European robot manufacturer, who changed the focus from simply developing and selling robots to the service of monitoring and optimizing the customer's shop floor through connectivity and big data analysis (Krueger et al., 2015). The last stage consists in high levels of digitization where the focus lies on factory and customer integration at the same time, attending again the Industry 4.0 requirement of aggregating value for both customer and internal manufacturing processes. This is the case of the so-called *factory-integrated adapting services*. Considering the same case of ABB robots, we fall in this stage when the company not only uses the collected data to monitor and optimize customer's processes, but also to adapt and improve its own product functionalities and manufacturing planning (Krueger et al., 2015). In other words, value is generated for both customers and internal processes. A similar dynamic emerges in another example, as John Deere used to manufacture multiple engines with different levels of horsepower to serve different markets and segments; however, it can now modify the horsepower rating on the same engine using software alone while they also employs IoT, data management and geolocalization to provide recommendations to farmers (Kowalkowski et al., 2017; Porter and Heppelmann, 2014). Porter and Heppelmann (2014) provide an additional case that we place in this category: Joy Global, a mining equipment manufacturer. The company focuses on both customer and process value by monitoring operating conditions, safety parameters, and predictive service indicators for entire fleets of equipment and it also monitor operating parameters across multiple mines in different countries for benchmarking purposes (Porter and Heppelmann, 2014). In this case, the collected data via smart products are used for the optimization of the service provided as well as for the product and production process planning and control. These three configurations – manual, digital and factory-integrated adapting services – can be positioned in Fig. 1 as a mixed positioning between a high technology-push innovation trajectory and a moderate market-pull innovation trajectory (intersections of Quadrants 1–3 and 2–4), since the progressive addition of technology is on a moderate level of Servitization. In this case, we consider a moderate level of service because the services themselves are still product-oriented instead of customer-oriented (Ayala et al., 2017). In other words, we find an adaptation in the product, but it is still restricted to the product's initial configuration condition.

The last type of services considered in the proposed conceptual framework are the substituting services: a) Manual substituting services, b) Digital substituting services and c) Factory-integrated substituting services. The first level, *manual substituting services*, includes pure substituting services without or with low digital technologies involved. Most of the traditional pay-per-use-services may fall into this services category. For instance, Daimler diversified their offering model by including the Mercedes-Benz's car-rental service (Williams, 2007). Another example is Ford, which is investing in bus shuttle companies as well as bike sharing initiatives to diversify their transportation solutions (Williams, 2007). Both companies included pure substituting services in their portfolios, since they are focusing on customer value added by offering the product as a service. These solutions have low digital technology content, since the model is focused mainly on the way customers pay for the product usage. The second level, *digital substituting services*, occurs when this pay-per-use model is strongly supported by Digital tools. We cited the case of Daimler for manual substituting services, but this company has also digital substituting services with the Car-to-Go® service (Belk, 2014). The car sharing service consists in offering the Daimler's Smart car model in a pay-per-use system within the main city centers. Using apps, electronic identification, GPS and many other services, customers can easily access to the cars which are parked in different points of the cities. In this case, substituting services are focused on customer's value added. However, the last type, *Factory-integrated substituting services*, focuses on feedbacks for the manufacturing process aiming to deliver value also for the internal processes. It would be the case should the Car-to-Go® system (Belk, 2014) use the information of the service operation not only to improve service quality, but even to improve product planning and control. One example of such an approach is found in Michelin, a tire company, which offers a pay-per-kilometer solution that includes sensors and devices installed in the vehicles (i.e., trucks and cars) to transmit information such as total kilometers, fuel consumption, temperature and tire pressure (Gebauer et al., 2017). The data feedback their own processes and also serve to develop new solutions in a wide range of areas, such as outsourced tire management, vehicle productivity and fuel efficiency. Another example is Prosumir,[1] a Brazilian startup dedicated to power cogeneration and energy efficiency. This company installs pressure-reducing turbines that transform vapor pressure waste in additional energy; the turbines allow the company to collect data from operation which is used for both customer operation improvements and engineering design improvement. In both examples on *Factory-integrated substituting services* the value of the service is for both sides, customer and internal processes, while the customer is paying for the results produced by the product. Again, this last category is the only one that pursues the complete value of the Industry 4.0 concept. These three configurations – factory-integrated manual, digital and substituting services – can be positioned in Fig. 1 at Quadrants 3 and 4, from a strong technology-push to a convergent innovation trajectory between a demand-pull (high Servitization level) and technology-push (high digital technology level).

We summarize the aforementioned concepts and examples in Fig. 3 where we relate the innovation trajectories (Fig. 1) with the configurations of our conceptual framework (Fig. 2).

4.2. Levels of business complexity in different Servitization and Industry 4.0 configurations

The proposed framework of Fig. 2 differentiates levels of complexity of the twofold BMI implementation (i.e. focused on both technology-push and demand-pull trajectories at the same time): this is shown by using different intensities of colors (varying from dark green – very low complexity – to dark red – very high complexity). In this sense, from the Servitization side we understand complexity from a BMI perspective, as the breadth – i.e. the value architecture elements involved – and depth

[1] Information available at: http://www.prosumir.com.br/en/pressure-reducing-turbine (March 2018).

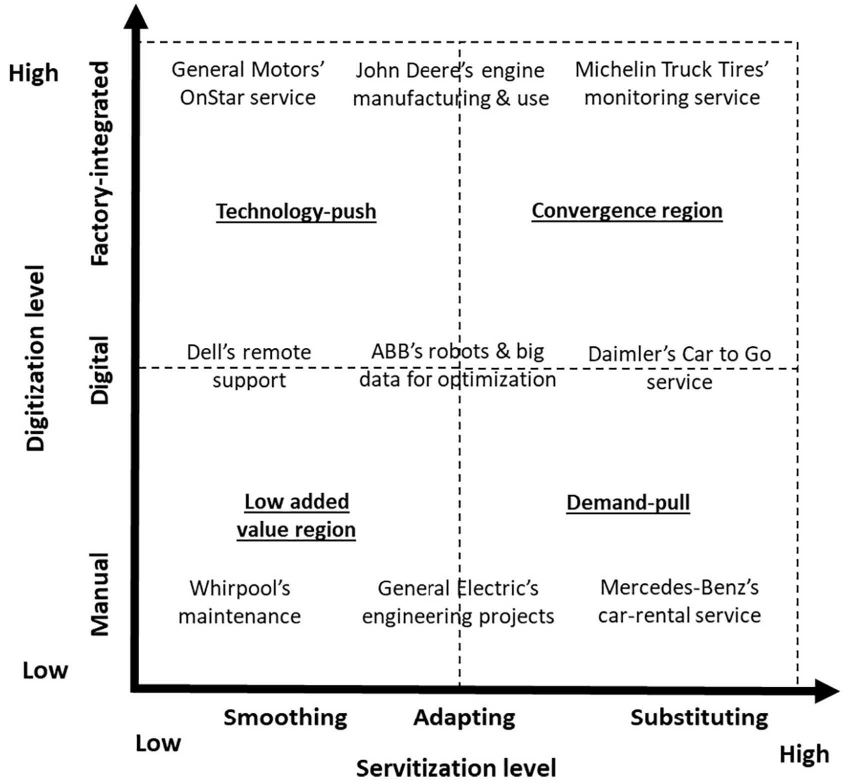

Fig. 3. Examples of different configurations resulting from the conceptual framework.

– i.e. the degree to which each element of the BM should change – of BMI necessary; and consequently, the level of effort the manufacturing company has to place for the implementation of the different configurations proposed. On the other hand, from the digitization side we understand complexity as how advanced the technology to be implemented is, which may require more specialized knowledge for both implementation and use of such technology.

Firstly, considering the service offering types and, consequently, the level of Servitization and the necessity of changes in business model they demand, there is a progressive complexity regarding the changes needed to implement this BMI when a company moves from smoothing to adapting and then to substituting services approach. In this sense, we cross Cusumano et al. (2015) typology with other classifications, like Tukker's (2004) and Baines and Lightfoot's (2013), who supported the idea that the more a product firm moves towards full Servitization as a trajectory to innovate it business model, the more complex such BMI process becomes. Such increasing complexity is due to the complementarities existing between different business model elements (Foss and Saebi, 2017): although Servitization directly refers to a change in a business model's value proposition – i.e. value creation mechanisms –, its full implementation requires manufacturing companies to change and align also their value delivery and capture mechanisms (Fliess and Lexutt, 2017; Sousa and da Silveira, 2017; Tukker, 2015).

Smoothing are the least complex services to be implemented, considering that even when such additional services are included, the company's business model is still mainly geared towards selling products. Therefore, this process can be easily outsourced to service suppliers (Ayala et al., 2017). This is what happens, for instance, with the maintenance services for car manufacturers, which are mostly offered by car dealerships. The second level of complexity in BMI is when adapting services are included: such an inclusion can call for a significant change in the BM's resources and competencies, since, for instance, it may require a high flexibility of engineering teams (Fliess and Lexutt, 2017; Gremyr et al., 2014; Kindstrom and Kowalkowski, 2009); it also produces an important change on the value capture dimension, as the company alters its focus from mass production to customized product-service systems (Cusumano et al., 2015). Finally, the last type of service offering, substituting services, shows the highest complexity concerning BMI process implementation, because it forces product firms to adopt an overarching result-oriented model. The complexity in this case is due to a pervasive paradigm change, where both customers and the company modify the way they interact and exchange value embracing a dependence model, where value is embedded in the service offering rather than the mere product. Whereas in the two first types (smoothing and adapting) the product firm still follows a product-dominant logic, in this last case of substituting services the product firm must change its mindset and overall positioning to a service-dominant logic (Baines et al., 2017; Cusumano et al., 2015; Fliess and Lexutt, 2017; Tukker, 2015). Moreover, complexity is also higher for substituting services since the revenue model also changes radically, calling for a marketing and financial restructuring of the company to face this innovated Servitization model (Baines et al., 2017; Oliveira et al., 2018).

On the other hand, the technology-push side of the BMI has a more simple and intuitive complexity dynamics for its implementation. The first level considers cases when there are little to no digital aspects in the service offering. Then, a moderate level of digitization is added when services become digital by means of using apps, software, IoT, among others: in this case, complexity grows since product firms are not necessarily used to develop digital solutions, which may be challenging due to the need to develop a new and different knowledge and capabilities endowment (Ayala et al., 2017). Finally, the last level of complexity is when digital services are integrated within the factory, which we consider as the highest level of convergence between Servitization and Industry 4.0. Integrating the collected data from the service offering to enable the improvement of internal activities and the adaptation of the manufacturing process naturally involves a higher complexity of implementation. At this level, new digital competences are needed such as sensoring, cloud computing management, and big data analytics as these solutions represent a new competitive knowledge from the digital era (Bharadwaj et al., 2013). In such a case, neither service nor technology competences alone are enough: connecting capabilities are needed to integrate the digital service solutions to the factory processes. Moreover, analytical competences associated to cloud computing and big data are necessary (Ardolino et al., 2017; Coreynen et al., 2017; Kamp and Parry, 2017; Opresnik and Taisch, 2015). Considering both sides of BMI complexity, it is expected that the twofold BMI implementation will imply a growing complexity as shown in Fig. 2, varying from those configurations which are easier to implement (green color) to those which are harder (red color). The most complex level is when the BMI is focused on factory-integrated substituting services, as it targets the achievement of a high business value for the internal manufacturing process and, at the same time, it also offers a high added value to customers; this coexistence or convergence has pervasive and deep implications on all the product firm's business model components of value creation, delivery and capture.

5. Discussions - consequences of the proposed conceptual framework

Our proposed conceptual framework offers a new and complementary perspective to the extant research on Servitization and Industry 4.0. In Section 3 we provided an overview of prior research on this topic, which we now compare to our theoretical development in order to propose a future research agenda.

Firstly, the – still limited – prior research on this topic has been mainly devoted to study the digitization of Servitization – i.e. the progressive adoption of digital technologies for service offering in product firms –, while the Industry 4.0 concept has been addressed only tangentially. Consequently, extant works focus on how digital technologies in the context of Servitization can add value only to customers, while the benefits they can bring to the internal processes of the companies have been dismissed. For instance, a relevant work on this topic is the one from Coreynen et al. (2017). These authors proposed three main Servitization pathways boosted by digital tools: industrial Servitization, commercial Servitization and value Servitization; some of them supported by front-end or back-end digitization, or both. However, in the three cases, much attention is paid to how digital tools can enhance customer value-added, while no discussions are made on process value-added – even back-end digitization is considered only in terms of how it can help to better deliver the service offering. This means that front-end and back-end digitization are considered from the demand-pull point of view. In our framework, the categories from Coreynen et al. (2017) may fall into the digital services level, which we considered as a previous step to the Industry 4.0 level. We also included the technology-push trajectory point of view and the convergence of it with the demand-pull trajectory for the Industry 4.0 level of Servitization. In such a sense, the front-end digitization of Servitization can also serve as a valuable support to the back-end digitization, which closes and reinforces a loop of twofold BMI enhancing manufacturing companies' value architecture. Thus, an integration of internal and external organizational process can be foster by means of digital tools (Scuotto et al., 2017a). We follow Kamp et al. (2017) and Rymaszewska et al. (2017) works on the returns of the digital services for the internal processes of the company. Kamp et al. (2017) considered how digitization of internal processes can contribute to the creation of smart connected manufacturing systems; and Rymaszewska et al. (2017) considered the efficiency improvement in the value chain of the company. Other research streams, such as the one which considers smart connected products, have also addressed this aspect indirectly, as for example in Porter and Heppelmann (2014). However, this literature does not clearly discriminate between types of services, digital tools and products; it considers everything together in a bundle. Our framework connects also with this research stream, as we leveraged the real-world cases it introduced to illustrated our different configurations. Based on these comparisons between our framework and prior research, we provide the following proposition:

Proposition 1. Industry 4.0-related services should have a twofold value-added focus, considering benefits for customers and for internal processes. Servitization supported by digitization can bridge these two apparently dichotomous focuses of the company.

Moreover, when this twofold value perspective is considered, the complexity of BMI implementation would be higher, since beyond technological challenges the product firm finds additional behavioral challenges related to the need of building trust between customers and companies to exchange data useful for both sides (Caputo et al., 2018; Kamp et al., 2017). In this work, we considered the business aspects of the integration perspective: however, behavioral aspects related to the resistance to customer-company integration due to data security, ethical aspect of monitoring customers, among others, are main concerns that the literature should address at the Industry 4.0-related service levels, as highlighted in a prior study from Grubic (2014). Some initial efforts have been made, as for instance, in Caputo et al. (2018), who studied the behavioral aspects of the use of IoT based products, that support our next proposition:

Proposition 2. Behavioral aspects on the data collected, involving trust, ethics and security, are essential to achieve the highest proposed level of convergence between Servitization and Industry 4.0.

Extant literature clearly shows an agreement about the role of digital technologies as an important innovation driver for manufacturing companies. In this regard, we provided several examples which can help to understand which levels of digitization and service offering types are involved in Servitization and Industry 4.0 innovation trajectories: still, we did not deepen the discussion on the different roles of specific technologies. For instance, other prior works have addressed many details on digital technologies and on Industry 4.0-related technologies for Servitization. Our point of view follows Ardolino et al. (2017) recent analysis on the core digital technologies for Servitization and Frank et al. (2019). According to them, the Internet of Things (IoT) is the basis for any digital service offering, followed by cloud computing and predictive analytics: indeed, such digital technologies are the essential tools to enable the convergence between Industry 4.0 and Servitization, since they allow offering digital solutions to the customer, while gathering the data generated through customer interactions to create prediction capabilities impacting the manufacturing or for the engineering internal processes of the company. Ardolino et al. (2017) study provides also the resulting set of digital capabilities that should be necessary to deliver what we named Industry 4.0-related services. However, a future step in this direction is needed, since the authors do not specify their analysis according to the types of services the company may offer. Considering that such specification can provide a broader comprehension of tools and capabilities needed to foster Servitization and Industry 4.0 BMI, we introduce the following proposition:

Proposition 3. Industry 4.0-related services need the support of three main integrated digital technologies – IoT, cloud computing and predictive analytics digital tools – which allow to bridge the twofold BMI focuses (customer and internal processes value added).

In the perspective of our study, we emphasized that Industry 4.0-related services may provide value from Servitization to the internal processes of the company. In this sense, one may wonder what specific internal value the product firm main gain. Some of these benefits and returns were highlighted in Kamp et al. (2017), and span from in-field quality control – by increasing the chance of rapid detection of anomalies in the manufactured products being used by the customers – to manufacturing efficiency – by providing a clearer view of the supply chain needs and capacity. Additionally, the company can shorten product lead time by releasing smaller changes, thus reducing the impact on product engineering activities (Rymaszewska et al., 2017). Another manufacturing value stemming from such integration is highlighted by Grubic (2014, p.100): "*Servitization centers on the transfer of risks from the customer to manufacturer. By providing real-time information about current and predicted health of a product in the field, remote monitoring technology can mitigate some of those risks*". These benefits expand the need of future research and discussion on Servitization performance and its possible paradox (Kastalli and Van Looy, 2013; Visnjic et al., 2016; Suarez et al., 2013). The literature on this topic has focused on the additional profits services can generate in sales (e.g. Suarez et al., 2013). Nonetheless, when considering the value-added integration between the customer and the internal processes by means of Industry 4.0-related services, one should also assess whether the convergence of Servitization and Industry 4.0 can reduce manufacturing and engineering internal costs, or increase manufacturing productivity and flexibility. This means that the twofold BMI brings also a new perspective for the literature of Servitization performance. Therefore, we present a fourth proposition:

Proposition 4. When Servitization and digitization strategies are focused on the Industry 4.0-related services category of the proposed framework, manufacturing and engineering internal processes can obtain value-related improvements and gains from the external product-service offering, resulting in internal gains such as costs reduction, increase of productivity and gain of flexibility.

6. Conclusions

In this study we argued that product firms can benefit from Servitization and Industry 4.0 in the attempt to innovate their business models through their Digital Transformation journey, and that these two innovation trajectories – the former based on demand-pull while the latter based on technology-push – can find a convergence when digital technologies are used to integrate the services with the factory in order to achieve the Industry 4.0 concept. By referring to and systematizing several cases from the literature, we showed that this level of integration between such two forms of business model innovation has the feature of providing value for both the external customer and the internal firm's processes (e.g. reducing time to market, production planning and control), while other types of digital services, which are the most commonly treated in the literature, largely focus only on the value creation for the customer. We argued that services can bring value to customers and, at the same time, they can become the channel of data and information gathering, aiming to foster a business feedback that enables internal improvements. As a result, we proposed a conceptual framework that divides Servitization in manual services, digital services and Industry 4.0 related services, which implies in different levels of complexity of the twofold BMI implementation. Notwithstanding its limitations, mostly referred to the conceptual nature of the contribution aiming at connecting a plethora of fragmented literature streams, categorizations and approaches, the study can be valuable for both theory and practice.

The main theoretical contribution of this study is that we take the original BMI perspective and direct the attention to an unexplored dimension of Servitization in the context of digitization, since we advance extant works by showing that introducing digital services can constitute a preliminary step to embark in a Digital Transformation journey of both the offering and the internal processes, thus enabling the Industry 4.0 concepts to deliver value for both company's sides – internal and external. The conceptual framework presented has some main contributions. Firstly, it sheds light on the potential combinations of service offerings and digital technologies and establishes which are the combinations that result in value for both customer and internal processes. In this sense, it offers scholars a theoretical understanding of which is, in fact, the real interface between Industry 4.0 and Servitization, as well as other possible classifications such as digital services and manual services. Following this, the framework provides a conceptual basis for advancing in this common field merging these two areas of research. Secondly, the proposed framework also shows the complexity – at a combined BMI-technological level – of implementing different configurations between Servitization and digital technologies. This may guide future discussion on what level of configuration should be appropriate for the specific situation of the companies when they face risks related to such business transformation.

Regarding the practical contribution, as a whole, the proposed conceptual framework can show strategic decision makers how to combine service offerings and digital technologies (levels of digitization); as a result, it may help managers to align their service offerings growth with decisions about the digitization of their business and the related transformation. Our framework shows a set of complexity levels for the joint implementation of digital levels and service levels in the product offering, and these levels can also guide managers in an evolutionary BMI process. However, this does not mean that managers should always aim to achieve the most complex level of Servitization (in terms of transformation complexity), since this may depend of the strategic options stemming from the company's business model. Product firms' strategists and managers can use this framework to rethink such aspects when directing their business model innovation endeavors in a growingly servitized and digitized environment.

Our study presents some limitations that open new avenues for future research. The first limitation is that our study is only theoretical, based on examples taken prior research. Although our effort of gathering and systematizing extant cases can be deemed valuable, further empirical research is still needed to validate the elements of our model as well as the propositions made. While qualitative case studies may be useful to provide more insights on the different elements proposed in this framework, quantitative survey studies could be useful to test, as hypotheses, the propositions that end our discussion, in order to validate and generalize them. A second limitation of this framework is that we did not consider the boundary conditions in which the framework can be suitable or not. In this regard, we have not considered human and economic factors that can affect the success for the implementation of these types of BMI or the influence of the digitization of different parts of the supply chain on the different configurations proposed (Ayala et al., 2017; Scuotto et al., 2017b, 2017c). Future studies can advance in this direction by analyzing the different types of configuration proposed in this framework in different industries and countries, in order to understand differences in emphasis given to the proposed configurations. Moreover, we did not include the industry life-cycle conditions. Recent studies have demonstrated that Servitization is influenced by the industry life-cycle (Cusumano et al., 2015), industry type and its environment (Visnjic et al., 2019). The relevance of each of the configurations proposed in our framework can be different depending on these variables. Hence, future studies can expand this understanding by including our framework in such a stream of research.

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