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Information technologies and product-service innovation: The moderating role of service R&D team structure

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Abstract

Drawing on the ambidexterity and organizational design theoretical lenses this article analyzes the interplay between R&D team structure, firm's Information Technology (IT) processes deployment and innovation outcomes. The evidence presented herein upholds the importance of IT and R&D team structure for strategic decisions and to better exploiting firm's innovation capabilities. Concretely, we argue that R&D team structure (centralized vs formalized vs autonomous) moderates the relationship between IT processes and innovation because it influences the way in which IT is utilized. Considering these facts, we focus on a specific type of innovation, *Product-Service Innovation* (PSI), largely underexplored despite being increasingly important in modern manufacturing companies. PSI differs from other technological innovations in that it involves continuous engagement with customers and logistics. Through estimation of a Multiple-Indicators Multiple-Causes (MIMIC) model with a unique sample of 352 Manufacturing Multinational Enterprises (MMNEs), we find that customer and logistics IT processes are positively linked to higher levels of PSI and that, as hypothesized, service R&D team structure moderates this relationship. In firms with autonomous R&D teams, customer-based IT processes lead to higher PSI levels, whereas in firms with formalized R&D teams, logistics-based IT processes is conducive to higher PSI levels. IT processes are not an input of PSI in centralized service R&D teams.

Keywords: Product-Service Innovation, IT Processes, R&D teams, Centralization, MIMIC.

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1. Introduction

The research on organizational ambidexterity has largely discussed that whilst exploration and exploitation are equally important in building firm's competitive advantage, the achievement of technological innovation is largely explained by the exploration of internal (R&D) and external knowledge (Danneels, 2002; Junni, Sarala, Taras, & Tarba, 2013; Stettner & Lavie, 2014). However, in an increasingly digitalized world, systems of reverse innovation are enhancing the relevance of exploitation in achieving innovation outcomes, such as in the case of service innovation in product firms, also described as *product-service innovation* (PSI) (Bustinza et al., 2018; Bustinza, Gomes, Vendrell-Herrero, & Baines, 2019a).

Contrary to the widely accepted conceptualization of product and process innovation in which R&D is the main input of innovation (Cooper & Kleinschmidt, 1986; Martinez-Ros, 2019), PSI follows a reverse innovation process, in which design precedes technological development (Jovanovic, Raja, Visnjic, & Wiengarten, 2019). This study's argumentative line proposes that service innovation exploitation requires the deployment of Information Technologies (IT) supporting management platforms, which, in turn, strengthen relationships with customers (Coreynen, Matthyssens, & Van Bockhaven, 2017) and optimize logistics activities (Rai, Pavlou, Im, & Du, 2012). By assessing the relationship between IT processes and PSI this research contributes to the IT literature as it responds to a number of calls for studies analysing how information technologies affect innovation outcomes (e.g., Majchrzak, Griffith, Reetz, & Alexy, 2018; Nambisan, Lyytinen, Majchrzak, & Song, 2017).

Organizational design literature has focused extensively on analysing how different governance structures lead to different forms of the organization of production (DeSantola & Gulati, 2017), yet it still misses the link to the organization of innovation (Helfat & Campo-Rembado, 2016). The present research argues that organizational design moderates the relationship between IT processes and PSI. More specifically, it focuses on a particular organizational design factor, the organization of R&D teams (Hoisl, Gruber, & Conti, 2017). R&D is a function traditionally developed at the organization's headquarters, or at least in the home market, but increasingly partly or fully offshored to other countries for various reasons, such as access to skills or cheaper labor (Steinberg, Procher, & Urbig, 2017). The organization of R&D team structures is increasingly important for firms operating in multiple (geographically dispersed) locations, as the coordination and development of new knowledge depends on team's incentives and capacity to take their own decisions (Ambos & Schlegelmilch, 2004). The strategic design (i.e. decision-making and incentives) of R&D teams therefore play a decisive role on businesses' innovative outcomes and it requires to be in alignment with the firm's objectives (McIver, Lengnick-Hall, Lengnick-Hall, & Ramachandran, 2013). As an instance, firms in the pharmaceutical sector, centralize part of their applied research (e.g. pharma labs testing new medical treatments), but concurrently, they also offer high levels of autonomy for R&D teams developing basic research on new treatments (Cardinal, 2001).

When R&D is offshored, management and knowledge transfer coordination costs are considerably higher (Ahammad, Tarba, Liu, & Glaister, 2016; Del Giudice & Maggioni, 2014). A central element in reducing these costs is determining whether innovation decisions are dictated at organizational level (Hage & Aiken, 1967; Miner, 2015). This study contributes to the organizational design literature by further understanding how R&D team structure is connected to IT infrastructure and innovation outcomes (Tilson, Lyytinen, & Sørensen, 2010; Yoo, Henfridsson, & Lyytinen, 2010). In doing so, we classify service R&D teams[1] in three categories depending on their decision-making capacity: (*i*) single centralized teams, (*ii*) multiple but formalized teams, and (*iii*) fully autonomous teams.

Another contribution is the focus on large Manufacturing Multinational Enterprises (MMNEs) rather than smaller companies. MMNEs are not only more inclined to integrate innovative business models into their portfolios (Vendrell-Herrero, Gomes, Bustinza, & Mellahi, 2018); they are also more likely to face the threats and benefits of having and coordinating multiple national and international R&D teams in the organization's structure (Mudambi, 2011). To this vein, a key strength of this study is the use of a representative sample of 352 MMNEs. This unique cross-sectional survey was conducted in collaboration with two industry partners and includes information on PSI level, acquisition of customer-based and logistics-based IT processes, and composition of the service team(s). By estimating a Multiple-Indicators Multiple-Causes (MIMIC) model through Generalized Structural Equation Modelling (GSEM)

[1] In this study, *service teams* develop the various tasks necessary to deliver a customized value-added service, including R&D, service design, and technology implementation and management. As in service innovation, the R&D function cannot be isolated, and its innovation activity must be seen more broadly. We use the expressions *R&D teams, service teams,* and *innovation teams* interchangeably.

and a number of stochastic analyses, this article obtains empirical results that shed light on existing debates regarding optimal paths to innovation and governance of R&D teams.

One initial result is that firms with multiple service teams (decentralized decision-making) obtain higher levels of PSI than firms with a single service team (centralized decision-making). This finding is important because it provides empirical validation for the idea that PSI in large organizations requires creation of a number of decentralized service teams (Baines et al., 2017; Turunen & Toivonen, 2011). Having identified the superiority of establishing multiple service teams, we analyze which IT processes are most appropriate for managing teams with autonomous or formalized decision-making. We find that firms with autonomous teams succeed in PSI by implementing customer-based IT processes, as they must reinforce the company's front-end operations. Firms with formalized decision-making, however, standardize service provision by reinforcing back-end operations—e.g., implement logistics IT processes—to enhance PSI.

The remainder of the paper is organized as follows. The following section presents the theoretical background of the study and develops testable hypotheses on the interconnections among PSI, IT processes, and service team composition. The third section describes the data and provides definitions and graphical description of the variables. We then present the results and conclude with discussion, limitations, and implications for future research.

2. Literature review and hypothesis development

2.1 Product-service innovation

Product-service innovation (PSI hereafter) is regarded as the capabilities provided by manufacturers in the form of customer-specific product-service "solutions" developed through close producer-customer relationships (Bustinza et al., 2019a). These solutions are fundamentally dependent upon two mutually reinforcing dimensions: product-service development, and customer engagement. The former encompasses a change in capabilities of the core offering (i.e., product) by offering timely value (i.e., critical performance information) throughout the different stages of the product lifecycle. The latter involves a process of continuous interaction and co-production of value propositions (i.e., reconfigurable joint developments) between producers and customers (Opazo-Basáez, Vendrell-Herrero, & Bustinza, 2019).

Therefore, overcoming the complexities underlying the development and implementation of PSI require companies to build a bi-dimensional approach relying on two essential factors. On the one side, it calls for a "*technological upgrading*" through the adoption of advanced technological capabilities that enable firms to effectively gather and integrate customer-specific requirements, uncover hidden consumers' patterns, and improve continuously (i.e., reconfigure) the solution (i.e., product-service offering) for meeting customers' needs in a constant manner (Parry, Bustinza, & Vendrell-Herrero, 2012). On the other side, it demands for an "*organizational change*" geared to enhance structural effectiveness and competitiveness (Oliva & Kallenberg, 2003). For this purpose, tight cross-functional and intra-organizational integration and coordination to avoid interdepartmental barriers and tensions is essential, to thus reap the benefits of technological capabilities comprised in product-service offerings (Brax & Visintin, 2017; Rabetino, Kohtamäki, & Gebauer, 2017). In the next sections, we discuss in turn the roles of technological upgrading – in the form of IT adoption – and organizational change – in the form of R&D team structure – in enhancing PSI.

2.2 Information technologies and product-service innovation

Research on knowledge-intensive organizations has largely identified the paradoxical need of developing exploration and exploitation capabilities within the organization (Junni et al., 2013). Firms that appropriately combine exploration and exploitation capabilities are usually described in the literature as ambidextrous organizations (Stettner & Lavie, 2014). The research on innovation has used this framework to develop a better understanding of the innovation dynamics of technological innovation (Danneels, 2002; Lafuente, Vaillant, & Leiva, 2018; Slater, Mohr, & Sengupta, 2014). However, there is a stream of thought that consider that these frameworks of innovation dynamics need to be revisited as digital technologies are changing paths to innovation as well as innovation outcomes (Majchrzak et al., 2018; Nambisan et al., 2017; Yoo et al., 2010). Empirical research has already detected that in some contexts there are reverse processes of innovation implying that traditional innovation inputs (i.e. R&D) are replaced by other activities within the organization (Bustinza, Vendrell-Herrero, & Gomes, 2019b; Jovanovic et al., 2019). In this section we analyze the specific role of IT processes as an input for PSI.

IT is a fundamental component supporting firms' overall business success (Yunis, Tarhini, & Kassar, 2018). Widely identified as an indispensable factor for speeding up innovation in manufacturing operations, IT has redefined the business landscape by capitalizing on the potential of IT processes to integrate, design, execute, and control operational processes (Soto-Acosta, Popa, & Palacios-Marqués, 2016). Such processes involve humans, organizations, applications, documents, and other sources of information for business purposes (Neubauer, 2009).

At present, IT processes are considered as a decisive factor in supporting organizations' core competences, as they remove internal communication barriers and expedite interconnectedness in business networks (Giannakis & Papadopoulos, 2016). Further, since IT processes are performed in an integrated (conjoined) variety of technologies—including database systems, internet, data analytics, and a wide range of software applications (Zhao, Fang, Huang, & Zhang, 2017)—they grant operations professionals the means to classify, index, search, and retrieve data in real time (Forslund, 2010). These technological features enable companies to record, process, and disseminate data accurately (Gupta & Misra, 2016). Organizations can thus use the data and the purposeful information derived from it for a variety of purposes, including enhanced management monitoring and control, more accurate and expedited decision-making, improvement of human resource performance, and better response to customers' demands in a timely manner (Coreynen et al., 2017).

The literature indicates that IT processes are an increasingly important component for innovation (Parida & Örtqvist, 2015). At intra-firm level, prior research emphasizes the relevance of IT processes in restructuring work practices, integrating routine tasks, and overcoming departmental boundaries to enhance information flows and knowledge sharing within organizations (Majchrzak & Malhotra, 2016). In this context, IT processes are responsible for expediting information and knowledge exchange from multiple functional groups and departments facilitating the company's innovation speed and quality (Wang & Wang, 2012), as well as its innovation flexibility (Liao & Barnes, 2015). At inter-firm level, IT processes are proven to improve information flows beyond firms' borders, gathering in-depth knowledge about customers, partners, and providers (Gressgård & Hansen, 2015). In this context, IT processes enable companies to enrich their knowledge base with purposive inflows and outflows of knowledge from employees, suppliers, customers, and partners to accelerate innovation and expand markets for external use of innovation (Arvanitis, Loukis, & Diamantopoulou, 2013). The literature shows that IT processes, whether internal or external, act as catalysts for the firm's innovation purposes, principally by expediting exchange of information and knowledge within the organization or across business networks (Parida & Örtqvist, 2015).

A growing body of quantitative research assesses the relationship between IT process and innovation, but most of these studies are limited to product and process innovation. In terms of products, recent articles show that IT processes exert a positive influence on product innovation by supporting supply chain collaboration (Liao & Barnes, 2015) and innovation orientation of the firm (Bouncken, Plüschke, Pesch, & Kraus, 2016), as well as facilitating new product configurations (Mazzola, Perrone, & Kamuriwo, 2015). As to processes, current literature suggests that IT processes influence process innovation by integrating organizational practices (Prajogo, 2016), facilitating intra- and inter-organizational openness (Trantopoulos, Von Krogh, Wallin, & Woerter, 2017), and enhancing business process management techniques (Diaz-Chao, Sainz-Gonzalez, & Torrent-Sellens, 2015).

Previous studies have examined the role of IT processes on PSI in a somewhat loosely manner, without indicating precisely what IT processes are required to be developed for the PSI distinctive orientation in which two interacting dimensions (products/services) play a determining role in the firm's innovation. Within product-service settings, innovation is co-produced through the interaction between suppliers and customers (Bigdeli, Bustinza, Vendrell-Herrero, & Baines, 2018). Hence, customers become operant resources in the co-creation of value, prompting firms to more innovation-based and difficult-to-imitate offerings (Benedettini, Neely, & Swink, 2015). As such, achieving PSI initiatives depends greatly on successful interaction between these actors, and how closely aligned to the customer the organization is in addressing customer needs (Parry et al., 2012).

To obtain greater customer closeness, however, it is crucial to redefine internal structures and processes (Opazo-Basaez et al., 2019), due primarily to the fact that PSI offerings rely on the intertwining of traditional manufacturing products and customer knowledge to achieve fluent PSI co-production and customer satisfaction (Hakanen, Helander, & Valkokari, 2017). To thrive in PSI, it is thus of utmost importance to ensure proper interaction between 'front-end' or customer-oriented operations and ‘back-end’ or logistics-oriented operations (Oliva, Gebauer, & Brann, 2012; Storbacka, 2011). Such interaction prevents misalignment within organizational structures and enables the firm to overcome internal cross-functionality problems when managing PSI initiatives (Coreynen et al., 2017; Oliva et al., 2012). We propose that IT processes, taken together, serve as a fundamental links that enable firms to aggregate real-time information from suppliers and customers in PSI developments (Opresnik & Taisch, 2015). These processes facilitate integration of customers in co-creation initiatives aimed at PSI offerings. IT processes also play a crucial role in coordinating information flows between organizational ‘front- and back-end’ operations (Raja, Chakkol, Johnson, & Beltagui, 2018), incorporating both customer-based and logistical operating perspectives in PSI execution.

Rather than focus on a particular IT technology or software platform, this study adopts the IT processes perspective (Tarhan, Turetken, & Reijers, 2016). This approach is not intended to override the firm’s existing IT infrastructure but to encapsulate business processes performed by many different types of software platforms and systems, regardless of its scope (e.g., Finance, Purchasing, Marketing, Human Resources, Production, among other business units), to focus on their effect on PSI. Thus, this argument suggests that IT processes in PSI endeavors function as a communication tie between suppliers and customers (Cenamor, Sjödin, & Parida, 2017), enabling tighter coordination between organizational structures within the company—that is, between front- and back-end operations (customer- and logistics-based IT processes, respectively) (Parida, Sjödin, Lenka, & Wincent, 2015). Since adopting IT processes depends heavily on the firm’s strategic orientation, the company must recognize—and later adopt—the IT processes it deems appropriate for its innovation strategy goal and to better connect the organizational front-end and back-end units (Jovanovic et al., 2019). Based on this reasoning, we argue that IT processes play the role of input into the innovation process of companies that pursue PSI as an outcome.

Customer-based (or front-end) IT processes refer to electronic business processes aimed at finding customer satisfaction and achieving better understanding of customers’ value-creating processes (Storbacka, 2011). Such processes enable organizations and customers to interact directly and share in-depth information in a timely, accurate, and effective manner (Coreynen et al., 2017). The information gathered can then be used proactively to communicate problems and respond better to specific customer contingencies that might emerge during PSI developments (Tao, Cheng, Zhang, & Nee, 2017). This research focuses on the role of (i) ‘Library incidents’, an IT process through which customers and suppliers can interact and keep track of their PSI activities. Library incidents act as a knowledge repository of searchable interactions, mishaps, and eventualities (experiential data) of ongoing and preceding PSI developments, which can be accessed and retrieved for use in composing future projects and/or for decision-making purposes (Nasr, Kilgour, & Noori, 2015); and (ii) ‘Diagnose software’, an IT process that focuses on identifying (diagnosing) consumer needs throughout the development of PSI initiatives. Using advanced technologies such as real-time diagnostic data, embedded systems, and automated algorithms, this IT process enables organizations to conduct real-time checkups, intelligently discover emergent customers’ needs, and respond to customer contingencies in a timely manner (Kwon, Lee, & Shin, 2014).

Logistics-based (or back-end) IT processes, on the other hand, focus on enhancing operational performance (Rai, Pavlou, Im, & Du, 2012). They facilitate reconfiguration of internal production and enable organizations to manage stock and inventory more efficiently (Payne & Frow, 2004). Supported by diverse digital technologies (Coreynen et al., 2017; Opazo-Basáez, Vendrell-Herrero, & Bustinza, 2018), they enable identification and virtualization of both intangible and tangible assets of a manufacturing enterprise (Opresnik & Taisch, 2015), increasing transparency for better-informed decision-making, such as the allocation of resources in PSI initiatives (Ness et al., 2015). The present analysis focuses principally on the following: (i) ‘Forward logistics’, an IT process oriented to predicting replacement of the customer’s components/parts/equipment over the course of a PSI project. Supported by interconnected technologies, such as cloud computing and big data analytics, this IT process provides organizations with a means of monitoring the health status of components and predicts (through predictive analytics) when and where an incident may occur (Wang, Gunasekaran, Ngai, & Papadopoulos, 2016). Companies can thus anticipate possible deficiencies and replace critical components before they fail, potentially achieving fault-free operations; (ii) ‘Reverse logistics’, an IT process oriented to responding to customers’ need for components/parts/equipment during development of a PSI initiative. Deployed in conjunction with supporting technologies such as RFID and sensors, this IT process enables organizations to track components up to delivery (Kong, Fang, Luo, & Huang, 2015), to improve synchronization and optimization of operations. Thereby, companies can cope with customers' abrupt or unexpected replacement needs more quickly, minimizing customer waiting times while assuring operations reliability.

Based on the foregoing, we argue that IT processes play a crucial role in coordinating information flows between organizational front- and back-end operations through the particular role of customer-based IT processes and logistics-based IT processes, respectively. These processes are thus decisive inputs, and not only technological enablers, for companies embarking on PSI initiatives. Based on this discussion, we posit the following set of hypotheses:

H1: Customer-based IT processes are positively related to PSI.

H1a: Library incidents IT process is positively related to PSI.

H1b: Diagnose software IT process is positively related to PSI.

H2: Logistics-based IT processes are positively related to PSI.

H2a: Forward logistics IT process is positively related to PSI.

H2b: Reverse logistics IT process is positively related to PSI.

2.3. Organizational design and the role of the service R&D team structure

Organizational design can be defined as a process of designing roles, rules, and relationships that govern any organizational activity (DeSantola & Gulati, 2017). Although organizational design structure is a critical contingency variable in developing innovation, research has neglected to address its effect more accurately (Helfat & Campo-Rembado, 2016). Moreover, there is a need of uncovering the elements surrounding specific organizational design for IT infrastructure (Tilson et al., 2010) and innovation (Vargas-Halabi, Mora-Esquivel, & Ortiz-Acuña, 2015; Yoo et al., 2010). The debate on the effect of organizational design on innovation is thus unresolved (Del Giudice, & Della Peruta, 2016) and may even increase if we consider PSI instead of other types of technological innovation.

From the perspective of organizational structure, some authors suggest that the organization of service and IT innovation in manufacturing is a "*make-buy-ally*" decision (Shook, Adams, Ketchen Jr., & Craighead, 2009). Hence, If the manufacturers prefer in-house service production (*make*) decisions, one alternative is to integrate some or all services into existing business functions (typically, advanced services are handled by a new business function) (Oliva et al., 2012; Turunen & Toivonen, 2011). Other alternatives are to externalize service production (*buy*) (Neely, 2008) or to contract a specialized firm (*ally*) to deliver services via partnership (Bustinza et al., 2019a). But organizational structure is not just a question of optimization of organizational service production. Service teams' decision-making configuration is also critical to developing innovation (Johnsson, 2017).

Service R&D teams develop innovation in manufacturing by placing great emphasis on managing the relationship with customers (Baines et al., 2017) and by bundling products and services (Gebauer, Paiola, & Edvardsson, 2012). Moreover, the goal of implementing service innovation in product firms is to achieve competitive advantage during the full product lifecycle by incorporating technology-enabled business models in the form of knowledge-based services (Bustinza, Vendrell-Herrero, & Baines, 2017). Technology and customer involvement thus play a critical role in developing PSI (Coreynen et al., 2017; Parry et al., 2012; Payne & Frow, 2004), as do other contextual variables such as size (Neely, 2008), internationalization (Vandermerwe & Rada, 1988), industrial sector (Visnjic & Van Looy, 2013), and organizational structure (Bustinza et al., 2019a).

From an organizational design perspective, we analyze two dimensions in the composition of service R&D teams. First, the breadth in service R&D teams within the organization. Some companies might have single service units whilst others might decide to create multiple teams to focus on different markets or clients. Second, we focus on the team participation in the firms' decision processes. To this end, there is an ongoing debate evaluating the role of centralization, decentralization and formalization of decision making in organizational behavior (Hage & Aiken, 1967; Miner, 2015), firm performance (Hall, 1977; Joseph, Klingebiel, & Wilson, 2016) and innovation (Lin, 2014). The empirical evidence is inconclusive. Whilst some authors consider formalization and centralization as detrimental to innovation (Cohn & Turyn, 1984; Yang, Zhou, & Zhang, 2015), others find centralization useful in developing innovation (Hurley & Hult, 1998). Building on the two dimensions we identify three main typologies of service team structure, presented in Figure 1. These team typologies depend largely on how the service business model is designed and implemented (Vendrell-Herrero et al., 2018).

--- Insert Figure 1 about here ---

Some organizations have a hierarchical structure in which the service development department supports the firm's views and strategies (Ferner et al., 2004; Mack & Szulanski, 2017) by developing services that support and enhance product capabilities. Product firms with Single Team (ST) structures tend to develop standardized services for a large number of clients. *IBM's* research group is a good example of a single service team successfully developing and selling standardized IT and cloud solutions worldwide (Eggers, 2016; Spohrer, 2017). Other firms have a flatter organizational structures and decentralized service teams with the capacity to take their own decisions (Miner, 2015). The latter seems to be linked to higher levels of product innovation (Anzola-Román, Bayona-Sáez, & García-Marco, 2018). In PSI, decentralized organizations are common in contexts with a number of strategic corporate clients with specific service needs, which make deployment of multiple service teams optimal. We define two types of decentralized organizational structures. The first, referred to in this study as Multiple Teams with Autonomous decision-making (MTA), aims for more customer engagement and rapid adaptation to customer needs, granting service teams autonomous decision-making. One example of this category is the multi-product Japanese firm *Hitachi*. *Hitachi* established a British subsidiary that provides train solutions to UK rail operators. Based on its capacity to make its own decisions, the British subsidiary was one of the first service teams in the sector to provide long-term outcome-based contracts successfully (Visnjic, Turunen, & Neely, 2013). The second group, referred to as Multiple Teams with Formalized decision-making (MTF), work as independent entities but must follow rigid rules and specifications in decision-making. Rules can be formulated, as service provision is more dependent on management of logistics than on customer engagement. A good example of MTF is the provision of logistical services in the industrial equipment company *Caterpillar*. At this company, a number of service teams deliver warehousing and modular suites of interconnected supply-chain services to a worldwide customer base of over fifty companies (Visnjic et al., 2013).

Firms implement PSI strategies by selecting the service team structure that best creates synergies with their IT processes (Johnsson, 2017). Considering that R&D organizations differ in degree of centralization/decentralization and level of formalization (Joseph et al., 2016), and that the decision-making structure chosen by manufacturing firms may strengthen or weaken the technological requirements and innovation goal pursued (Von Zedtwitz, Gassmann, & Boutellier, 2004), we argue that service R&D team structure moderates the relationship between IT processes and PSI in the following way: (*i*) customer-based IT processes have a more conspicuous effect on developing PSI in MTA firms, as these companies' business models require articulating a technological link with their customer base, (*ii*) logistics-based IT processes are key enablers of PSI in MTF firms, whose business model is grounded in efficient use of logistics; and (*iii*) customer- and logistics-based IT processes have a limited effect on how ST firms develop PSI, as their extreme underlying level of service standardization intensifies the importance of both customer engagement and logistical efficiency. Based on these arguments, we propose the following hypotheses:

H3: Service teams' autonomous decision-making (MTA) positively moderates the relationship between customer-based IT processes and PSI.

H4: Service teams' formalized decision-making (MTF) positively moderates the relationship between logistics-based IT processes and PSI.

3. Method

3.1. Sample and data collection

This study is based on an extensive survey of technological practices in manufacturing enterprises that have implemented service business models. The survey characterizes various forms of IT deployment and R&D team composition, while including specific items to compute PSI. The survey was part of a large collaborative project involving an academic institution and two industry partners, a service management solutions company (Partner A), and a global advisory firm (Partner B). Based on its extensive industrial experience, Partner A possesses a business catalogue composed of 7,000 MMNEs, all of which had annual revenues of over $1 billion. Before survey administration, the target sample was assessed by a panel of industry experts, who agreed that this set of firms could be seen as the global population of MMNEs seeking to undertake PSI. Once the population was determined, a stratified (by industry) random sample was created. The determination of the target sample was determined using a Gaussian distribution with a confidence level of 95% and a margin error of 5%. By using these standard parameters (Gregoire & Affleck, 2018), the target sample size is of 365 firms.[2]

Partner B was responsible for questionnaire implementation. Companies were contacted by email and by phone weekly. Implementation of the questionnaire took 6 weeks in 2013 (November 8 - December 19, 2013). Data were obtained using a recruited sample (Van Selm & Jankowski, 2006), meaning that respondents were given a username and password. This method assured that the same firm could not enter two responses in the online survey. In line with previous studies conducted in various countries, the survey was translated and back translated whenever required by respondents (Chidlow, Plakoyiannaki, & Welch, 2014). The online survey was closed when 370 answers were obtained, five more than the minimum required to reach the representative sample.[3] Since 18 surveys were incomplete, the sample used in the present study is composed of 352 MMNE. Variables of interest are presented in the next section; Table 1 shows descriptive statistics and correlation matrix for those variables.

--- Insert Table 1 about here ---

3.2. Variables

Dependent variable: Our dependent variable is a multi-item construct measure of Product-Service Innovation (PSI). The scale to measure the variable PSI has been validated by previous research (Bustinza et al., 2019a; Vendrell-Herrero et al., 2018). The construct is based on four items (see Table A1 in the appendix for further description) following a 5-point Likert scale (1=completely disagree, 5=completely agree) that compose two second-order dimensions: a) a product-service development dimension with two items, product innovation and updated product lifecycle; and b) a customer engagement dimension, with two items, product-service alignment, and service feedback & analytics. The statistical program chosen for analyzing the data was

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[2] $n = \frac{N*Z^2*p*(1-p)}{(N-1)*e^2+Z^2*p*(1-p)}$, where n is the target sample size, N is the population (N=7000), Z=+/-1.96 (confidence level of 95%), e is the margin of error (e=5%), and p is a realistic estimate of the desired probability (p=0.50).

[3] Although the answer rate (370/7000 = 5.3%) is relatively low compared to other studies (Chidlow, Ghauri, Yeniyurt, & Cavusgil, 2015), this rate is irrelevant in evaluating this study, since the sample finally obtained is representative of the full population. Other business studies rarely identify the full firm population before sending out the questionnaire, as it has been certainly done in this study.

Stata 15.1, which enables us to test Generalized Structural Equation Model (GSEM) estimations through generalized linear response functions (Stata, 2017).

Principal component analysis (PCA) with Varimax rotation—Kaiser-Meyer-Olkin test, 0.854 (>0.8); Bartlett's test of sphericity $\chi2$=87.192 (p=0.000); Total Variance Extracted 66.059%—validated the second-order dimensions (Hair, Anderson, Tatham, & Black, 2001). A subset of criterion-referenced tests enabled analysis of the scale's internal consistency, showing a Cronbach's alpha value of α=0.889 (Cronbach, 1951). Scale reliability measures were 0.881 for Composite Reliability and 0.564 for Average Variance Extracted. These values were consistent with previous research in validating the scale's consistency and reliability. For the Confirmatory Factor Analysis, factor loadings were statistically significant with R^2>0.5, while the Goodness-of-fit indicators such as Chi-square likelihood showed good fit: $\chi^2(2) = 28.555\ (p = 0.000)$; $TLI = 0.983$; $CFI = 0.987$; and $RMSEA = 0.045$. We used the linear prediction of the PCA to operationalize the value of PSI. The resulting continuous variables created can be interpreted as an index that describes the service continuum. The minimum, maximum, mean, median, and standard deviations of this variable were -3.75, 3.32, 0, 0.073, and 1.24, respectively. It follows that a firm achieves an above-average level of PSI when the PSI value imputed to it is positive.

Independent variables: The independent variables are a set of single-item indicators that measure the introduction of customer-based (library and diagnose) and logistics-based (forward and reverse) IT processes in the firm (see Table A2 in the appendix for further description). Following the proposal of Heiberberg and Robbins (2014) on how to display Likert scale items graphically, we construct bar charts for the items used (see Figure 2). The bar charts compare the answers given by team type and provide information on how the underlying question in the survey was formulated. According to Figure 2, MTF firms seem to have more IT processes in place, and this is true for each of the IT processes analyzed. One numerical way of visualizing this result is to compute the average of each IT process by team type. Considering the IT processes as *Library*, *Diagnose*, *Forward,* and *Reverse*, in this particular order, the average vectors for firms with ST, MTA, and MTF are *(2.97, 3.05*, 3.01, 2.84), (3.04, 3.17, 3.19, 3.11), and (3.29, 3.39, 3.48, 3.41), respectively. While the differences between ST and MTA are not statistically significant, the differences between MTF and the other two groups are mostly significant at 5%.

--- Insert Figure 2 about here ---

Figure 3 descriptively displays how each IT process analyzed is linked to PSI through box plots, a standard approach to presenting the distribution of a continuous variable, in our case PSI. This approach enables comparison of PSI distributions depending on the intensity of the IT process considered. The box plot provides five key indicators: minimum, first quartile, median, third quartile, and maximum. The central rectangle spans the first to the third quartile. The line inside the rectangle indicates the median, and the lines above and below the rectangle specify the minimum and maximum excluding outliers (4 standard deviations above the third quartile or 4 standard deviations below the first quartile). The descriptive analysis suggests: (i) a certain degree of variation in the sample indicating the existence of top innovation performers when IT processes are low, and low innovation performers when IT processes are high; and (ii) a positive correlation between IT processes and PSI, that is, the minimum, maximum, and median increase with the intensity of the IT processes.

--- Insert Figure 3 about here ---

<u>Moderating variable</u>: The formation of service development teams in the sample is geographically dispersed, with more than two thirds of firms having the service development unit in a different country than the firms' headquarters. To this extent, the firms were asked about the composition of their service development teams (see Table A3 in the appendix for further description). As depicted in our framework (Figure 1), they were given three options: (1) single team (ST), (2) multiple teams with autonomous decision-making (MTA), and (3) multiple teams with formalized decision-making (MTF). Slightly more than two thirds of the firms' sampled (241 companies) claimed that they had multiple teams. This is an expected result, since MMNEs sell their products to a number of clients with heterogeneous needs who require considerable attention. A majority of these firms (197, or 56% of the sample) let the teams take their own decisions (autonomous), whereas 44 firms (12.5% of the sample) had formalized rules for making final decisions on how innovation was to be developed and implemented. The remaining set of firms (111, or 31.5% of the sample) had a single service department. In Figure 4, we plot Kernel density distributions, comparing the distributions of PSI based on team type. The graphing exercise shows that firms with multiple teams stochastically dominate ST firms (Kernel distributions of multiple teams are located to the right of the ST distribution), implying that firms with multiple teams

achieve higher levels of PSI than ST firms do. According to the Kolmogorov-Smirnov test, this result is statistically significant at 5%.

--- Insert Figure 4 about here ---

It is important to depict how these team types differ in characteristics of industry, region, and size. We consider four size categories depending on the firm's annual revenues: $1-$4.9 billion, $5-$9.9 billion, $10-19.9 billion, and more than $20 billion. The first three groups had similar representation in the sample (roughly 30% each), whereas the fourth (the group with the largest firms) comprised 10% of the firms. The firms' headquarters were located in four different world regions[4]: Europe, North America, Asia, and Oceania. Almost half of the firms were European (47.4%), followed by Asian (28.1%), and American (23%) firms. Only a handful of firms represented Oceania (1.5%). Figure 5 compares the region and size distributions by team type. As expected, firms with STs are smaller than firms with multiple teams. This difference is especially notable when comparing MTF firms. While 66% of the MTF firms had annual revenues above $10 billion, the percentage was lower for MTA firms (45.7%) and even lower for ST firms (32.4%). As to geographical distribution, there is little difference between team types. Perhaps the only remarkable issue is that ST firms are more prevalent in Asia (35.1% vs. 28.1% of the full sample) and less prevalent in North America (18.9% vs. 23% of the full sample).

--- Insert Figure 5 about here ---

The sample has even distribution across the seven manufacturing industries considered in this study. All of the industries have 48-52 observations and are represented in the sample as follows: Aerospace and Defense (13.6%), Automotive and Transportation (13.6%), Commercial or Cargo Airlines (14.5%), Electronics and High Tech Equipment (14.5%), Heavy and Industrial Equipment (14.8%), Medical Devices and Equipment (14.2%) and White Goods Manufacturing (14.8%). We find no significant sectoral differences between team types.

3.3. Tests for non-response and common method bias

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[4] The European countries are Belgium, France, Germany, The Netherlands, Denmark, Finland, Italy, Norway, Sweden, and Russia. The countries in North America are Canada and US. The Asian countries are China, Japan, Singapore, and Hong-Kong. Finally, Australia represents Oceania.

To assess non-response bias (NRB), we compared early and late respondents (first and last decile) for the dependent, independent, and moderating variables (Armstrong & Overton, 1977). The t-test demonstrates that there are no statistically significant differences between early and late respondents, even at 10% (p-value> 0.1). In addition, Partner A compared the number of employees of responding and non-responding firms. The differences between the two groups were not statistically significant at the usual levels (p-value >0.1).

Common Method Bias (CMB) can arise when the same method/respondent is used to measure multiple constructs, a possible outcome of the generation of spurious correlations. We took two ex-ante precautions against CMB. First, due to their underlying complexity, moderating effects go beyond a respondent's cognitive map and reduce CMB (Chang, Van Witteloostuijn, & Eden, 2010). Therefore, including team type as a moderating variable in our model can reduce CMB. Second, an effort was made to ensure that respondents were familiar with topic of study (MacKenzie & Podsakoff, 2012), in this case, service business models. We sought evidence that respondents were responsible for one or more cost or profit centers within their company's service business. Of the total, 45.9% of respondents were directors, 43.2% held a corporate-level position, and 11.9% were executive vice-presidents. Continuing with the approaches for assessing CMB, we also conducted standard validity assessment through the Unmeasured Latent Method Factor (ULMF) procedure. ULMF is an ex-post CMB test consisting on a confirmatory factor analysis (CFA) in which all variables of interest in the study (dependent, independent, and moderating variables) were loaded onto a common method factor (Min, Park, & Kim, 2016). The fit of the resulting model was poor (TLI = 0.624 and CFI = 0.775, acceptance range >0.900; RMSEA = 0.097, acceptance range 0.050-0.080). Additionally, to completely rule out the existence of CMB in our data a more sophisticated post-hoc procedure is undertaken, the CFA marker technique. This technique is considered one of the most accurate techniques for detecting CMB (Richardson, Simmering, & Sturman, 2009). CFA marker technique estimates CMB as a function of a considered *marker* –in our case and following Bagozzi (2011) recommendations, the second smallest positive correlation among the manifest variables – and the substantive model. This procedure remove shared variance and permits comparing the path-analysis parameters of our model with and without the correction for the marker. Following Simmering et al. (2015), we calculate 95%

confidence intervals around each uncorrected model relationship. As including a CFA marker yields corrected estimates that are inside of the confidence intervals of the original estimates, there are no meaningful differences to presume CMB. In light of this evidence, we can determine with confidence that NRB and CMB affect neither the data nor the results.

4. Results

4.1. Main specification: Multiple-Indicators Multiple-Causes modelling

The theoretical predictions in this study follow a Multiple-Indicators Multiple-Causes (MIMIC) structure, in which a set of ordered categorical variables (IT processes) influence a latent construct (PSI). This type of model is widely employed in management literature and has been used to test the effect of a set of ordinal factors in determining latent constructs, such as entrepreneurial orientation (Anderson et al., 2015), dynamic capabilities (Barrales-Molina, Bustinza, & Gutiérrez-Gutiérrez, 2013), and strategy execution (De Oliveira, Carneiro, & Esteves, 2018).

We estimated the MIMIC model using Stata's Generalized Structural Equation Modelling package. The MIMIC model estimates the relationship predicted between IT processes and PSI, that is, the likelihood that an IT process (*Library*, *Diagnose*, *Forward* and *Reverse*) will cause PSI (coefficients to test hypotheses H1a, H1b, H2a, and H2b, structural model) or be related to the specific items that estimate a PSI measurement model (*product innovation*, *updated product lifecycle*, *product-service alignment*, *service feedback & analytics*). To assess the moderating role of team composition, we ran the model for the ST, MTA, and MTF subsamples. Figure 6 represents the model graphically and reports the significant parameters. Discussion of the results starts with the structural model (Hypotheses H1 and H2), continues with the measurement model, and concludes with the moderating effects (H3 and H4).

--- Insert Figure 6 about here ---

In the structural models, all estimated coefficients are positive and statistically significant. All IT processes for the full sample were thus inputs/generators of PSI, supporting H1a, H1b, H2a, and H2b. Examining these results in more detail, we observe some heterogeneity in the strength of the IT processes-PSI relationship. The coefficients of the customer-based IT processes (β_{1a} and β_{1b}) were larger and more significant than those of the logistics-based IT processes (β_{2a} and β_{2b}). The largest coefficient was

$\beta_{1b} = 0.234$ ($t = 3.62$; $p < 0.01$), the coefficient that measures the relationship between *Diagnose software IT process* and PSI. This next-largest coefficient measures relationship between *Library Incidents IT process* and PSI, $\beta_{1a} = 0.157$ ($t = 2.64$; $p < 0.01$). The coefficients of *Forward logistics IT Process* (β_{2a}) and *Reverse logistics IT Process* (β_{2b}) were fairly similar (0.099 and 0.097, respectively) and statistically significant at 5%.

We analyzed the measurement model by interpreting the PSI item loadings (λ_i) as the average difference in the probit index when analyzing the direct effect on a PSI item. By construction, the first item loading (product innovation) was constrained to 1, and the other item loadings measured in relation to it. Item loadings weighted the effects of IT processes for each individual PSI item (product innovation, updated product lifecycle, product-service alignment, and service feedback & analytics). The weighted effect of each IT process on the PSI items was obtained by multiplying coefficients estimated in the structural model with item loadings obtained in the measurement model (β*λ). Following this procedure, *Library Incidents IT process*, for example, has a larger effect on updated product lifecycle ($\beta_{1a}*\lambda_2 = 1.497*0.157 = 0.235$) than on product innovation ($\beta_{1a}*\lambda_1 = 1*0.157 = 0.157$). As expected, the largest item loadings were on updated product lifecycle and service feedback & analytics, (simply) implying that these items are more IT-driven than the other PSI components (product-service alignment and product innovation).

We now analyze the moderating role of service teams' decision-making configuration (ST, MTA, MTF) in the relationship of customer-based IT processes (H3) and logistics-based IT processes (H4) to developing PSI. The results of the MIMIC models for each subsample show clear patterns indicating that the effect of customer-based IT processes on PSI is positive and significant for MTA ($\beta_{3a} = 0.240$ ($t = 1.99$; $p < 0.05$); $\beta_{3b} = 0.228$ ($t = 2.46$; $p < 0.05$)), but not statistically significant for the other team configurations (ST and MTF). This result supports H3. The results also indicate that the effect of logistics-based IT processes on PSI is positive and significant for MTF($\beta_{4a} = 0.612$ ($t = 1.98$; $p < 0.05$); $\beta_{4b} = 0.409$ ($t = 2.01$; $p < 0.05$) but loses significance for the other subsamples (ST and MTA). This result supports H4. In sum, these results imply, as predicted, that MTA firms enhance their PSI by acquiring customer-based IT processes, MTF firms must enable logistics-based

IT processes to boost PSI, and that IT processes do not affect ST firms’ capacity for developing PSI.

4.2. Additional specification: Stochastic analysis

The results presented so far are a variation of the regression analysis. Although MIMIC is appropriate for analyzing the relationship between categorical and latent variables, it does not control for underlying uncertainties. This result can be better assessed through stochastic analysis (Cassiman, Golovko, & Martinez-Ros, 2010), an approach that controls for the stochastic nature of the outcome (e.g., innovation) rather than analyzing what happens to the average firm in a sample (as in regression analysis or, in our case, Generalized Structural Equation Modelling). One advantage of stochastic analysis is that it does not require making assumptions about the form of interdependence between IT processes and PSI.

This methodology can be implemented graphically through cumulative distributions and their underlying Kolmogorov-Smirnov equality of distributions test. As this test requires binary categorization, we transformed the IT processes into dummy variables. To simplify, we added the components of customer-based (Library + Diagnose) and logistics-based (Forward + Reverse) IT processes. For each of these categories, we took values below and above the mean, considering firms with values above (below) the mean as having high (low) endowment of the specific IT processes.

The results of the stochastic analysis are reported graphically in Figures 7 and 8. These results are very similar to those obtained using MIMIC and thus also support H3 and H4. Both categories of IT processes (customer-based and logistics-based) are positively linked to PSI (full sample), and team type plays an important moderating role in this relationship. As to customer-based IT processes (Figure 7), the difference in PSI distributions is larger in the MTA subsample; PSI differences between high and low customer-based IT processes are statistically significant at 1% for the MTA subsample; and significant at 5% and 10%, respectively, for the other subsamples, ST and MTF. Analysis of logistics-based IT processes (Figure 8), in contrast, shows the difference in PSI distributions to be larger for the MTF subsample; PSI differences between high and low logistics-based IT processes are statistically significant at 1% for the MTF sample, significant at 10% for MTA, and non-significant for ST.

--- Insert Figures 7 and 8 about here ---

5. Discussion of the results

This study investigates the interconnectedness between IT infrastructure and innovation. This is an important research objective as digitalization of the economy is reshaping the innovation landscape (Majchrzak et al., 2018; Nambisan et al., 2017; Ness et al., 2015) as well as boosting the importance of exploitation capabilities (Bustinza et al., 2019b; Jovanovic et al., 2019). More specifically, we analyse how two types of IT processes, customer-based (H1) and logistic-based (H2), are related to PSI. The results confirm both hypothesis using GSEM and stochastic analysis. Whilst the results go in line with previous empirical research showing that IT is an increasingly important component for innovation (Majchrzak & Malhotra, 2016; Parida & Örtqvist, 2015; Trantopoulos et al., 2017), it extends current knowledge in two different ways. First, it uncovers new paths for PSI generation based on exploiting firm's technological resources (Cenamor et al., 2017; Tarhan et al., 2016). Second, and more importantly, it distinguishes between two types of IT processes that bridge firm's front-end and back-end operations and have important implications for innovation (Oliva et al., 2012; Storbacka, 2011). It is important to emphasize that supporting these hypotheses have substantial implications for the development of reverse innovation frameworks, that in turn influence the paradoxical embeddedness of exploration (e.g. R&D) and exploitation (e.g. IT) capabilities (Jovanovic et al., 2019) within the organization. In traditional product innovation, IT processes are technological enablers, not innovation inputs (Opresnik & Taisch, 2015). However, consistent with the results herein presented, IT processes are important inputs for innovation outcomes in PSI.

The present work also examines the moderating role of R&D teams, an important organizational design factor (DeSantola & Gulati, 2017; Mudambi, 2011) that connects technological infrastructure and innovation (Tilson et al., 2010; Yoo et al., 2010). Based on previous research (Hage & Aiken, 1967; Joseph et al., 2016; Miner, 2015), the framework for R&D team structure (Figure 1) proposes three categories of service teams based on the level of centralization and autonomy of decision-making (ST, MTF, and MTA). We propose that the optimal input (IT)-output (PSI) route to innovation is a function of the type of organizational structure (service R&D team). More specifically we hypothesize that customer-oriented IT processes will be more valuable for autonomous R&D teams (H3), whilst logistics-oriented IT processes will be more valuable for formalized R&D teams (H4). The evidence supports both hypothesis. A direct implication of the results is that centralization of decision-making is independent of technological infrastructure, enriching existing debates on the role of decision-making structure in innovation (Cohn & Turyn, 1984; Hurley & Hult, 1998; Yang et al., 2015). Hence, the observed heterogeneity in the design of service R&D teams suggests that organizations adopt different structures to cater to the tastes of two types of stakeholders: shareholders and corporate customers, being operational efficiency and consumer satisfaction the respective desired goals. To this vein, the study contributes to unveil how internal structures is conducive to organizational change, and open the debate on the value of both strategic fit (R&D team structure) and innovations driven by the adoption of PSI as decisive elements of organizational renewal (Brax & Visintin, 2017; Oliva & Kallenberg, 2003).

6. Conclusions

6.1. Theoretical implications

The literature on innovation has traditionally divided technological from non-technological innovations (Azar & Ciabuschi, 2017), but this distinction is increasingly blurred with the disruption of service business models in product firms, since technological innovation is concomitant with the organizational innovation in PSI (Baines et al., 2017). The conventional linear models of product innovation in manufacturing firms (Basic R&D → Applied R&D → Patenting → Market Testing and Product Design → Production Scaling → Sales) are thus not applicable in PSI (Bustinza et al., 2019b). This change in innovation dynamics is transforming existing theoretical frameworks that explain causes of innovation, as for example ambidexterity (Danneels, 2002; Junni et al., 2013; Stettner & Lavie, 2013). The present study contributes to this research stream by considering IT processes an innovation input that underlies firm's exploitation capabilities. Although previous literature highlights primarily the technological capabilities associated with adoption of IT processes (Giannakis & Papadopoulos, 2016; Parida & Örtqvist, 2015; Zhao et al., 2017), IT has been largely considered as a secondary input in technological innovation, with basic and applied R&D being viewed as primary (Anzola-Román et al., 2018; Majchrzak & Malhotra, 2016; Wang & Wang, 2012). It is argued and empirically demonstrated, however, that both customer and logistics IT processes are fundamental to service innovation in product firms.

Additionally, the study contributes to the organizational design literature (DeSantola & Gulati, 2017; Tilson et al., 2010; Yoo et al., 2010) by proposing a framework for understanding service R&D team structure and assessing it in terms of innovation outcomes. The evidence suggests that optimal organizational design is contingent to the type of IT processes possessed by the firm. The present work also shows that optimal organization of service R&D teams somewhat resembles the widely-accepted organization of technological innovation (Danneels, 2002; Lafuente et al., 2018; Slater et al., 2014; Von Zedtwitz et al., 2004). For instance, in PSI, as in technological innovation, large corporations empower teams' autonomy; in the sample, seven out of ten firms have decentralized service teams. This R&D team structure is particularly important in the PSI context as it is conducive to higher innovation standards.

6.2. Managerial implications

The management of R&D is becoming increasingly complex as more workers are involved in this function. As an illustration, according to OECD (2019) in the European Union the number of researchers has increased from two to three million in the last fifteen years. Additionally, as part of the Industry 4.0 movement, industrial manufacturing firms are increasingly broadening their product-oriented business models to enhance consumer satisfaction by adding services to their portfolio. Services offered are not homogeneous, and the main underlying trade-offs are between achieving more competitive advantage and locking in customers by increasing the level of the firm's exposure to risk. In this fast-changing and complex scenario, the findings presented in this work are certainly valuable for practitioners. The following points summarize managerial implications.

- Interconnectedness and engagement with customers is much more efficient when the organization possesses IT processes in place that enables it to search for incidents and other experiential data of ongoing and preceding innovation developments, as well as quickly to diagnose the nature of customer needs and their underlying solutions.

- Back-end operations are more efficient and deploys higher innovation outcomes when tracking (e.g., sensors) and predictive (e.g., big data) IT processes are in place.
- When designing the service team structure, managers must be aware that establishing formal rules and monitoring mechanisms do not necessarily inhibit high-innovation standards.
- Organizational design must be aligned with the business model deployed. Customer-based (front-end) IT processes are more valuable in firms undertaking consumer-centered business models (MTA), whereas Logistics-based (back-end) IT processes are more desirable in firms undertaking a formalized and efficiency-based business model (MTF).

6.3. Limitations and further research avenues

The analysis undertaken stresses an important discrepancy. While many studies argue that imposing formalized rules and processes in decision-making generates rigidities to the detriment of innovation (Cohn & Turyn, 1984; Yang et al., 2015), the results obtained in this study show that formalized and autonomous teams are indistinguishable in terms of PSI outcomes. As the complexity of intra- and inter-firm systems of innovation increases, the formalization vs. autonomy duality becomes more important (Joseph et al., 2016; Lin, 2014; Miner, 2015). Scholars must revisit this duality in multiple contexts, including different sectors, type of innovations, and/or cross-border operations and production specificities.

Another important factor of this research is the classification of IT processes related to front-end and back-end links; customer-based and logistics-based respectively. Despite these IT processes cover a wide business spectrum, there might be other IT processes, overlooked or omitted in this study, that go beyond this classification. This is a matter of future inquiry. Similarly, in the present research, the degree of service innovation in product firms has been analyzed in isolation and no other (manufacturing-based) innovation outcomes have been introduced. Future research might introduce a more holistic view of innovation introducing synchronous innovation outcomes in an integrated model (Damanpour, 2014).

Additionally, it is acknowledged that the current study has a number of limitations. Firstly, the cross-sectional nature of the data does not permit controlling for the dynamic nature of innovation. Further, accessing longitudinal data on firms developing

PSI strategies is crucial to determining optimal innovation pathways. Secondly, the data utilized in this study does not contain information on R&D investment nor firm productivity. Although these elements are clear determinants of innovation in SMEs, they are less important for large multi-product multinationals that have already succeeded in developing products. Since all firms in the sample are of this type, we believe that not controlling for these variables do not affect the results obtained. Future research with datasets including MNEs and SMEs might be able to clarify whether this is the case.

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List of Tables

Table 1. Descriptive statistics and correlation matrix for the variables of interest

		Mean	St. Dev.	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1)	**Product-Service Innovation (PSI)**	0.00	1.24	-3.75	3.32	1.00						
(2)	**Library**	3.05	0.71	1.00	5.00	0.34*	1.00					
(3)	**Diagnose**	3.16	0.67	1.00	5.00	0.26*	0.21*	1.00				
(4)	**Forward logistics**	3.17	0.70	1.00	5.00	0.23*	0.22*	0.19*	1.00			
(5)	**Reverse logistics**	3.06	0.81	1.00	5.00	0.23*	0.16*	0.22*	0.25*	1.00		
(6)	**Single team**	0.32	0.47	0.00	1.00	-0.17*	-0.07	-0.11*	-0.16*	-0.19*	1.00	
(7)	**Multiple Teams Autonomous (MTA)**	0.56	0.50	0.00	1.00	0.07	-0.02	0.01	0.04	0.07	-0.76*	1.00
(8)	**Multiple Teams Formalized (MTF)**	0.12	0.33	0.00	1.00	0.13*	0.13*	0.13*	0.16*	0.16*	-0.25*	-0.43*

Total number of valid observations for all variables is 352. (*) denotes statistical significance at 5% (p-value<0.05).

List of Figures

Figure 1. Service R&D team structure framework

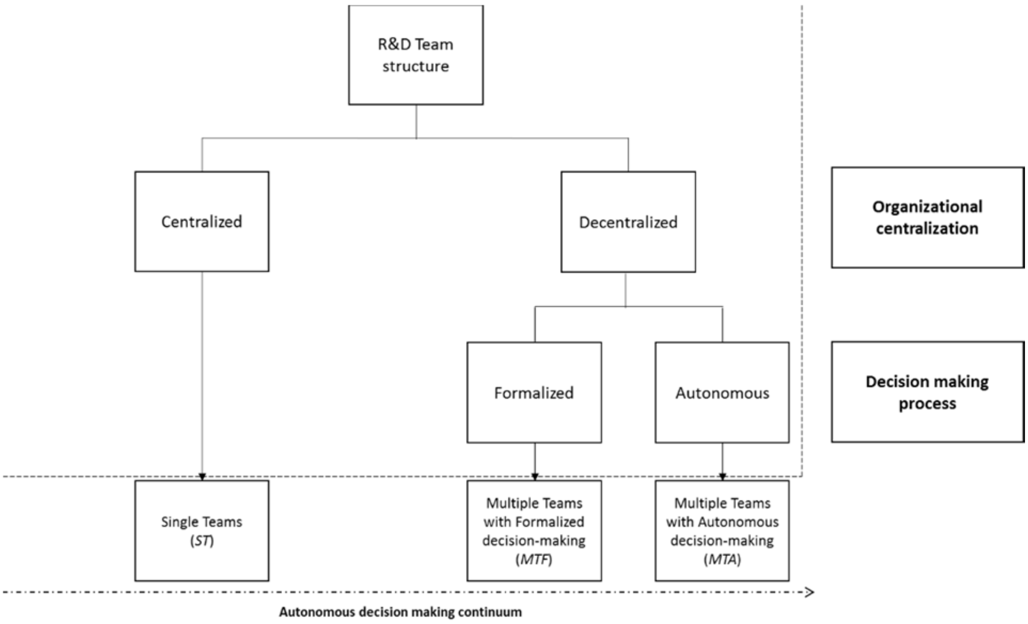


Figure 2. IT processes items by team type

Figure 3. Box plot: IT processes and PSI

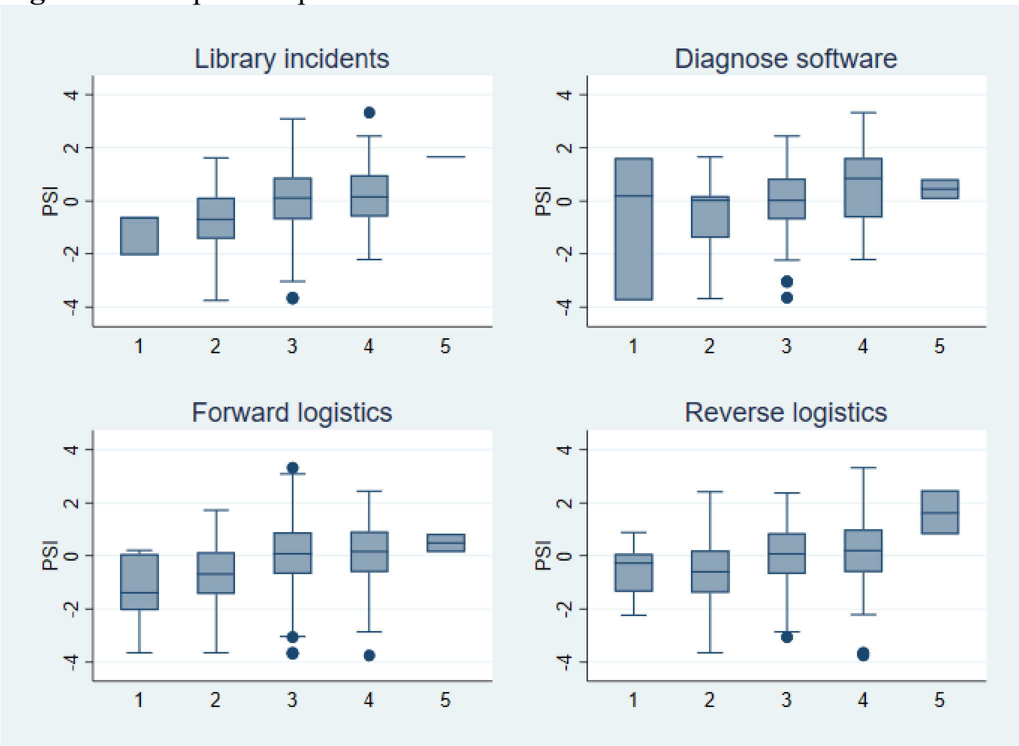
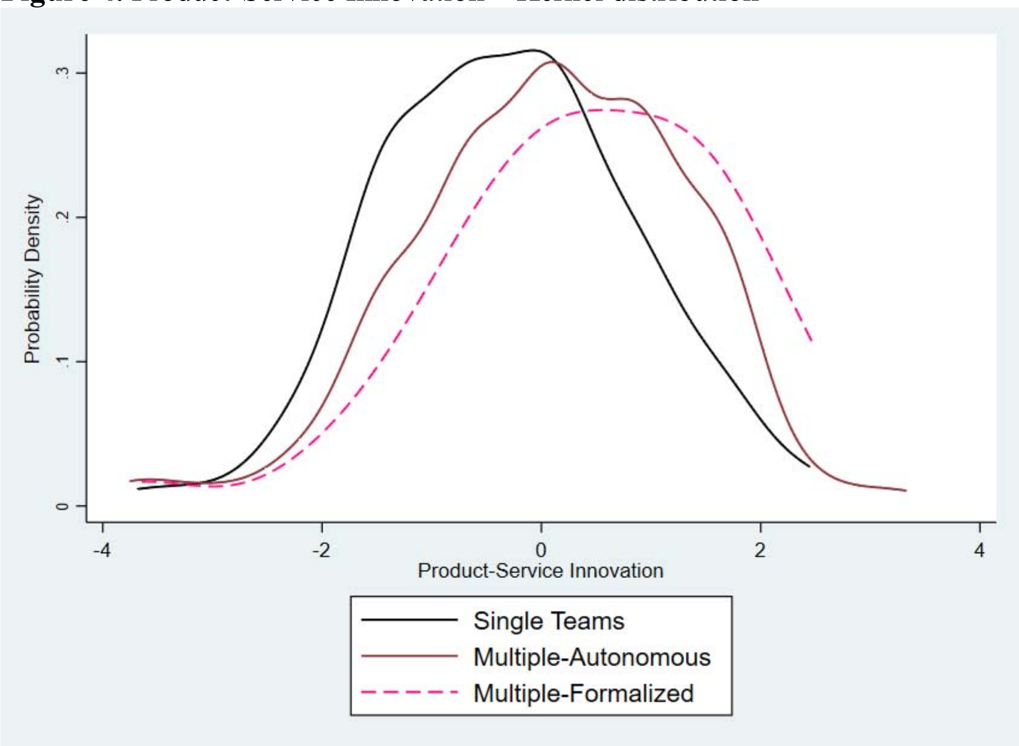


Figure 4. Product-Service Innovation – Kernel distribution



Note: According to Kolmogorov-Smirnov test the difference in PSI distributions between ST and MTA is statistically significant at 5% (p-value = 0.032). Similarlt, difference in PSI distributions between ST and MTF is statistically significant (p-value = 0.008). No differences between MTA and MTF PSI distributions (p-value = 0.476).

Figure 5. Team type: Size (turnover) and world region distribution

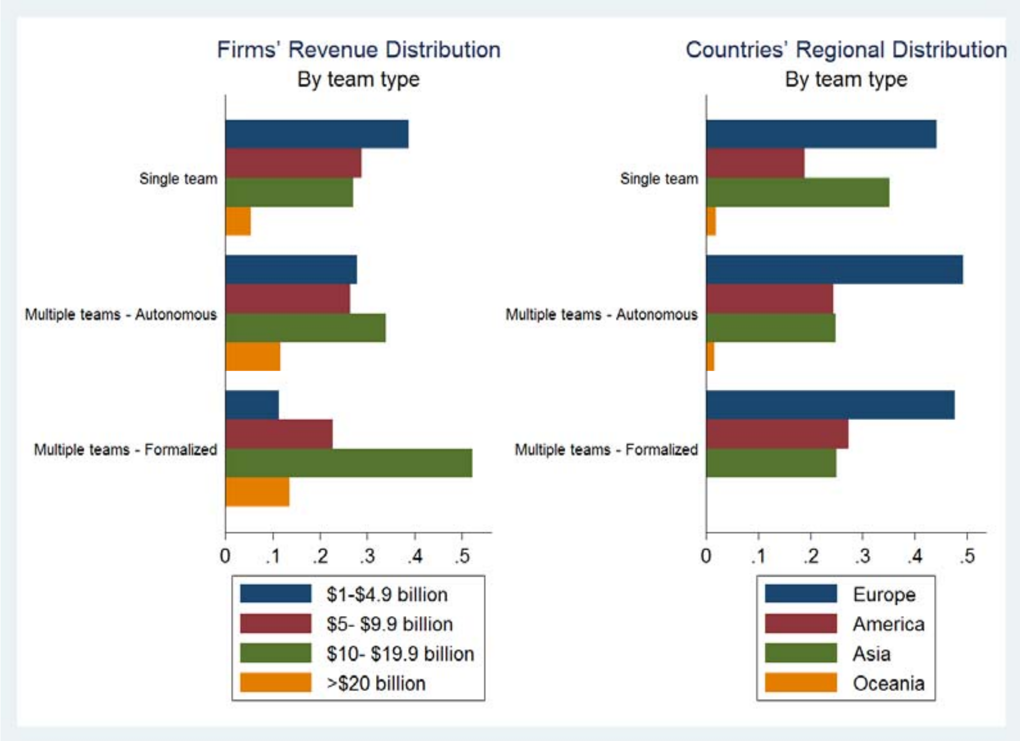
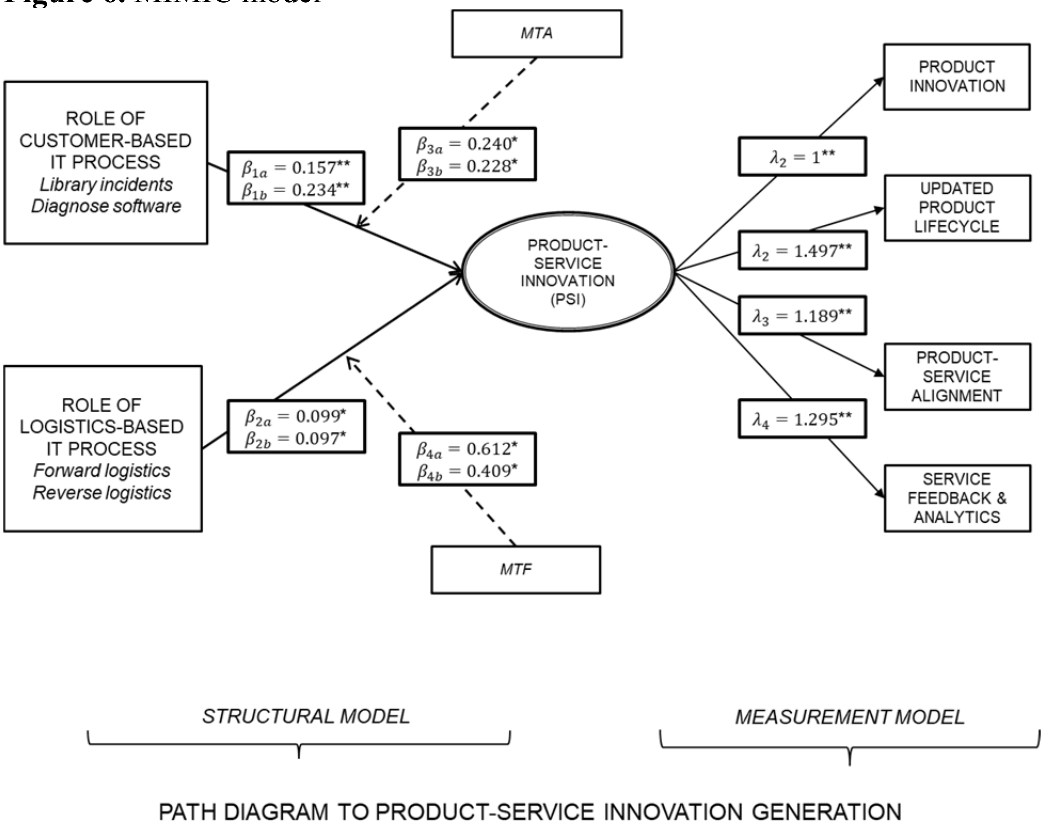
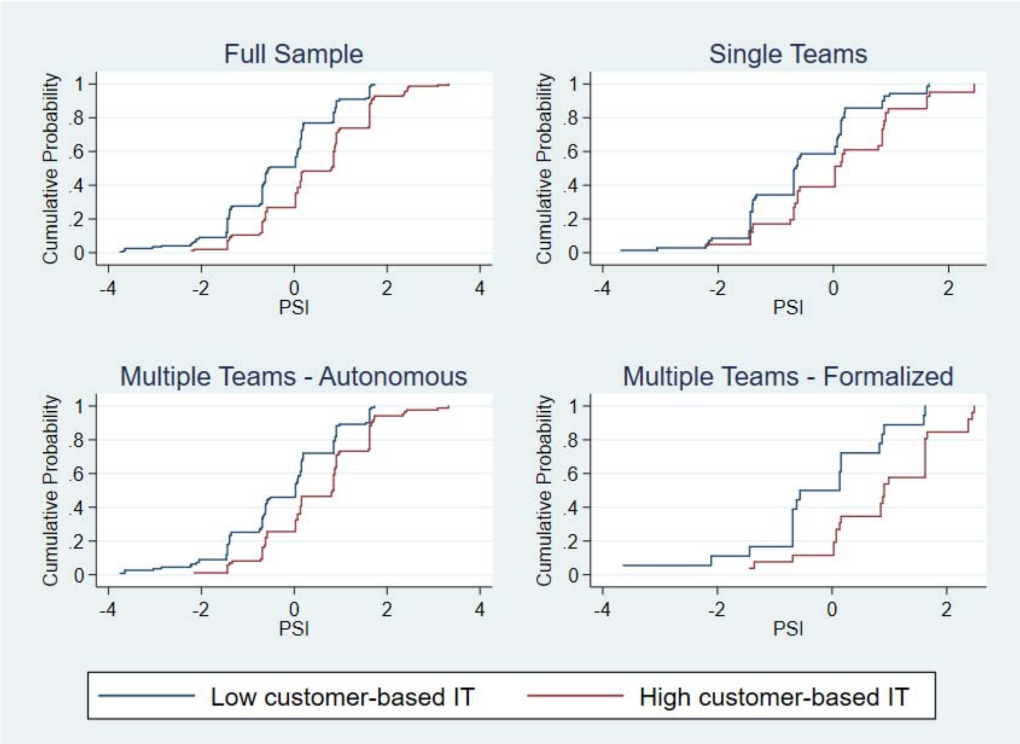


Figure 6. MIMIC model



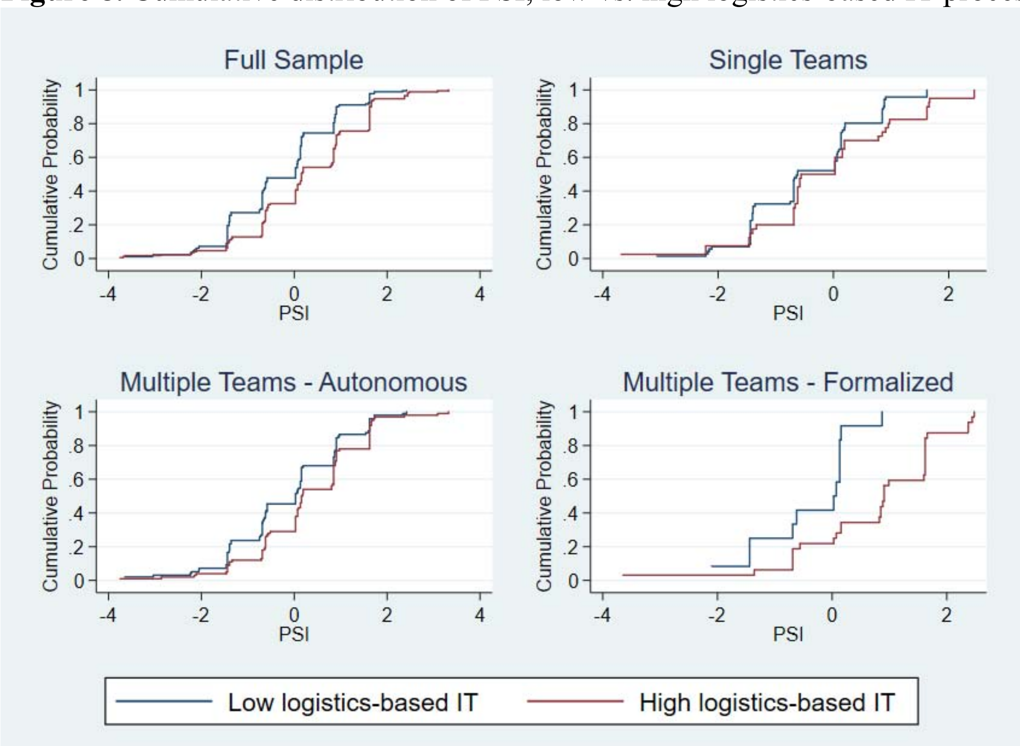
Note: Levels of statistical significance are: * p-value<0.05 and ** p-value <0.01

Figure 7. Cumulative distribution of PSI, low vs. high customer-based IT processes



Note: According to the Kolmogorov Smirnov test the significance levels are 0.000, 0.081, 0.004, and 0.038 respectively.

Figure 8. Cumulative distribution of PSI, low vs. high logistics-based IT processes



Note: According to the Kolmogorov Smirnov test the significance levels are 0.001, 0.293, 0.072, and 0.006, respectively.

APPENDIX A: Item description

Table A1: Items for dependent variable, Product-service innovation (PSI)

Please indicate the extent to which you disagree/agree with the following statements using a 5-point scale where 1="completely disagree" and 5="completely agree"		
ID	ITEM	QUESTION
PSI1	Product Innovation	Regarding to your new product introductions (before product release). Are engineering and service leadership equitable collaborators in defining and delivering new solutions to meet customer-driven demands?
PSI2	Updated Product Lifecycle	Regarding to your product-lifecycle related updates/changes. Is the impact of service-proposed engineering changes evaluated, approved and implemented through each phase of the offerings upgrading process?
PSI3	Service Feedback and Analytics	Regarding to your service feedback and analytics. Are engineering and service leadership equitable collaborators in capturing and analyzing product and service information for continuous improvement; and hence, they foster the design of new product and service offerings?
PSI4	Product-service Alignment	Regarding to your collaboration tools usage (after product release). Are Product-Lifecycle Management (PLM) and Service-Lifecycle Management (SLM) processes and systems highly integrated with each other?

Table A2: Items for independent variables, IT processes

Please indicate the extent to which you disagree/agree with the following statements using a 5-point scale where 1=" completely disagree" and 5=" completely agree"		
ID	ITEM	QUESTION
IT1	Library incidents	Does your IT system contain a searchable knowledge base?
IT2	Diagnosis software	Does your IT system attempt to diagnosis customer problems before dispatch?
IT3	Forward logistics	Do you offer total coverage including same-day/on-site replacements?
IT4	Reverse logistics	Does your IT system track all parts and components up to delivery?

Table A3: Items for moderating variable, service R&D team structure (RDTS)

ID	Category	Question
RDTS1	Single Vs Multiple teams	Does your firm have more than one R&D team focused on service development? a. Yes [multiple teams] b. No [single teams]
RDTS2	Autonomous Vs Centralized decision making	If yes in previous question. Do you have a centrally managed global-field service organization that reports to a senior service executive? a. Yes [centralized] b. No [autonomous]