Technological Innovation, Organizational Change and Product-Related Services

Arman AVADIKYAN
avady@unistra.fr
BETA (UMR-CNRS 7522) - Université de Strasbourg
61, avenue de la Forêt Noire
F-67085 Strasbourg Cedex

Stephane LHUILLERY
Stephane.lhuillery@icn-groupe.fr
ICN Business School and BETA (UMR-CNRS 7522)
3, place Edouard Branly
F-57070 Metz Technopole

Syoum NEGASSI
Syoum.Negassi@univ-paris1.fr
Management Science Department - University of Paris 1 Panthéon-Sorbonne,
17, rue de la Sorbonne
F-75231, Paris Cedex 05

Abstract

The literature regarding the determinants of servitization emphasizes the role of organizational change and usually overlooks the role of technological change. Using an original sample of 1,129 German manufacturing firms, we reverse the hierarchy: product novelty is a main driver of product related service activities. It especially boosts consulting and training services. The structure of the PRS portfolio is depending on product novelty. Organizational changes towards a more flexible company or the adoption of new advanced manufacturing processes are found, with few exceptions, to hardly influence the decision to offer a product-related service. However, our results suggest that process innovation is positively linked to the breadth of service surrounding products, whereas organizational innovation is more prone to lead to a larger breadth of services surrounding customer offerings. Product, process and organizational innovation are not found to be complementary drivers of product-related service offerings.

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JEL CLASSIFICATION: O3, L2, L6

INTRODUCTION

When exploring the evolution of the modern manufacturing firm, scholars insist on the increasing bundling of products and services, which is variously referred to as ‘servitization’ (Vandermerwe and Rada, 1988), ‘servicization’ (Quinn et al., 1990), ‘going downstream’ (Wise and Baumgartner, 1999), ‘transition to services’ (Oliva and Kallenberg, 2003), ‘integrated solutions’ (Davies, 2004), “hybrid offerings” (Ulaga and Reinartz, 2011) or product-service systems (Mont, 2002). Despite some steps back (Finne et al., 2013) and some reluctance (Gebauer and Fleisch, 2007), there is evidence that a large and ever-increasing proportion of manufacturing firms already adopt such servitization strategies (Rosen, 1998; Cohen et al., 2006; Tuli et al., 2007; Fang et al., 2008; Neely, 2009). Based on a large international database, Neely (2009) found that the proportion of manufacturing firms reporting to provide services is now at least 30%. The share is approximately 58% in the United States, 29% in Germany, 25% in the UK and 11% in Japan.

The servitization process is expected to provide competitive advantage to firms: servitized firms are more likely to compensate for the loss of revenues arising from stagnant demand or fluctuating business cycles and initiate new growth opportunities and more stable revenues (Sawhney et al., 2004; Cusumano, 2004; Cohen et al., 2006). Services are less capital-intensive to produce than products, and servitized firms tend to have higher margins (Wise and Baumgartner, 1999). Services are a critical differentiation factor in a firm’s strategy mix and a strategic tool to develop clients’ loyalty (Mathe and Shapiro, 1993). However, empirical studies have provided scattered and contradictory findings regarding the impact of servitization: whereas some authors have found direct positive effects (e.g., Fang et al., 2008; Visnjic and Van Looy, 2011; Visnjic et al., 2012; Thether and Bascavusoglu-Moreau, 2012), others have not (Robinson and Chiang, 2002; Visnjic et al., 2012). Neely (2009) even found mixed results: servitization has a positive link on profitability, whereas the extent of servitization has a negative effect on profitability. Findings also highlight the non-linearity of the effects of servitization on performance and/or the differences among industries (Fang et al., 2008; Suarez et al., 2013; Visnjic and Van Looy, 2013).

Several explanations can be put forward to explain the “servitization paradox”. A first possible explanation underlined by Cusumano et al. (2014) is that the results regarding servitization, with very few exceptions, rely on poor data: mono-sectorial data (Eggert et al., 2011, 2014; Suarez et al., 2013), small samples (Fang et al., 2008; Antioco et al., 2008) or biased samples (on listed companies for example, Neely, 2008; Fang et al., 2008; Visnjic et al., 2014) combined with the usual problems related to time lags and mismeasurement (Brynjolfsson, 1993).

A second related point is that studies do not properly take into account the heterogeneity of services involved and that different services do not impact performances in the same way. For example, some services can be offered to diversify activities when usual markets and performances are down, whereas other services can be offered to support products or processes introduced in growing markets. Along with Mathieu (2001), a distinction can also be made between services supporting products (hereafter SSPs, such as installing documenting, repairing) and services supporting client actions (hereafter SSCs, such as financing, training or consulting) that can provide different competitive advantages to manufacturing firms (See Eggert, 2011).

A third strand of the literature emphasizes that HR or organizational capabilities are not properly taken into consideration: there is a lack of managerial motivations or competencies (Gebauer et al., 2005), top-manager commitment (Gebauer, 2009; Antioco et al., 2008), training activities (Santamaria et al., 2012), service culture and mind-set (Neely, 2009). Other authors emphasize the absence of adequate organizational arrangements to enable firms to derive value from services (Bowen et al., 1989; Neu and Brown, 2005; Oliva and Kallenberg, 2003; Davies et al., 2006; Gebauer et al., 2009b) or a lack of slack resources (Fang, 2008).

We contend that the main caveat likely to explain the lack of results is instead that previous studies have overlooked technology. Often, the literature focuses on product quality, in which the technological dimensions or other dimensions of novelty are not explicit (Ulaga and Eggert, 2006). Thirty years ago in a seminal paper, Teece (1986) emphasized that product-related services can be a critical complementary asset that allows firm to exploit innovation. Whereas many contributions have explored the role of services on performances, very few have considered technology as a critical driver of servitization that is likely to influence performance.

In the following, we contend that servitization cannot be analysed without considering the sparking role of technological innovation. To reinstall the role of technology into the analysis of servitization, the present article addresses three main research questions: is technological change a driver of PRS strategies? What is the link between technological change and organizational change as a PRS driver? To what extent do these determinants depend on the type of PRS considered?

To answer these questions, we propose an econometric model that explains PRS offerings in terms of the strategic orientations – including product innovation, process innovation and organizational change – chosen by 1129 German manufacturing firms. Radical product innovation is found to be the main driver of PRSs, whereas the positive influence of organizational change and process innovation are reduced. New product and new organizations are not found to be complementary determinants of PRSs. A further contribution is that technology is demonstrated to influence diverse PRSs in different manners, shaping PRS portfolios. Our analysis also challenge the standard classifications of PRSs proposed by scholars. Despite performing a cross-sectional analysis, our article proposes a much more precise view than previous works in the field and addresses several gaps: it uses a large-scale sample including multiple industries and firm sizes, and it focuses on product related services, whereas many articles on servitization mixed product related services with product unrelated services.

The reminder of the paper is organized as follows. In Section 2, we propose an integrative perspective regarding the determinants of PRSs in manufacturing. Exploring the literature, we particularly rejuvenate the importance of technology in addition to organizational aspects for PRS strategies. We first present the role of process/product innovations in servitization and then discuss the role of organizational practices. We then consider the hierarchy and heterogeneity of influences driving PRS offering. In Section 3, we present the method that we implement to test our empirical hypotheses, including the data, the different variables, and the econometric modelling. Section 4 presents our statistical results regarding the determinants of PRS portfolios. A final section concludes and discusses the main contributions and implications of our results. We then address limitations and future research.

THEORY AND HYPOTHESES

TECHNOLOGY AND PRSs

Technology expands the opportunities for firms to offer not only new products but also new processes. New products may create opportunities to expand the importance and scope of existing PRSs; new products may also create opportunities for novel PRSs. In a similar manner, new process technologies may develop or redefine the manner in which products and product related services are produced and delivered. We review the evidence regarding product and process innovation in turn.

An interesting feature of the literature about servitization is that servitization is considered to be irruption of customer orientation in manufacturing organizations: servitization is considered market- and customer-driven. Customers' willingness to pay for a product will be particularly increased by PRSs. A particular case is when the product is innovative, either in a radical or incremental manner. In this case, PRSs can be considered a role model of complementary assets likely to enable firms to exploit technological innovation (Teece, 1986). Still, the link between the degree of novelty and PRSs is not clear in the literature.

On one hand, PRSs are a substitute for product innovation. Oliva and Kallenberg (2003) consider that services are proposed when related to an installed base of manufacturing products to expand product life cycles and to compensate for a lack of improvement. In this setting, PRSs can be considered a substitute to address a lack of innovation capability, and radical innovation has a crowding-out effect on PRS offerings. The point can be made compatible with incremental innovation: at the end of the life cycle, incumbents introduce incremental innovation to maintain the value of their products. In this case, PRSs surround incremental innovation but are still a substitute for radical innovation. PRSs can furthermore be considered as a means for incumbents, especially in mature industries, to create switching costs for their customers. The switching costs induced by PRSs are less critical for recent and radically new products. A final substitution possibility is also that the introduction of a radically new product shrinks the market for services: some product with radically new auto-diagnostic and auto-repair properties, for example, would dissuade firms from proposing maintenance and repair activities. A new machine with radically new user-friendly controls would also dissuade firms from offering training sessions to their customers.

On the other hand, the literature about servitization often implicitly or explicitly considers technology as a threat for customers likely to face products that they do not need or do not understand. For instance, Bowen et al. (1989) asserted that customer services should be a requisite consequence when manufacturing firms differentiate their products from others through innovative technologies and designs. Users may be hesitant to adopt innovative technologies because of uncertainties about product performance and quality. This phenomenon is in agreement with the marketing literature, in which extensive PRSs may be required to overcome barriers to the adoption of innovative products by customers (Araujo and Spring 2006). PRSs can be thus critical especially for radical innovations, for which novelty is difficult to comprehend by users and firms must help customers learn about and appropriately perform new product functionalities. The complementarity view is also supported by the fact that PRSs can be an interesting means of appropriation implemented by pioneers to prevent imitation (Levin et al., 1987).

The empirical literature does not significantly help clarify the two views. The influence of product innovation on related services, including the degree of novelty of technological innovation, has been barely taken into consideration in empirical studies (See Fang et al., 2008; Neely, 2009; Visnjic and Van Looy, 2011; Visnjic et al., 2012; Thether and Bascavusoglu-Moreau, 2012). Some empirical insights have come from expert interviews: Matthyssens and Vandenbempt (1998) confirmed, for instance, a strong and positive relationship between leadership in product innovation and market leadership in industrial services. Econometric evidence is, however, still rare and vague: some scholars have found empirical evidence that firms with low innovative capabilities may counterbalance their weakness through higher complementary assets (e.g., Rammer et al., 2009), and PRSs may be a commonly used asset in this respect. However, Eggert et al. (2011) found indirect evidence for a positive impact of product novelty on PRSs. More precise is the positive and direct link found by Santamaria et al. (2012), where R&D intense firms are more likely to innovate in services. Visnjic et al. (2014) found a positive and complementary role in terms of long-term performance for the adoption of a service-oriented business model and technological innovation approximated by R&D intensity. In the two previous references, product-related services and product-unrelated services were not differentiated, but the former can be positively related to technological innovation and the later negatively related to technological innovation.

Based on these different works, we propose a first general hypothesis related to product innovation:

> H1: Firms that introduce product innovations, especially pioneer products, are more likely to offer PRSs.

Because servitization is a general downstream orientation in which integration of customer and service units is performed, scholars have explored the role of adopted technologies in the servitization process. ICTs and advanced manufacturing technologies (hereafter AMTs) have been the main technologies investigated.

Contrary to product innovation, scholars have been able to incorporate new technological processes as a positive means to improve servitization: for instance, ICTs were first documented as an enabler of servitization (Barras, 1986; Kellogg and Nie, 1995; Windahl et al., 2004; Lightfoot et al., 2011). Information technologies and techniques help firms identify and adapt to customers' characteristics and needs (Nonaka and Teece, 2001; Froehle, 2006) and to transform and exploit external knowledge (Joshi et al., 2010). These technologies and techniques thus help firm define new business opportunities and differentiate their PRS offerings. New technologies such as ICTs are lowering the delivery costs of services: by lowering internal information, coordination, production and transaction costs, they help transform potential services into profitable services. ICTs are also interesting because they allow new PRSs. For example, car rental companies can propose navigational system. ICTs can also be intertwined with complementary technologies (using sensors for example) to produce or deliver new services. Customers can also track online, step-by-step, the processing and delivery of their products. The strong linkages between firms and clients increase switching costs and develop future product and service opportunities.

ICTs are, however, only one part of the technology used in manufacturing companies. They are often combined with AMTs – defined as a group of hardware- and software-based technologies designed to improve the efficiency and effectiveness of firms in the design, manufacturing and testing of products – that can lead to more flexible product design, combining manufacturing efficiency and customer differentiation (Lei et al., 1996; Hofmann and Orr, 2005)[1]. AMT resources and competencies may allow customization of product functionalities, quality or reliability with the possible fast delivery of small batches. Integrating IT computers and networks with databases, firms with recent AMTs are more likely to encourage their customers to interact directly on specifications, production and delivery, thereby allowing for the synchronization of upstream CAD (computer-aided design) and CAE (computer-aided engineering) with downstream CAM (computer-aided manufacturing) and PDM (product data management) activities. AMTs thus create a manufacturing system that is a more favourable environment for PRSs, thereby enabling an extended scope of PRSs offered to customers and higher-value-added services. By integrating and standardizing the management principles of services, implementing AMTs in the back office may support and create new opportunities for the effective delivery of services in the front office.

Empirical works provide many examples of service-orientation and high customization in manufacturing firms that are significantly and positively driven by not only ICTs and communication infrastructure but also remote-monitoring technologies (e.g., Barabba et al., 2002; Davies et al., 2006; Johnsson et al., 2008; Antioco, 2008; Grubic et al., 2014). Mixing product and process dimensions, some technologies such as cloud computing and/or digitalization, have even been demonstrated to disrupt entire industries and create entirely new services opportunities (Sultan, 2013; Fichman *et al.*, 2014 and references therein). Indirect evidence is provided by labour studies that demonstrate that firms with AMTs are employing skilled labour (Doms et al., 1997), especially in service-related industries (Kaiser, 2000), thereby suggesting that firms that adopt AMTs are more likely to identify and propose PRSs to their customers. Specific evidence linking AMT innovations with services is, however, still scarce: Santamaria *et al*. (2012) proposed the main empirical results, based on a large sample of Spanish firms. Their results support the general hypothesis that firms with advanced manufacturing processes are the ones that are more service oriented. Still, whereas ICTs can be considered a general source of servitization, AMTs are more related to the manufacturing products and thus should be particularly relevant to achieve a subset of PRS strategies.

Based on the reviewed literature, we pose a second hypothesis regarding technology:

H2: Firms that introduce new advanced manufacturing technologies are more likely to offer PRSs.

FLEXIBLE ORGANIZATION AND PRSs

In the literature about servitization, firms establish appropriate organizational arrangements to manage the service production process, in which customers' needs and market changes are key (Bowen et al., 1989; Nambisan, 2001; Mathieu, 2001; Galbraith, 2002; Oliva and Kallenberg, 2003; Davies, 2004; Gebauer et al., 2005; Neu and Brown, 2005; Gebauer et al., 2009). The literature has first explored the possibility of achieving successful services through organizational design and the creation of a separate service unit, such as a service function or a service division (Oliva and Kallenberg, 2003; Gebauer et al., 2005; Gebauer et al., 2009; Oliva et al., 2012). The authors usually contend that a dedicated service unit is the only means to develop service businesses inside manufacturing firms (see also O'Reilly and Tushman, 2004). The creation of a separate function allows some autonomy, some specialization effects and a specific attention to clients. Scholars believe that this type of

[1] The point is very similar for the case of flexible manufacturing systems (Buzacott and Yao, 1986).

organizational arrangement is not, however, a sufficient condition for achieving effective servitization: it may validate the co-existence of product and services within the manufacturing firm, but it does not guarantee that services are customer-centred, and it may hamper the transversal development of specific PRSs that would satisfy the clients' need (e.g., Miller et al., 2002; Gebauer et al., 2009).

Scholars consider two dimensions of enabling adaptation and subsequent efficient service activities: decentralization and integration.

To be able to propose services, including PRSs, manufacturing firms should first achieve decentralization of their units (Neu and Brown, 2008; Gebauer et al., 2005; Acemoglu et al., 2007), and delegate decisions and control to lower hierarchical levels. Decentralization allows firms to more efficiently manage the use of information dispersed among employees and thus allow specialists to design and efficiently manage customer-centric activities (Galbraith, 2002)[2]. A problem is that the autonomy derived from decentralization may damage interactions with other intra-firm units and competencies. Integration is thus considered a second organizational trait required by firms aiming at servitization. Firms should integrate the different units through different practices, such as standardization, formalization, information systems or cross-functional teams (Mathe and Shapiro, 1993; Galbraith, 2002). Implementation of these costly practices is considered effective because it lowers communication and coordination costs among units through a better and faster reactivity between the service unit(s) and the other functional units or customers (Bowen et al., 1989; Turunen and Toivonen, 2011). Among these different integration practices, teams seem to be considered a main solution to rapidly develop customer-specific services (see Galbraith, 2002). Teams are indeed particularly interesting because they are problem-solving entities, able to capitalize knowledge (Lenfle and Midler, 2009) and may even boost creativity, especially when complex products are provided (Boning et al., 2007).

Both dimensions have received little systematic empirical support. Regarding decentralization, the literature implicitly considers that a better information system is a means to decentralize organizations. The already-cited results regarding the role of ICTs in servitization should be considered, in this perspective, as clues supporting the positive role of decentralization. Bowen et al. (1989) highlighted that implementation of control mechanisms is indeed very costly because of the rapidly changing and uncertain idiosyncratic services managed by employees. In a case study, Neu and Brown (2008) confirmed that servitization is enabled by senior management through delegation of decision-making authority to mid-level managers. Until now, little empirical evidence regarding the role of decentralization has been available. To our knowledge, Eggert et al. (2014) is the only econometric contribution based on a large sample; this study demonstrated that decentralized manufacturing firms are able to derive significantly higher growth revenue and profit from SSC. Regarding integration, the literature is also still largely based on anecdotal evidence or case studies. Using a sample of 107 international firms, Antioco et al. (2008) made a significant effort to test the link between integration and service orientation. However, the authors failed to find any significant impact of cross-functional communication on the service orientation of manufacturing firms.

Taking stock of these different organizational traits that a manufacturing firm should adopt to succeed in services leads us to define an organization as "organic" or "flexible" when it is characterized by few

[2] This positive effect is well documented for products with econometric results on large samples (e.g. Auh and Menguc, 2007).

levels of hierarchy, strong decision-making power at the employee level and strong communication among the different organizational units to better coordinate activities and employees at lower costs (Burns and Stalker, 1961; Miller, 1986; Bowen et al., 1989; Youngdahl, 1996; Bahrami, 1996). Such decentralization and integration are expected to enable organizations to satisfy customer needs effectively, in quality, in quantity, in design and in a timely manner. Flexible firms have better interactions with clients and other stakeholders that are also likely to provide innovative services (Von Hippel, 1986; Plé et al., 2010; Saccani et al., 2014).

We can propose a third empirical hypothesis:

H3: Firms that adopt a more flexible organization are more prone to propose PRSs.

DOMINANCE, COMPLEMENTARITY AND HETEROGENEITY

The organizational and technological determinants of servitization are rarely compared. Polar views can be inferred from the literature: studies usually focus on the market orientation of organizational arrangements, whereas the role of technology is overlooked. This caveat suggests that scholars working on servitization would rather consider that organizational change is the dominant driver of servitization: PRSs can be based on already existing products, but some organizational arrangements are required to be able to deliver PRSs (Oliva and Kallendberg, 2003). However, when technological innovation occurs, it can also require some organizational changes, and it will impact negatively PRS offerings. In this view, the complementarity between organizational change and the degree of novelty of technological innovation is implicitly negatively related to PRS offerings.

However, the point is different for scholars who consider PRSs as arranged around incremental innovation. These stable core competencies can in this case be a source a source of rigidities that hamper the adaptation of firms (Leonard-Barton, 1992) and thus hamper the delivery of PRSs. In this view, incremental innovators are less able to adapt and to propose new PRSs if they do not complement their incremental innovation with organizational change. The combination of organizational change and product innovation should thus be positive for incremental innovation. At the same time, a pattern of radical innovation combined with organizational change should lower the need for PRSs.

A third view considers that firms can overcome the latter problem and build dynamic capabilities (Teece et al., 1997) to be able to be and stay innovative over time, either with incremental innovation or with radical innovation. Services are not related to an installed based but are solutions, integrated with new competencies and products allowed by organizational change (Davies, 2004). Product and process innovations are articulated with organizational change and even AMTs to propel PRSs. Innovation and organizational change should then be observed as complementary. The degree of novelty of product innovation should be positively correlated with the degree of novelty of organizational practices. In this setting, organizational change is to be deployed either for radical innovation or for incremental innovation to offer PRSs. In this framework, the combination of organizational change and technological change is always expected to be positively related to PRSs, and the relative importance of the two drivers is blurred.

In the face of such a lack of clear predictions regarding the relative importance of the different PRS determinants, empirical studies should help. In Santamaria et al. (2012), the impact of new processes and the link with customer (decentralization) were found to be positively linked to service innovation, but the difference between the two determinants was not tested. In Antioco *et al.* (2008), the modelling adopted hampered clear conclusions regarding the magnitude of the positive effects. Their results suggested that technology is dominant over organization. There is, however, a lack of studies that allow us to generalize this result. A further problem is that to our knowledge, there is no result available regarding the complementarity issues.

Facing a lack of strong insights from the literature, we will adopt the two following hypotheses:

H4a: Technological innovation is a dominant driver of PRS offerings.

H4b: Technological innovation and organizational change are complementary drivers of PRSs.

Some authors offered more subtle and more complete analyses in which the role of the determinants of PRSs changes according to the type of PRS. Servicing profiles may differ depending on whether the role of services is to support the introduction/development of new and innovative products to the market or to complement existing products and support the already installed product base. Cusumano et al. (2014) recently proposed an interesting categorization of PRSs in which some services are oriented towards incremental innovation or to mature industries whereas others address radical innovations. The former are “smoothing” services (such as financing, repairing, training, installing, and documenting) that enable firms to maintain their margins, whereas the latter are “adapting” services (such as software and consulting) that accompany radically new products to create a margin. The degree of technological novelty will thus support different types of PRSs.

However, scholars often use the older SSP and SSC classification (See Mathieu, 2001) to argue that pioneers on markets should first propose SSPs and then afterward propose SSCs in their PRS portfolio once the product novelty vanishes with its related SSP opportunities. According to Eggert et al. (2011, 2014), the heterogeneity is due to an arbitrage among competing resources: through learning, radical product innovators benefit from comparative advantages in specific resources that enable them, at low cost, to complement their product with SSPs. Laggards are not able to develop such competitive advantages but have relatively more resources left to invest in SSCs. Despite its reliance on anecdotal evidence, this type of co-evolution has been widely accepted by scholars. Based on a large sample of 414 German mechanical engineering firms, Eggert et al. (2011) made a breakthrough contribution that demonstrated a positive and higher impact of SSPs for pioneer firms (with novel products) but also some higher impact of SSCs for laggards (products that are not new to the market but new to the firm) on profit growth.

The heterogeneity in organizational change should be consistent with the heterogeneity in product innovation. The integration and reactivity allowed by flexible organizations particularly encompass a better ability to interact with external bodies such as suppliers and customers. An interpretation derived is that flexibility should thus boost the opportunities to propose customer-oriented services (SSCs) and to develop close customer-supplier relationships that are less critical for developing product-oriented services (SSPs). Once again, the empirical results are not very helpful: Antioco (2008) do not find any differences in the roles of integration practices on PRS, and cross-functional communication is found to be influential neither on SSCs nor on SSPs. In Eggert et al. (2014), a positive role of decentralization is undeniably found for SSCs, whereas the role of decentralization is not even explored for SSPs.

Finally, we can consider that AMTs, including ICTs, are likely to help firms improve their manufacturing capabilities and to integrate them, plan them and control them efficiently. Dedrick, et al. (2003) confirmed in a review of the empirical literature that IT enables fundamental changes in organizational structures. AMTs should for instance impact warehouse management, delivery, installation or repair aspects, whereas financing or consulting activities should be enabled and influenced by cheaper and deeper communication with customers regarding production processes and costs. However, it seems more difficult to determine whether AMTs are more prone to influence SSPs than SSCs. Antioco et al.'s empirical results (2008) confirmed the broad influence of ICTs with an impact on both SSP and SSC differentiation.

According to theoretical and empirical insights, we propose the following minimal hypothesis:

H5: The impact of technological and organizational change depends on the type of PRS.

METHOD

Data: the European Manufacturing Survey (EMS)

Every two years since 1993, the Fraunhofer Institute for Systems and Innovation Research (ISI) has monitored technological and organizational changes in the German manufacturing industry using a written survey ("German Manufacturing Survey") mailed to manufacturing companies. The survey addresses diffusion patterns of new organizational, managerial and technological changes in addition to cooperation, relocation and performance issues (Kirner et al., 2009; Lay et al., 2010). Since 2003, the survey has been extended to other European countries in the form of the European Manufacturing Survey (EMS). The second EMS conducted during 2006, and used here, surveyed 13,426 manufacturing firms from Germany with more than 19 employees that belonged to various manufacturing sectors (from 15 to 37 in the NACE rev.1 classification). 1,663 firms responded (response rate 12.4%). Some cleaning combined with the effect of missing values reduced the number of observations. The questionnaire uses specific questions regarding the introduction of organizational changes or technological processes performed over time. The organizational changes and product and process innovations can thus be identified over the 2003-2005 period. PRS activities are identified in 2006. Once missing values were taken into account and firms younger than 4 years were removed, our final sample included 1129 firms.

Variables

We first define the explained variables. Explanatory variables are then defined in turn. Table 1 reports the different variables and their definition.

INSERT TABLE 1 NEAR HERE

We define four different explained variables. First, we identify whether a firm proposed at least one PRS in 2006 (PRSYes is set to 1; see Table 1). A second set of variables provides more details: it is a set of 7 dichotomic variables measuring the PRS offerings proposed in 2006, of the 7 different PRSs listed in the questionnaire (consulting (design, consulting, project planning), technical documentation, software development, financial services (leasing, rental, funding), installation, training, and repairing (maintenance, repair))[3]. We thus want to explain to what types of PRSs are related to innovation and organization. To be able to further characterize the differences among PRS portfolios, we introduced the standard difference between SSCs and SSPs: the SSC index is computed as the sum of consulting, financing, training services, whereas the SSP index is defined as the sum of documenting, software, installing and repairing services. Actually, these indexes measure the breadth of SSPs and SSCs. A larger breadth of PRSs measures the offering of a different type of PRS but not a novel PRS. Note also that the quality of the answers regarding PRSs hampered the possibility to directly define variables regarding new PRSs without losing the main part of our sample because of missing values.

INSERT TABLE 2 NEAR HERE

Regarding the independent variables, we define product innovators using a standard approach (see OECD, 2005) relative to the 2003-2005 period. We define two levels of product innovators: among product innovators, we differentiate between those who introduced radical products – that is to say a product that was new to the market ($PRODUCT^{RADIC}$) – and those who produced only incremental innovations ($PRODUCT^{INCRE}$) for comparison to non-innovative-product firms. Thanks to the EMS questionnaire, we further identify different process innovations: with regard to processes, the EMS survey lists 11 different types of process innovations (See Table 1)[4]: the PROCESS index can thus be computed as the sum of the new advanced manufacturing technologies implemented by firms over the 2003-2005 period[5].
Finally, organizational traits related to PRSs are mainly characterized by integration and decentralization practices. A firm is thus considered more flexible (FLEXIBLE) when, over the 2003-2005 period, it introduced new integration or new decentralization practices (see Table 1).

Five control variables are considered. The EMS questionnaire enabled us to further characterize firms according to the share of their employees with a 3rd-level educational qualification in 2005 (SKILLED). Subcontractors (SUBCONTRACTOR=1), as are the ages of the firms. Young firms (YOUNG=1) are firms founded after 1995 (set to 0 otherwise). The size and the sectorial effects are measured, respectively, by the logarithm of the number of employees (SIZE). At the sectorial level, a set of four industry dummies (Low Tech, Medium-Low, Medium-High, and High Tech) defined at the 2-digit level of the NACE classification and measuring the sectorial level of R&D (OECD, 2002) were also computed. These sectorial dummies approximate the degree of maturity of an industry: Low Tech and Medium-Low Tech firms approximate mature industries, whereas High Tech and Medium-High Tech industries approximate young industries.

Econometric Model

Our model tests the determinants of PRS offerings. Any manufacturing firm can, of course, introduce PRSs. We contend, however, that firms anticipate difficulties: the ones that are able to innovate and to

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[3] The question used was "Which of the following services related to your products do you offer to your customers?" The "exploitation" service is not maintained in the following because too few firms declared that they provided production at the location of their client.

[4] Actually, three items were deleted because they were highly specific to only a few manufacturing industries: "Clean Rooms", "Biotech processes" and "Catalytic conversion".

[5] A transformation into a dichotomic variable was made but did not change our results.

arrange flexible arrangements are the ones that are more likely to derive value from PRSs. Hence, they are more likely to launch and/or maintain PRSs and thus to subsequently to offer PRSs. Adding control variables, our core model explaining PRSs is

$$PRS_i^j = \alpha_1^j PRODUCT_i^{RADIC} + \alpha_2^j PRODUCT_i^{INCRE} + \alpha_3^j PROCESS_i \ + \alpha_4^j FLEXIBLE_i \ + Z_i^j + \varepsilon_i^j \quad \text{(Eq1)}$$

where PRS is a set of j variables, PRS = {PRSYes, Consult, Doc, Soft, Finance, Install, Training, Repairing, SSP, SSC}; Z is a set of control variables that includes graduated, young, subcontractor, size and industry dummies; and ε_I are random errors. Positive outcomes are expected because radical product innovators are also anticipated to be more prone to develop and maintain PRS offerings than incremental product innovators (H1: $\alpha_1^j > 0,\ \alpha_2^j > 0\ and\ \alpha_1^j > \alpha_2^j,$). Beyond product innovation, a positive effect for organizational change (H3: $\alpha_2^j > 0$) or process innovation is also expected (H2: $\alpha_3^j > 0$). Finally, the results regarding technology are to be compared with the magnitude of the positive effect expected for organizational change towards a flexible firm (α_4). Either technology is dominant over organization (H4), with $\alpha_1 > \alpha_2 > \alpha_4$, or $\alpha_1 > \alpha_4 > \alpha_2$ and $\alpha_3 > \alpha_4$, as suggested by the literature on innovation, or organizational change is the dominant driver of servitization and $\alpha_3 < \alpha_4$ or $\alpha_2 < \alpha_1 < \alpha_4$, or $\alpha_1 < \alpha_2 < \alpha_4$, as suggested by the literature on servitization. To be able to compare magnitudes, marginal effects are computed for non-linear models. Additional Wald tests are conducted. Comparing the coefficients between equations for the same explanatory variable, we are able to test H5. For example, because the literature suggests that the type of PRS depends on the novelty of products, we test the hypothesis that the impact of radical innovation is the same for different PRSs (that is, H2b: $\alpha_1^j = \alpha_1^k, j \neq k$) and particularly SSCs and SSPs. Comparing the coefficient within an equation, we are able to test difference in magnitude among the determinants (H4a). We introduced different variables crossing technological variables (product and process) and an organizational change variable to test for complementarity (H4b).

With respect to control variables, employees with a 3rd-level educational qualification are first introduced because they are usually associated with the ability of firms to adapt more efficiently from an organizational point of view (Caroli and Van Reenen, 2001). We thus expect a positive effect of the share of such employees on the ability of manufacturing firms to offer PRSs. Following Acemoglu et al. (2007), young firms have less experience with technologies and organizational arrangements. Following this general idea, we therefore expect that they may be less able to offer PRSs than other firms. It can, however, also be argued that young high-tech firms encounter more financial constraints and consequently, PRSs (including consulting and R&D, for example) are a means to survive when their products have not yet reached the market. The expected direction of the impact of the YOUNG variable is thus not well defined. A similar trade-off is expected for the variable SIZE because large firms are supposed to be more diversified and consequently more likely to propose PRSs, whereas small firms may be more flexible and close to clients. Indeed, the latter’s comparative advantage is their ability to provide PRSs to their customers. Sub-contractors are less likely to provide new PRSs surrounding their products because the contractual arrangements are likely to limit the extent of their offerings to their customers. The negative effect is likely to occur in particular when subcontracting is performed for capacity and cost reasons rather than for capability reasons. The heterogeneity of determinants can also rely on sectorial differences. For example, following (Cusumano et al., 2014), we can expect that firms in mature industries (Low-Tech and Low-Medium-Tech industries) are more prone to offer services such as “smoothing” services (financing, repairing, training, installing, or documenting), whereas sectors in a more rapidly developing phase (Medium-High-Tech or High-Tech) are more likely to propose “adapting” services (software or consulting).*

To cope with the different limited dependent variables measuring PRSs, non-linear models were implemented. A probit model was introduced to explain the dichotomic variable PRSYes. When dealing with the different types of PRSs introduced by firms, the strategic choices regarding these PRSs are not independent of each other. For example, a lack of resources may induce some arbitrage among PRSs, or some PRSs may be linked to other PRSs. For example, maintenance services may be critical after sale services. A further possibility is that firms benefit from economies of scope (Kowalkowski, Brehmer, and Kindström, 2009). When some installing or maintenance activities are provided, consulting services can be provided at lower cost, for example. To cope with these strategic interactions and possible economies of scope in PRS offerings, we implemented a multivariate probit model (as in Santamaria et al., 2012). We were therefore able to take into account the unobserved strategic orientations regarding some PRS bundles offered to customers. The correlation among residuals controls for complementarity, independence or substitutability among the different PRSs proposed by firms (Gourieroux, 2000). Hence, the PRS bundling is taken into account but not assumed, as is often the case in the literature (e.g., Antioco et al., 2008; Eggert et al., 2011, 2014). Still, we also implement a bivariate ordered probit model to identify the differences between SSC and SSP determinants. Deploying a multivariate model, we are thus able to test H5 and the heterogeneity of the role of explanatory variables on different PRSs.

RESULTS

As reported in Table 2, approximately 66% of firms launched at least one new product over the 2003-2005 period. 36% of firms declared that their innovations were new to the market. Only 41% of firms introduced advanced manufacturing processes during the same period (0.7 on average). New practices for a flexible organization were adopted by 12% of firms. Only 12% of manufacturing firms did not offer any PRS to their clients. Consulting activities, documentation, software and training services were the most common PRS supplied. Table 3 indicates that firms proposed different types of PRSs with heterogeneous frequencies. It also demonstrates that firms that introduced product innovation, process innovation and flexible innovation were more prone to be active in PRSs. The increment is, however, less obvious for process innovation or organizational innovation than for product innovation.

INSERT TABLE 2 & 3 NEAR HERE

The econometric results regarding the determinants of PRSs are reported in Table 4. The next hypotheses address the impact of product innovation on PRS strategies: H1 stated that radical product innovators are more likely to introduce PRSs or that PRS portfolio structures depend on the degree of product innovation introduced by firms. Controlling for a large number of variables, innovation is found to be a significant determinant of servitization. An incremental product innovation boosts the likelihood to offer PRSs by 4.5% (Col. 1 in Table 4), whereas the introduction of a radical product innovation during the same period makes firms twice more likely (+9%) to offer PRSs. A Wald test confirms that radical innovation has a significant and higher impact than incremental product innovation (the Wald critical value is 4.64, $p<0.05$). The positive effect of radical innovation holds for all PRS types except for financial services (Col. 5, in Table 4) and repairing services (Col. 8), whereas incremental product innovation plays a positive and significant role only for consulting services (Col. 2) and training services (Col. 7). Computation of marginal effects of the multivariate model allows us to interpret the magnitude of the impact of radical innovation on PRSs. Table 6 indicates that radical innovation especially boosts the probability of developing consulting activities (+7%, Col. 1 in Table 1) and training activities (+7%) and also, in a minor way, documentation services (+1.4%) and repairing services (+0.8%). From Table 6 (Col. 1 and Col. 6), we can see that when significant, the impacts of radical product innovation are about twice the impacts of incremental product innovation, in agreement with H1. Radical innovation positively influences SSCs and SSPs (Col. 9 and Col. 10, respectively), whereas incremental innovation is found with a lower magnitude than radical innovation.

On the whole, our results support H1 and the importance of product innovators in PRS offerings. More precisely, they support the idea that radical product innovations are critical to offer PRSs.

INSERT TABLE 4 NEAR HERE

The results regarding PROCESS confirm that firms that introduced or adopted many such innovations during the past three years were more likely to launch services around their products (Col. 1 in Table 4). The adoption of one additional AMT increased the likelihood to offer PRSs by 2% (Col. 1, in Table 4). However, process innovation was found to be linked, with $p<0.1$, only to consulting services (Col. 2 in Table 4). In contrast with the literature, our results do not provide clear support for H2 and the role of process innovation in PRS strategies. They suggest, however, that new processes can help firms extend their SSP offerings (Col. 10 in Table 4).

A similar result was found for H3. A more flexible organization was not found to influence the propensity to enter into PRS activities (Col. 1). The conclusion is similar when the different types of PRSs are scrutinized: flexibility is found to be influential only on the likelihood to do repairing activities (Col. 8). Our results provide weak support for H3. Organizational innovation seems to favour the number of SSCs proposed to consumer (Col. 9). This result is in agreement with Eggert et al. (2014).

The different coefficients can be compared to look for a hierarchy among the three determinants of PRS (H4a in Table 4). A set of Wald tests underline that radical innovation is dominant over process innovation, whereas the dominance is not found over organizational innovation. The adoption of one additional AMT increases the likelihood to offer PRSs by 2%, whereas the introduction of radical product innovation boosts the same probability by a significantly higher 9% (Wald is 3.90, $p<0.05$ in Col. 1, Table 4). The impact of radical product innovation is found to be dominant over process for the different services, except for financial and installation services. The dominance of radical innovation is found particularly for consulting services (Wald is 5.58, $p<0.05$), the only PRS for which AMTs play a role. It also confirms that radical innovation is dominant for consulting and training. Organizational innovation is found to be dominant over radical innovation only for repairing services. The dominance of product innovation is found to be weaker, as expected, when incremental innovation is considered: the results presented in Table 4 suggest that incremental product innovation is less important that organizational innovation for installing services.

When SSCs and SSPs are considered, the hierarchy is, however, more refined. Regarding the SSP index, radical innovation is still the dominant driver, dominating process and organizational innovation. Incremental product innovation impact is found to be superior to process innovation. Regarding SSCs, pioneer products are the only driver with a positive influence of more flexible organization becoming significant (at 10%). The different results provide support for H4a, that product innovation is the main driver of PRS offerings and that despite some influences, especially on SSPs, organizational change and process innovation are found to be less influential.

The lack of significance of the parameters of cross-effect variables is surprising (tables available upon request). It suggests that technology and organization cannot or that process innovation and product innovation cannot be considered complementary in terms of their impact on PRS offerings. H4b is thus not supported. A consequence of the result is that the parameters reported in Table 4 and Table 6 provide a reliable view of the different impacts of the different determinants of PRSs and their hierarchies.

We can finally consider to what extent the role of product novelty differs according to the type of PRS (H5). To answer this question precisely, we first focus on the multivariate probit model (Col. 2 to Col. 8 in Table 4) and perform Wald tests to test the heterogeneity of the positive impact of radical product innovation on PRSs. The Wald critical value is 26.39 (with $p<0.01$); thus, we reject the hypothesis that the coefficients of radical product innovation are equal among the different PRS types. The same result is obtained for the positive impact of incremental product innovation (Wald is 12.12 at $p<0.10$). More precisely, it was found that pioneers in an industry are more prone to offer consulting activities (+6.6% in Col. 1 in Table 6) and training services (+6.7% in Col. 6 in Table 6), whereas their propensity to offer documentation (+1.4% in Col. 2) or repairing services (+0.8% in Col. 7) is enhanced only weakly. In other word, the structure of PRS portfolios depends on innovation and the degree of innovation recently introduced by firms. To characterize the heterogeneity, we further tested the heterogeneity of coefficients on the bivariate ordered probit model: the coefficients of radical product innovation, incremental product innovation and even process innovation were found different between the two SSP and SSC classes (the Wald critical values are, respectively 13.9 with $p<0.01$, 5.33 with $p<0.05$ for Col.9-10 in Table 4). Only organizational innovation seems to not influence SSCs and SSPs in a different manner. Our results support H5 and the idea that firms tune the structures of their PRS portfolios according to the type and strength of technological innovation.

INSERT TABLE 6 NEAR HERE

With regard to control variables, we systematically find a positive influence for the share of employees with a 3rd-level educational qualification within a firm. The PRS strategy does not usually depend on company age: neither age nor age squared is significant in the estimations reported in Table 5 even if young firms exhibit a significantly lower likelihood to propose software (Col. 4). Size negatively influences the probability to propose installing services (Col. 6). Conversely, large firms are more prone to offer financial services and training sessions (Col. 5 and 7, respectively). As expected, subcontractors are less likely to be involved in PRS strategies. This result is, however, not found for consulting and documentation services (Col. 2 and 3, respectively). When the coefficients of sectorial dummies are considered, our results indicate that mature (low-tech) industries are less involved in PRSs, regardless of the explained variable. The computation of marginal effects (see Table 6) further documents sectorial differences: firms that belong to mature industries are less prone to offer repairing services, installation services or training services than firms from medium-high-tech industries. In ferment phase industries (high tech), software and financial services are much more likely to be proposed by manufacturing firms (see Col. 3 & Col. 4 in Table 6). Consulting services (see Col. 2 in Table 4) are the only PRS that are not less likely to be proposed in mature industries. Our results suggest that young firms are not necessarily the ones with original PRSs or original business model proposals; rather, industry characteristics and, as formerly detailed, individual technological capabilities are more important than firm age.

Finally, the positive correlations among residuals (see Table 5) suggest that the different PRS activities are complementary. The positive correlation among residuals provides little evidence for bundling patterns: some SSPs are rather highly correlated with each other, thus suggesting some potential SSP bundles. The same table also indicates that SSCs are poorly complementary or even independent (consulting and financing services for example). Table 5 demonstrates that some customer-oriented services are proposed with some specific product-oriented services: specifically, repairing is proposed with training, documentation is proposed with consulting or training with software. These relationships are confirmed by the positive correlation among residuals in the bivariate ordered probit model (Table 4) that further shows that some SSCs are proposed with some specific SSPs.

DISCUSSION AND CONCLUSIONS

This research examined whether technology and organizational changes facilitate servitization and whether they influence the structure of service portfolios offered by manufacturing firms. We further explored to what extent the influence depends on the type of PRS offered. In addition, we considered the hierarchy among the determinants of PRS strategy and their complementarity. The study's results indicated that product novelty is a main driver of PRS activities. It especially boosts consulting and training services. The structure of the PRS portfolio is depending on product novelty. Organizational change towards a more flexible company or the adoption of new advanced manufacturing processes is found, with few exceptions, to hardly influence the choice of PRS. However, our results suggest that process innovation is positively linked to the breadth of SSPs when organizational innovation drives the breadth of SSC offerings. Product, process and organizational innovation are not found to be complementary drivers of PRSs.

In the following, we first discuss our contributions to the literature and their managerial implications. We conclude by addressing the main limitations of our studies and research avenues.

CONTRIBUTIONS AND IMPLICATIONS

Our first contribution to the literature is to provide empirical evidence that technological innovation has to be reinstalled in the PRS debate, which has historically focused on the organizational dimension. Our results underline that technology is not separable from services (Mathieu, 2001; Gebauer et al., 2005; Baines et al., 2007, 2009); rather, technological novelty of products allows and supports the ability of firms to offer services. We further demonstrate that it is radical innovation is the primary determinant of PRSs and that the suggested critical influence of incremental innovation is reduced and linked only to the SSP number or training or consulting activities. This study is to our knowledge the first time that such a link has been clearly identified using a large multi-sector sample; the causality was, until now, only suggested or indirectly obtained in the literature (see Eggert et al., 2011; Sultan, 2013; Tongur and Engwall, 2014). The result offers clear consequences for the top managers who want to redefine their business model through services. It first indicates that the introduction of services is not a simple task that can be performed by every manufacturing firm: managers should first evaluate the degree of novelty of their products to identify related service opportunities. They should particularly pay attention to opportunities in consulting and training services when they are not at the technological frontier. Prospects in documentation services and repairing services are also to be explored.

Our results suggest that the literature considering process, product, services and organization as an integrated system is still a normative literature: it seems that it does not explain what is going on in industry, in which the development of PRSs is mainly driven by the degree of product novelty. It may, however, be argued here that organizational traits are an overall characteristic of servitized firms and are not a determinant of individual PRSs: a more flexible organization is required when many PRSs are to be coordinated, which may explain why the coefficients are downward biased. To check this idea, we employed a count model explaining the total PRS breadth computed as the sum of the seven possible PRSs (results available upon request) that confirms the positive role of organizational change. The results of this robustness check are thus broader that the one we obtained for SSPs and thus broader that Eggert et al.'s (2014) results. Managers should thus pay attention to improving the flexibility of their servitized organization when coordination of several PRSs is intended.

The importance of technology is critical also because PRSs depend on industry maturity as measured by its R&D intensity level. Our results indicate that PRSs are less prone to be delivered in (medium-tech) mature industries, at odds with the ideas that mature industries are more likely to propose services (see Teece 1986; Fang et al., 2008; Suarez et al., 2012). Our results also underline that some services are less prone to be delivered than others (Cusumano et al. 2014). If we consider that servitization is core to the transformation of business models (Visnjic et al., 2014), our article thus demonstrates that business model innovations do not occur only in mature industries (as in Sabatier et al., 2012; Massa and Tucci, 2013); rather, they are also more likely to emerge in medium-high-tech industries with more nascent traits even if high-tech industries are more prone to offer SSCs than SSPs. When firms are pioneers, top managers should thus pay more attention to complementing their product with PRSs when they are doing business in technological industries.

A second main contribution of our article is that we provide insights regarding the heterogeneity and complementarity of PRSs offered by manufacturing firms and their determinants. Our empirical results emphasize that pioneers implement PRS portfolios that differ from those of laggards. A difference between the determinants was even found for SSC and SSP classes. Still, an empirical classification is robust when there is an internal consistency of classes and thus when the determinants of PRSs are similar within SSP and SSC classes (see Gaiardelli et al., 2014 regarding service classifications). To test the robustness of the two classes, we tested the equality of the same coefficients inside SSC and SSP classes. In this case, the equality of the coefficients regarding technology and organization cannot be rejected (critical values are not reported but available upon request), thereby suggesting that the heterogeneity of determinants is rather between SSP and SSC classes than within SSP and SSC classes. The different results provide unexpected support for the conceptual classification of SSPs and SSCs often adopted after Mathieu (2001) (Antioco et al., 2008; Eggert, 2011, 2014).

A third contribution is that our analysis of the determinants of PRSs provides a path to solve the servitization paradox. Servitization in our model depends on product innovation; thus, the impact of servitization will differ depending on the proportion or leading firms in the sample or the repartition of firms among industries. Such sample selection, or a service variable that may be correlated with error terms in a service-performance equation, may introducing inefficiency and inconsistency in the estimation of parameters (see Hamilton and Nickerson, 2003). Our article contribute to the correction of sample selection biases or the specification of a more complex servitization-performance model where servitization is explained using an equation besides the main one regarding performance. A global implication of these clues is that the rate of return of PRSs may be different and higher than suggested by the literature. Despite the apparent failure of PRS strategies among industries, managers in charge of technological pioneers and flexible firms should be less averse regarding the apparently low rate of return of PRSs.

LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Due to data constraints, the model has been kept parsimonious. Consequently, some problems have been overlooked. The three main limitations we detail now – measurement, causality and dynamics - also delineate steps for future research.

The first limitation comes from the availability and the quality of the indicators. A limitation (Garcia and Calantone, 2002) already mentioned is that we do not know whether the different PRSs are innovative. Hence we explain the level of PRSs by technological change and organizational change[6], whereas changes in PRS strategies and a distinction between non-innovative and innovative services (not provided elsewhere by competitors) would be of great value. A second shortcoming is that the same type of PRS can cover different activities. For example, training sessions can be implemented to complement the introduction of new technological products, whereas they can also be provided for mature products. A service can be sometime classified either in an SSC or an SSP category (see Cusumano et al., 2014). A similar problem can be encountered for organizational change because a firm can adopt temporary decentralization routines to respond to particular customers (Tuli et al., 2007). Finally, some missing variables should also be mentioned. In the present article, we propose a focus on PRSs only. Our results are original because they avoid the noise and the difficulties inherent in disentangling PRSs (differentiation) from product-unrelated services (diversification). Still, in the present contribution, we were not able to control for product unrelated services, whereas the decisions regarding the two types of services could be interdependent and thus be investigated in a broader multivariate model.

The second main limitation in our analysis is linked to the causal links assumed in our model. Potential problems arise when the causality between the explanatory variables and the explained variables is taken into consideration. We contend that technology and organizational variables impact PRSs, whereas some scholars may advocate that services also drive firms to launch new (integrated) products (e.g., Levitt, 1976; Davies, 2004, Lindberg and Nordin, 2008) and therefore that product

[6] This type of shortcoming usually occurs in the economics of innovation, where scholars commonly explain the level of productivity by innovation (See Mohnen and Mairesse, 2010 for a survey). A first-difference approach is useful less for the precision it would bring to the present analysis of PRS changes than for the neutralization of hidden determinants that are specific to each firm and are not observed variables, assuming that these unobservable variables are time-invariant (Wooldridge, 2010).

innovation, process innovation and organizational changes may also be considered a consequence of PRS adoption. Firms learn from their customer when they enter into servitization; thus, they can use this accumulated knowledge to propose new products, new services and new organizational practices. We also considered a possible complementarity between innovation and organizational drivers whereby some sequences are possible: innovation could then be a determinant of organizational change (e.g., Henderson and Clark, 1990) or organizational change a determinant of product innovation (e.g., Zahra and Nielsen, 2002) or even AMT (Cardoso et al., 2012). We acknowledge these possibilities that would dilute the causal links we have claimed. In the present article, because of a lack a panel data, we can explain only one side of the story: PRSs are explained with lagged variables suggesting causality from innovation and organization towards PRSs. The aim to finally understand the complete causal links remains (see Visnjic et al., 2014), which leads us to avenues for future research.

A further step in this research would be to understand the frontiers of a servitized firms. Following Vargo and Lusch (2004), who redefined the service-centred activity of product firms, we can insist on the critical role of customers in the transformation of business models. The efforts performed by scholars to incorporate SSCs beside SSPs in servitization studies are thus a laudable but incomplete step. Following what has been performed for user innovation following Von Hippel's insights (1986), the identification of customers' characteristics and customer's roles into the servitization processes seems, in our point of view, vital. However, some competencies may rely on other types of cooperative links, crafted by firms to be able to servitize their products (Windahl and Lakemond, 2010). For example, software can be sub-contracted or elaborated with different types of suppliers (see Sabatier et al., 2012 for example), thus suggesting that analysis of PRSs requires a more open model of servitization à la Chesbrough (2003).

A second research avenue regards not the scope of PRS analysis but rather the analysis of servitization dynamics. The literature often considers cycles of exploration and exploitation activities. Considering radical innovation as an exploration phase, some PRS cycles should also occur within a manufacturing firm. Eggert et al. (2011) may suggest that the dominance of SSC and SSP should evolve over time: some PRSs may survive product replacement, whereas others may not (see Tripsas, 1997). An implicit assumption in the literature is that technological innovation does not destroy services. The counting of PRSs in a portfolio that we use in this article includes this potential PRS withdrawal. However, the analysis of PRS destruction or redefinition due to technological innovation remains to be measured and explored.

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Table 1: Definition of variables

Variable name	*Definition*
Dependent variables	
PRSYes*	Is set to one when at least one of the PRS listed above is proposed in 2006
CONSULT*	Conception, R&D, design, consulting offered as a service around the product in 2006
DOC*	Product documentation tendered as a service around the product in 2006
SOFT*	Software developments offered as a service around the product in 2006
FINANCE*	Leasing, renting, funding suggested as a service around the product in 2006
INSTALL*	Installing, launching the product supplied as a service around the product in 2006
TRAINING*	Training offered as a service around the product in 2006
REPAIRING*	Maintaining, repairing proposed as a service around the product in 2006
EXPLOITATION*	Product is operated by supplier for client in 2006
Independent variables	
Innovation var.	
$PRODUCT^{INCRE}$	Firms that introduced a new product that is not new to the market during the 2003-2005 period
$PRODUCT^{RADIC}$*	Firms that introduced a new product that is new to the market during the 2003-2005 period
PROCESS	Variety of new processes introduced during the 2003-2005 period as the sum of 11 different advanced manufacturing technologies.
FLEXIBLE ORG.*	Firms that introduced organizational innovation through the introduction of integration practices or decentralization practices during the 2003-2005 period.
Control variables	
YOUNG*	Firms created during the past three years (2003-2005)
SKILLED	Share of employees with 3rd level education in 2006
SUBCONTRACTOR*	Subcontractor or not in 2006
SIZE	Logarithm of numbers of employees in 2006
LOW TECH*	Low Tech industries
MIDDLE LOW TECH*	Medium Low industries
MIDDLE HIGH TECH*	Medium High Tech industries
HIGH TECH*	High Tech industries

*dummy variables

Table 2: Descriptive statistics

Variable	Mean	Std.Dev.	Min	Max
Explained variable				
PRSYes	0,88	0,33	0	1
CONSULT	0,74	0,44	0	1
DOC	0,60	0,49	0	1
SOFT	0,25	0,43	0	1
FINANCE	0,13	0,34	0	1
INSTALL	0,48	0,50	0	1
TRAINING	0,58	0,49	0	1
REPAIRING	0,46	0,50	0	1
Explanatory variables				
$PRODUCT^{INCRE}$*	0,30	0,46	0	1
$PRODUCT^{RADIC}$*	0,36	0,48	0	1
PROCESS	0,70	1,08	0	7
FLEXIBLE ORG.*	0,12	0,32	0	1
SKILLED	0,10	0,11	0	0,90
YOUNG*	0,11	0,31	0	1
SUBCONTRACTOR*	0,48	0,50	0	1
SIZE (log of employees)	4,50	1,14	2,3	10,1
LOW TECH*	0,15	0,36	0	1
MEDIUM LOW*	0,36	0,48	0	1
MEDIUM HIGH*	0,36	0,48	0	1
HIGH TECH*	0,13	0,33	0	1

Note: N is 1129

Table 3: The explained variables by our 3 main explanatory variables

	Product				Process				Flexible			
	No		Yes		No		Yes		No		Yes	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
N	386		743		668		461		994		135	
PRS Yes	0,80	0,40	0,92	0,27	0,85	0,36	0,93	0,26	0,87	0,33	0,93	0,26
CONSULT	0,64	0,48	0,79	0,41	0,71	0,46	0,79	0,41	0,73	0,44	0,80*	0,40
DOC	0,51	0,50	0,66	0,48	0,58	0,49	0,64	0,48	0,60	0,49	0,65*	0,48
SOFT	0,19	0,39	0,28	0,45	0,24	0,43	0,27*	0,45	0,24	0,43	0,30*	0,46
FINANCE	0,10	0,29	0,15	0,36	0,13	0,33	0,14*	0,35	0,13	0,34	0,15*	0,36
INSTALL	0,42	0,49	0,51	0,50	0,45	0,50	0,51	0,50	0,47	0,50	0,56	0,50
TRAINING	0,43	0,50	0,65	0,48	0,54	0,50	0,62	0,48	0,57	0,50	0,65*	0,48
REPAIRING	0,37	0,48	0,51	0,50	0,44	0,50	0,49*	0,50	0,45	0,50	0,57	0,50

* Equality no rejected at 5%

Process is 1 when at least one ATM is implemented over the period.

Table 4: The determinants of PRS offerings

Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Explained var.	PRSYes	CONSULT	DOC	SOFT	FINANCE	INSTALL	TRAINING	REPAIRING	SSC	SSP
Estimator	Probit				Multivariate Probit				Bivariate ordered probit	
Explanatory Var.	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t	coef/t
$PRODUCT^{RADIC}$	0,090***	0,515***	0,346***	0,142	0,028	0,168	0,616***	0,225**	0,243***	0,539***
	(5,160)	(0,111)	(0,102)	(0,109)	(0,131)	(0,103)	(0,103)	(0,104)	(3,017)	(6,493)
$PRODUCT^{INCRE}$	0,045***	0,252**	0,168	-0,117	-0,155	-0,054	0,198*	0,138	0,037	0,219***
	(2,576)	(0,108)	(0,102)	(0,115)	(0,131)	(0,101)	(0,102)	(0,101)	(0,442)	(2,581)
PROCESS	0,022**	0,074*	-0,021	0,022	-0,004	0,025	0,041	-0,006	0,042	0,164**
	(2,152)	(0,042)	(0,040)	(0,043)	(0,049)	(0,040)	(0,041)	(0,041)	(0,635)	(2,476)
FLEXIBLE ORG.	0,025	0,098	0,096	0,109	0,019	0,213	0,170	0,324**	0,181*	0,158
	(1,031)	(0,138)	(0,132)	(0,132)	(0,166)	(0,133)	(0,135)	(0,134)	(1,846)	(1,635)
SKILLED	0,005***	0,033***	0,026***	0,022***	0,004	0,027***	0,017***	0,022***	0,025***	0,021***
	(3,218)	(0,006)	(0,005)	(0,005)	(0,005)	(0,004)	(0,005)	(0,005)	(6,669)	(6,574)
YOUNG	-0,022	-0,077	-0,169	-0,595***	-0,172	-0,173	-0,198	-0,193	-0,293***	-0,137
	(-0,666)	(0,144)	(0,135)	(0,165)	(0,181)	(0,129)	(0,132)	(0,139)	(-2,707)	(-1,187)
SUBCONTRACTOR	-0,027	0,052	-0,083	-0,167*	-0,468***	-0,227***	-0,583***	-0,387***	-0,245***	-0,385***
	(-1,571)	(0,088)	(0,083)	(0,094)	(0,107)	(0,082)	(0,085)	(0,084)	(-3,663)	(-5,807)
SIZE	-0,012	0,017	0,069***	-0,102***	-0,099***	0,013	0,084***	0,031	-0,030	0,073**
	(-1,440)	(0,024)	(0,022)	(0,023)	(0,024)	(0,022)	(0,022)	(0,022)	(-0,977)	(2,383)
LOW TECH	-0,128***	-0,148	-1,089***	-0,920***	-0,589***	-0,950***	-0,654***	-1,227***	-1,231***	-0,499***
	(-3,095)	(0,125)	(0,119)	(0,145)	(0,146)	(0,125)	(0,122)	(0,132)	(-11,151)	(-4,413)
MEDIUM LOW	-0,045*	-0,036	-0,567***	-0,896***	-0,956***	-0,485***	-0,581***	-0,641***	-0,735***	-0,498***
	(-1,882)	(0,099)	(0,093)	(0,110)	(0,137)	(0,092)	(0,096)	(0,093)	(-9,383)	(-6,070)
HIGH TECH	-0,023	-0,417***	-0,316**	0,174	-0,568***	-0,450***	-0,299**	-0,082	-0,167	-0,475***
	(-0,632)	(0,151)	(0,139)	(0,137)	(0,179)	(0,141)	(0,145)	(0,136)	(-1,451)	(-4,530)
Log-Likelihood	-368,90				-3617,9				-2712,4	
H0: All coeff. =0	78,3***				645,35***				321,4***	
H0: All residuals' corr.=0					1129,7***				343,3***	
H1: Radic coeff. = Increm.coeff.	4.64**	6.64***	321,4***	4.15**	0.79	6.25**	17.54***	0.93	6.56**	16.33***
H4a: Radic coeff.= Process coeff.	1.36	13.75***	9.30***	2.83*	1.52	1.27	28.71***	3.73*	7.02***	27.26***
H4a: Radic coeff.= Flexible coeff.	3.90**	5.58**	2.52	0.08	0.29	0.28	6.82***	0.51	0.20	8.37***
H4a: Increm coeff.= Process coeff.	0.32	1.90	1.96	0.05	0.19	1.47	2.56	0.91	0.13	3.08*
H4a: Increm coeff= Flexible coeff.	0.33	0.67	0.08	0.87	0.00	4.22**	0.01	1.71	1.28	0.62
H4a: Process coeff. = Flexible coeff.	0.03	0.00	0.58	0.70	0.08	2.20	1.14	5.64**	2.72*	0.38
H5: All radical coeff equal					23.55***				13.91***	
H5: All incremental coeff equal					11.20*				5.33**	
H5: All process coeff equal					5.76				3.17*	
H5: All flexible coeff equal					2.96				0.09	

Note: .01 - ***; .05 - **; .1 - *, N=1129. No product innovation and Medium-High Tech are taken as the references. The independence of equation (2) to (8) is rejected (the critical value is 1129.3, p<0.01). The same is true for the independence of equation (9) and (10) (the value is 343,3,p<0.01). In other words, the decisions regarding the different PRSs are not made independently. The multivariate models were implemented using the Geweke-Hajivassiliou-Keane (GHK) simulator to evaluate the integrals in the likelihood function. The coefficients in column (1) are marginal effects, but those in columns (2) to (10) are not. The marginal effects for columns (2) to (8) are reported in Table 5. The Wald tests are two-tailed tests.

Table 5: Correlations among the residuals of the multivariate probit model

		(1)	(2)	(3)	(4)	(5)	(6)
(1)	CONSULT	1					
(2)	DOC	0,62	1,00				
(3)	SOFT	0,36	0,58	1,00			
(4)	FINANCE	0,15*	0,37	0,43	1,00		
(5)	INSTALL	0,41	0,62	0,47	0,42	1,00	
(6)	TRAINING	0,31	0,51	0,58	0,29	0,52	1,00
(7)	REPAIRING	0,30	0,63	0,53	0,43	0,84	0,60

Note: * significant at the 10% level; all other correlations are significant at the 1% level.

Table 6: Partial effects of the multivariate probit model

	(1) CONSULT	(2) DOC	(3) SOFT	(4) FINANCE	(5) INSTALL	(6) TRAINING	(7) REPAIRING
$PRODUCT^{RADIC}$	0,066	0,014				0,067	0,008
$PRODUCT^{INCRE}$	0,037					0,024	
PROCESS	0,011						
FLEXIBLE ORG.							0,028
SKILLED	0,004	0,001	0,005		0,002	0,001	0,001
YOUNG			-0,217				
SUBCONTRACTOR			0,031	-0,147	-0,004	-0,068	-0,022
SIZE		0,004	-0,045	-0,031			
LOW TECH		-0,051	-0,204	-0,067	-0,039	-0,038	-0,076
MEDIUM LOW		-0,025	-0,215	-0,258	-0,007	-0,048	-0,023
HIGH TECH	-0,067	-0,012	0,187		-0,050	-0,040	

The partial effects are computed considering the expected value of one PRS given that all other PRSs equal one. For example, the expected value of CONSULT given that all other PRS are equal to one is $E_{CONSULT}(CONSULT = 1|DOC = 1, SOFT = 1, \dots REPARING = 1)$. The derivative of the expected value with respect to all explanatory variables ($\frac{\partial E_{CONSULT}}{\partial x}$) is computed as the weighted average of the effects calculated in each observation and combined across the multiple imputations. Every column took 111 iterations and 15 hours to converge using a BFGH algorithm (with a 2.3-GHz i5 processor). To avoid confusion, partial effects are reported only for parameters significant in Table 4. Standard errors computed by bootstrapping are not reported.