Knowledge sharing dynamics in service suppliers' involvement for servitization of manufacturing companies

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Abstract

Manufacturing companies that adopt the servitization strategy usually show lack of knowledge regarding the service offering associated to their manufactured products. Acquiring external knowledge from service suppliers can be a way to tackle this problem. The objective of this study is to understand how manufacturing companies aiming at a servitization-driven business model innovation (BMI) integrate such knowledge from service suppliers. We focus on different types of collaboration that can occur and on the knowledge sharing (KS) dynamics of this collaboration. We employ a multiple-case study approach to analyze nine BMI processes from companies that transformed their traditional business model (BM) to a servitized BM. As a result, we obtain a theoretical framework that presents six possible KS dynamics for the servitization design by originally combining two main approaches for servitization-driven BMI (i.e. product-oriented and service-oriented product-service systems) and three main configurations of relationships with service suppliers based on traditional new product development classifications of buyer-supplier integration (i.e. white, grey and black box configurations). Implications of combining a BMI and a buyer-supplier KS perspectives to investigate the process of servitization for manufacturing companies are then discussed.

Keywords: Business model innovation; servitization; product-service systems; knowledge sharing; buyer-supplier integration

1 Introduction

Several manufacturing companies are innovating their existing Business Models (BMs), traditionally centered in product offering, by adding services to their products or by delivering these products as services (Brax and Visintin, 2016; Kohtamaki et al., 2013). This change is considered a form of Business Model Innovation (BMI) (Kindström and Kowalkowski, 2014) and was originally termed 'servitization' by Vandermerwe and Rada (1988). Servitization aims to create additional value to customers by offering a whole solution in the form of a Product-Service System (PSS), which is more difficult to be imitated, thus helping to reduce the threat of product commoditization (Baines et al., 2007; Chesbrough, 2011; Lindahl et al., 2014). Servitization can also determine higher and more stable profits, especially during economic downturns (Babu and Sachi, 2014).

The extant literature highlights some challenges that manufacturing companies are facing when dealing with servitization. Firstly, the adoption of a servitization strategy involves risks and uncertainties for the company, since it implies an important change in the BM that can impact directly on performance (Benedettini et al., 2015; Suarez et al., 2013). Secondly, changes may be needed in the manufacturing supply chain configuration and coordination, as new partners become relevant both for setting up the PSS offered and for sharing and reducing the associated business uncertainties and risks (Paiola et al., 2013; Saccani et al., 2014). These challenges are related to a deeper necessity: manufacturers need service knowledge in order to face such a BMI. Service-related knowledge is significantly different from that necessary for pure products design, and it may be hard for manufacturers to generate such kind of new knowledge by themselves (Alghisi and Saccani, 2015). Consequently, authors suggest that in order to support a servitization-driven BMI, manufacturers should acquire service knowledge from external service suppliers, these suppliers being an external organization or another business unit of the same company (Martinez et al., 2010; Windahl and Lakemond, 2006; Bastl et al., 2012; Davies, 2004; Lockett et al., 2011). Some examples on well-established manufacturing companies illustrate what the literature reports. Focusing on the automotive industry to allow comparability, one example is the collaboration between Fiat-

Chrysler and Google, where the two companies are merging their engineering teams to develop self-driving cars (Reuters, 2016b). Both companies want to keep their focus on their own core capabilities during the development of PSS solutions. Their servitization strategy faces the challenge of coordinating joint product development activities from two different teams, since differences in culture, knowledge, and development methods, can be barriers among them. Another automotive company, General Motors (GM), invested in Lyft, its car-sharing service partner; as part of the agreement, GM participates in Lyft's board (Reuters, 2016b). This allows GM to access to the partner's future plans and decisions. The servitization challenge in such case is how to gather access to strategic knowledge from the partner in order to keep the control of the business. Challenges are different in both cases regarding the buyer-supplier integration, the coordination mechanisms and the knowledge sharing dynamics between the partners.

Therefore, prior works highlighted that such manufacturer-service provider partnerships are only successful if they are carefully managed, which implies creating strong links of information and knowledge exchange (Bastl et al., 2012; Johnson and Mena, 2008; Lockett et al., 2011; Windahl and Lakemond, 2006). As Lockett et al. (2011) affirm, the adoption of a servitization strategy can have a negative effect on manufacturing companies if the relationship with suppliers is not correctly defined. In this line, studies suggested that different forms of collaboration and level of interaction with suppliers can be established in servitization, as also shown in the two examples above (Davies et al., 2007; Finne and Holmström, 2013; Hakanen and Jaakkola, 2012; Kowalkowski et al., 2011; Nordin, 2008). The proper level of suppliers' involvement may depend on aspects such as: the financial objectives of servitization and the desired level of contact with customers (Saccani, 2012); the service component's characteristics (Paiola et al., 2013; Saccani et al., 2014); the complexity of the solution (Finne and Holmström, 2013); and the level of servitization targeted (Bikfalvi et al., 2013), among others. However, there is a gap in the literature which consists in a lack of understanding on how manufacturing companies can involve potential service suppliers in a servitization strategy and how knowledge can be acquired from these suppliers to better face a servitization-driven BMI (Chirumalla, 2013; Hakanen, 2014; Leoni, 2015; Martinez et al., 2010; Reim et al., 2015; Windahl and Lakemond, 2006).

The integration of external knowledge sources by means of Knowledge Sharing (KS) activities has been a typical concern in other research fields (e.g. Athaide and Klink, 2009; Le Dain and Merminod, 2014; Petersen et al., 2005) and it can constitute an insightful theoretical lens for a better understanding of the problems identified. In this sense, KS can present different dynamics depending on the type of the buyer-supplier integration (Le Dain and Merminod, 2014) and on the type of servitization-driven BMI adopted (Bastl et al., 2012; Johnson and Mena, 2008). The analysis of such dynamics can shed light on the existing gap regarding how manufacturers can acquire knowledge from service suppliers in different servitization contexts. Therefore, the following research question emerges and is addressed in this study: *How do manufacturing companies aiming at servitization-driven BMI integrate knowledge from service suppliers?*

This research question considers companies that are evolving from a traditional manufacturing BM to a new servitized BM focused on different levels of PSS. Moreover, our research question contributes to the existing state-of-the-art by addressing the servitization transformation leveraging an unexplored approach, which stems from the integration of two different research fields that deal with servitization (i.e. BMI and buyer-supplier relationship for collaborative New Product Development), investigated through the theoretical lenses of knowledge management.

Consequently, the aim of this study is to understand the possible KS dynamics that happen in the service suppliers' involvement for a servitization-driven BMI in manufacturing firms. Using a KS theoretical perspective to address the suppliers´ involvement in the servitization context, we first bridge these two fields in a conceptual framework, and then we apply it in the analysis of a multiple case study on seven multinational companies in order to deepen the understanding of this phenomenon. Therefore, we explore the relationship between several differences concepts: we first classify product-service systems (PSS) offering into two different BMI orientations for servitization (product or service orientation) and then we relate such classification to three different types of NPD supplier involvement (black, grey and white box). Finally, the dynamics of KS in these different combinations is studied based on three main levels of KS:

transfer, translation and transformation. As a result, we present a final theoretical framework for KS dynamics between the manufacturing companies and their service suppliers.

The main research contribution from this work is that the proposed framework reveals different KS dynamics and intensities that can happen between the manufacturer and their service suppliers, as well as it explains how the KS dynamics are affected by the type of collaboration and the servitization strategic orientation adopted by the company. We show that, by integrating these perspectives, it is possible to obtain a more fine-grained description about the levels of KS among the involved actors. We also discuss different servitization strategies manufacturing companies may want to pursue, based on speed of implementation and level of dependency on service suppliers. In this sense, while some types of collaboration and BMI orientation will require higher levels of KS, resulting in the development of internal service capabilities in the manufacturing company, other configurations could be more appropriate for a faster implementation of servitization or for a less risky BMI. Therefore, different configurations of BMI and suppliers' involvement are discussed in our results.

2 Theoretical background

2.1 Servitization as a manufacturing business model innovation

The servitization strategy consists in an integration process of products and services into a system – widely named as Product-Service System (PSS). It requires a new form of organizing the manufacturing company and its stakeholders to provide functionality to consumers (Beuren et al., 2013; Manzini and Vezzoli, 2003). Therefore, it is considered as a BMI in the context of the traditional product development and manufacturing system (Ceschin, 2013; Visnjic et al., 2016). A company can target different levels of PSS in the servitization strategy (Bikfalvi et al., 2013). Consequently, the BM can undergo different degrees of transformation, from incremental BMI, where the central value proposition (i.e. the BM's "what and why" according to Mitchell and Coles, 2004) does not change dramatically (although other BM components may vary), to radical BMI, where the value architecture changes significantly (Teece, 2010; Cortimiglia et al., 2016; Massa et al., 2017). At initial levels (i.e. incremental BMI), the company offers the core product and

also some related services such as logistics and distribution, installation and commissioning, maintenance and upgrades, personal support and training (Durugbo, 2014; Wang et al., 2016). A more radical level of BMI (i.e. a deeper level of BM transformation) implies that the company will offer the product itself as a service, such as Rolls-Royce's offering of 'power-by-the-hour' instead of selling aero-engines (Baines et al., 2007).

Particularly, in this study we are considering manufacturing companies that keep their competence in technology, product development and manufacturing, and need to change the way such products are offered and commercialized. These companies might not want to abort their manufacturing activities, but need to transform how they offer their products and how they deal with customers – which are both key parameters of a BM (e.g., see Mitchell and Coles, 2004). Following Galbraith (2002) and Matthyssens and Vandenbempt (2010), a manufacturing company may choose between two main BMI orientations in their servitization strategy: (i) a product-oriented PSS, where changes are incremental the PSS design is more focused on finding as many uses as possible for the company´s products, and services are developed to improve or boost product utilization, e.g. maintenance, spare parts, upgrades, project engineering; or (ii) a service-oriented PSS, where changes are more radical and the PSS design is more customer-centered, i.e. more concerned with customer needs than with sales of products, which implies thinking about new solutions for customers which may not be restricted to products currently offered.

2.2 Knowledge sharing perspective for the involvement of service suppliers

The manufacturing company can offer different levels of PSS in the servitization strategy adopted. However, the more complex the PSS is, the greater the gap between what the company knows and what it really needs to offer the solution will be (Chirumalla, 2013; Leoni, 2015; Pawar et al., 2009). Such knowledge gap can be approached and diminished with the support of service suppliers (Davies, 2004; Kindström and Kowalkowski, 2014). In some cases, while the product is provided by one organization, the service component can be exclusively supported by a partner (Martinez et al., 2010; Windahl and Lakemond, 2006),

but other combinations and joint PSS development are also possible where different KS is needed among partners.

KS is considered as a process comprising two main actions: (i) the knowledge movement from a source to a recipient, and (ii) its subsequent absorption and use, taking advantage of previous experience (Frank et al., 2015). In our case, the sources are the service suppliers who hold relevant service knowledge for the business, and the recipient is the company's manufacturing business unit that is innovating its BM supporting a servitization strategy. From the different existing perspectives of KS (e.g. Frank and Ribeiro, 2012; Hooff and Huysman, 2009), in this study we adopt Carlile´s (2004) 3-T model. We also adopt the term KS instead of knowledge transfer to refer to knowledge moving between source and recipient, using a social perspective between actors (Frank and Ribeiro, 2014; Hooff and Huysman, 2009). We adopt this perspective following the same point of view of the conceptual framework for NPD collaboration proposed by Le Dain and Merminod (2004), which is used for our case study analysis. As observed in Figure 1Figure, Carlile's (2004) 3-T model distinguishes three levels of KS complexity across boundaries between actors involved in an innovation process: *transfer, translation* and *transformation*.

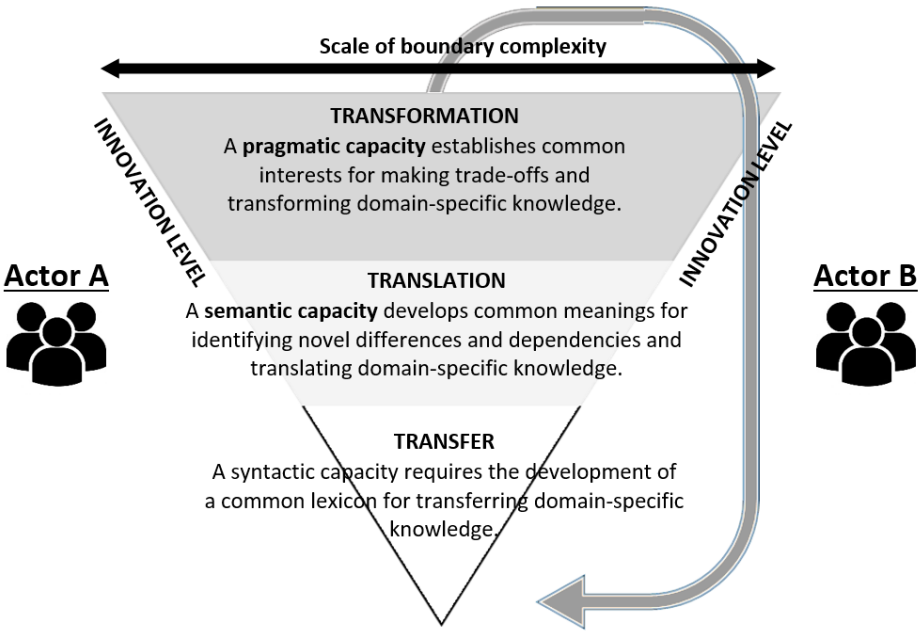

Figure 1 – 3-T framework to manage knowledge across boundaries

(Source: Adapted from Carlile, 2004)

The 3-Ts (*transfer, translation* and *transformation*) of Carlile's (2004) model are related hierarchically. According to the level of innovation, the actors will move up and down through the different levels of cross-knowledge complexity. Then, when the innovation level increases, knowledge transfer is necessary for the knowledge translation while the knowledge transformation process requires both transferring and translation; thus, the transfer knowledge process is at the basis of the framework. The loop in Figure 1 indicates that, because of the complexity, managing knowledge across a pragmatic boundary cannot be resolved with just one attempt: it requires multiple iterations. During the interaction of sharing and assessing knowledge, the actors will create new agreements and will make changes, developing a common lexicon, with shared meanings and interests to access knowledge across the boundary (Carlile, 2004; Le Dain and Merminod, 2014). In the following sections, we discuss in detail the meaning of each of these three levels of KS.

2.2.1 Knowledge Transfer

In this first level of KS – *transfer of knowledge* – knowledge is considered external, explicit and storable. In this case, knowledge can be transferred mainly using information processing tools, e.g. the implementation of a product data management system that provides a common workspace where product data can be shared (Carlile, 2004; Le Dain and Merminod, 2014). At the knowledge transfer level, the primary concern is about the syntactic capacity needed to develop a common lexicon that can be used to cross the boundary. If the level of innovation increases, merely transferring knowledge is not enough anymore because the current lexicon is no longer sufficient to represent the differences and dependencies (Carlile, 2004). In practice, knowledge transfer can be identified when an exchange of boundary objects between the actors occurs. Boundary objects are objects or documents that are created and used during collaborative activities, e.g. requirement specifications and timelines, prototypes, design drawings and e-mails (Carlile, 2004; Le Dain and Merminod, 2014).

2.2.2 Knowledge Translation

According to Carlile (2004), when the level of innovation grows, the complexity of KS increases and a transition is needed from a syntactic to a semantic or interpretative boundary, since some differences and dependencies become unclear and some meanings can be ambiguous. In this level, called *knowledge translation,* the complexity of knowledge naturally generates different interpretations, thus making it necessary to use mechanisms to create a shared meaning between actors in order to cross this new boundary. The creation of common meanings can become more than just a translation process; it can be a negotiation process of interests between actors that could result in a learning cost for some stakeholders. In practice, knowledge translation can be identified when there is a discussion between actors to avoid knowledge misunderstanding (Carlile, 2004; Le Dain and Merminod, 2014).

2.2.3 Knowledge Transformation

Finally, in the highest level of innovation, there is a transition from a semantic to a pragmatic boundary, where a solution has to be found for divergent actor interests. In this process, actors not only have the

learning cost of accepting a new knowledge, but they have to transform their existing domain-specific knowledge, and even the common knowledge, to be able to effectively share and assess knowledge at the boundary (Carlile, 2004). This stage is called *knowledge transformation* and is the most complex boundary, because the cost of transforming current knowledge can negatively affect the willingness of the actor to make the necessary changes. In practice, knowledge transformation activity can be identified when a complex problem-solving situation occurs during a project and it results in the building of a new solution (Carlile, 2004; Le Dain and Merminod, 2014).

2.3 Buyer-supplier integration approach to study KS in service suppliers' involvement

Buyer-supplier integration is a core topic in the new product development (NPD) literature, where there is concern about how to develop product solutions together with those suppliers that detain knowledge about materials and technologies which is complementary to what the main company knows (Koufteros et al., 2007; Ragatz et al., 2002).

Petersen et al. (2005) argue that the inter-organizational relationship between suppliers and buyers during an innovation process may be divided in three configuration levels, according to the supplier's involvement: (i) White Box (design is buyer-driven), (ii) Grey Box (joint design) and (iii) Black Box (design is supplier-driven). In the *White Box* level, the buyer is responsible for the whole design and specification of the solution and the supplier is mainly involved in the late project stage, commonly the execution stage. In the second level of buyer-supplier integration, the *Grey Box* configuration, the design solution activity is strongly integrated and none of the stakeholders has all the necessary knowledge; therefore, both supplier and buyer have the same level of responsibility and importance in the design. Consequently, stakeholders and buyer work in deep collaboration from the beginning of the project until the execution phase. Finally, in the *Black Box* configuration, the major responsibility falls on the supplier, who is in charge of both designing and executing the solution based on buyer's requirements and specifications. In this configuration, the buyer provides the functional requisites at the beginning of the project and the supplier

uses its expertise to interact with the buyer in order to clarify needs and to develop the adequate solution (Le Dain and Merminod, 2014; Petersen et al., 2005).

Studying the supplier' involvement in the collaborative NPD context, Le Dain and Merminod (2014) operationalized Carlile's (2004) framework by investigating how such KS framework explains the three types of supplier's involvement configuration. Le Dain and Merminod (2014) demonstrated that the dynamic of KS varies according to the supplier's involvement configuration, as illustrated in Figure 2. According to their results, the White Box configuration mainly consists in transferring knowledge, but this potentially generates knowledge translation to enable process capabilities and requirements to be integrated into the product design. The Grey Box configuration requires high knowledge transfer, translation and transformation and the process has a cyclical dynamic. In the Black Box configuration, a high knowledge transfer, substantial knowledge translation and medium knowledge transformation during the design phases to clearly define specifications are required, though, differently from the White Box configuration, in this case knowledge transfer calls for knowledge translation.

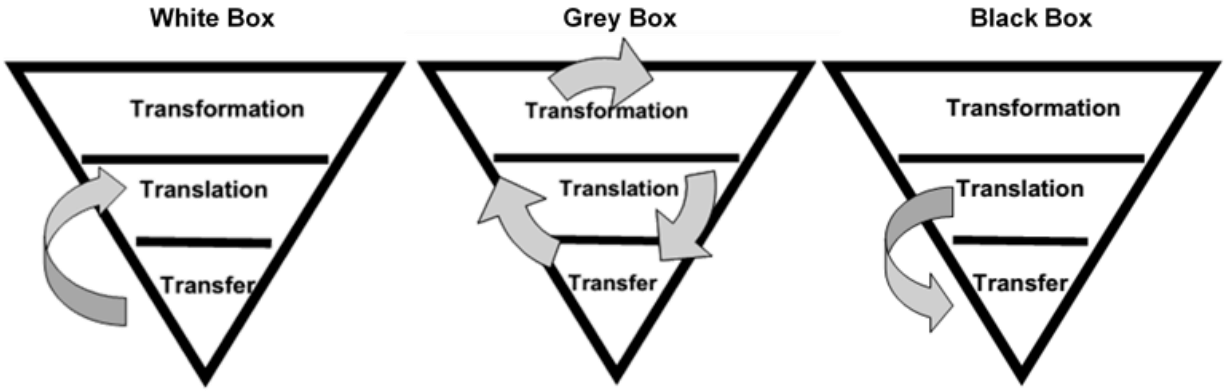

Figure 2 – Knowledge sharing dynamics for White, Grey and Black Box supplier's involvement configuration in collaborative NPD according to Le Dain and Merminod (2014)

Several authors stress the importance of knowledge management in the process of BMI for servitization (e.g. Belal et al., 2012; Chirumalla, 2013; Hakanen, 2014; Leoni, 2015). Therefore, as the most intensive KS in servitization happens between business units and their service suppliers, it becomes imperative to profoundly analyze this specific relationship and the possible ways of interaction (Martinez et al., 2010;

Windahl and Lakemond, 2006). Thus, we propose to adapt this understanding of KS activities in different types of NPD supplier's involvement to the context of BMI for servitization, as discussed in the following section.

2.4 Adapted framework for the innovation of solution business models

In the light of the theoretical background discussed, our study proposes to adapt the Le Dain and Merminod's (2014) framework to the relationship between a manufacturing company and its service suppliers in the context of BMI for servitization. We assume that this adaptation may be valuable for three reasons. First, servitization requires an involvement of external agents that implies to bring in external knowledge so as to integrate the internal one, similarly to what happens in the buyer-supplier integration in NPD (Martinez et al., 2010; Windahl and Lakemond, 2006). Second, the level of servitization chosen by the company can lead to different levels of complexity in BMI (Bikfalvi et al., 2013) and, consequently, to different levels of relationship with the service suppliers (Finne and Holmström, 2013), resulting in different configurations of such relationship – i.e. White, Grey and Black Box configurations. Third, in line with what happens in buyer-supplier integration, there is a need to understand the different KS dynamics that can occur for different configurations of service suppliers' relationship during the servitization-driven BMI (Bastl et al., 2012; Johnson and Mena, 2008). Therefore, we propose an adapted framework by joining the traditional research stream of buyer-supplier relationship in NPD to the recent research field of BMI for servitization.

Figure 3 introduces the conceptual framework that will guide our case study analysis. Following the BM orientation adapted from Galbraith (2002) and Matthyssens and Vandenbempt (2010) (as discussed in Section 2.1), we propose a classification of servitization-driven BMI into two main levels of value offering: (i) product-oriented PSS, where the tangible good is the most important part of the PSS offering and only goes through limited changes to complete the solution package, being service the most flexible part; and (ii) service-oriented PSS, where the service becomes the central aspect of the value-proposition for customers and the product can be flexible and adapted according to the service offering. In other words,

the product-oriented classification is a pushed-process, where the product usage triggers the opportunity to add new services to become more valuable for customers. In contrast, the service-oriented classification is a pulled-process, since new service opportunities for customers are the trigger for the creation of a servitized solution, similarly to the market-pull innovation concept (Rothwell, 1994). Additionally, in Figure 3 we propose that both BMI orientations for servitization can present different configurations of suppliers' involvement (as explained in Section 2.3). In this sense, we followed Petersen's et al. (2005) supplier's involvement configuration. As a result, in each intersection between the BMI for servitization and the types of service suppliers' involvement, we aim to collect data from the manufacturing companies studied regarding the integration modes, i.e. how integration happens between the company and the service suppliers; and, especially, we aim to understand how KS happens regarding the KS levels of Carlile (2004) previously treated in Section 2.2.

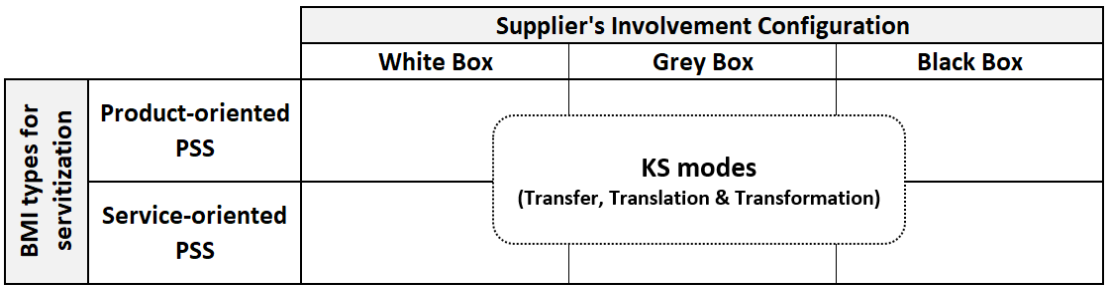

Figure 3 – Conceptual framework: KS modes in different configuration of servitization-driven BMI and service suppliers' involvement

3 Research Method

We adopted an empirical case study research approach based on qualitative data collection and analysis (Yin, 2009). We choose this research approach because it is useful for theory building based on a deep analysis of the field (Eisenhardt and Graebner, 2007; Yin, 2009). We selected a multiple-case approach rather than single-case analysis to augment external validity and to reduce the potential observer's bias (Voss et al., 2002). We employed the proposed conceptual framework (Figure 3) to ground the research and to guide our empirical study. The research design was based in Voss et al. (2002) guidelines, which is described next.

3.1 Case study selection

The cases were selected by means of a theoretical sampling. According to Eisenhardt and Graebner (2007), theoretical sampling means that cases are selected because they are particularly suitable to shed light on constructs. As a first step to identify the companies that could have the requisites to fulfill at least one of the quadrants of our conceptual framework (Figure 3), we considered an ongoing survey[1] on servitization carried out in an industrial research network coordinated by two Universities (Italy and Brazil), and we identified 95 manufacturing companies that affirmed to have a strong collaboration with service suppliers. We selected 39 of them that are large multinational companies (>500 employees) to take firm size and related complexity into account. We scrutinized the companies' profile and made a first telephone or e-mail contact to verify their availability and adequacy to our research propose. We intentionally chose companies from different industries and with different relationships with their service suppliers, aiming to produce contrasting results that can offer a broader picture on the phenomenon and facilitate the generalization of the results (Ceschin, 2013; Yin, 2009). On the basis of the information received, we selected seven companies; in two of them, we analyzed two different independent business units, i.e. we chose the company's business units (BU) as unit of analysis. Thus, we obtained nine different cases from seven different companies.

We analyzed servitization at this level because different BUs can have their own BM (Cortimiglia et al., 2016): therefore, as a potential service supplier we considered either another BU from the same company with independent processes and incomes, or a different company. In both situations, we considered the BU that developed traditionally manufactured products and implemented a servitization-driven BMI as the central BU of analysis; while other BUs or companies focused on service activities were considered the potential service suppliers. In the BUs where the PSS offering follows a service-oriented PSS, i.e. each solution is developed as a customized project for the client, we asked the interviewees to consider the

[1] To ensure anonymity of the double-blind review process, information of this survey can be provided upon request after the review process is completed.

service supplier integration to the most typical PSS offering that is developed. Table 1 provides a brief description of each case study; companies' and respondents' names were changed to preserve anonymity[2].

Table 1: Background of the cases

Case company	Description	Size	Business Unit analyzed	Data sources	Years in the company
A	German international company from dental/medical sector	+1,000 employees	Brazilian branch	Latin America (LA) CEO	12
				Service development engineer	4
				Service support consultant 1	4
				Service support consultant 2	3
B	US multinational company from the IT industry focused in computer, hardware and IT services	+ 100,000 employees	Computer BU	LA service sales manager	7
				Service solution manager 1	8
			Hardware BU	Service solution manager 2	5
C	Brazilian national company from tailor-made furniture market	+1,000 employees	Headquarters (HQ)	CEO	17
				Supply chain director	14
				Sales manager	8
				Purchasing manager	11
D	Swedish multinational from telecommunications industry.	+ 100,000 employees	Telecom hardware BU TV and Media systems BU	Senior project manager	10
				Product engineer	3
				Service sales manager	9
E	Swiss multinational from energy and automation industry	+ 140,000 employees	Spanish branch	Senior project manager	12
				Regional service manager	15
				Consultancy engineer	6
F	French multinational from energy industry	+ 150,000 employees	Field Service BU	Service Manager	2
				Company's consultant 1	-
				Company's consultant 2	-
G	US multinational from process and motion control.	+ 8,000 employees	Brazilian branch	Supply chain manager	15
				Purchasing analyst	1
				Sales engineer	4

3.2 Research instruments

As a primary source, we employed semi-structured interviews where we first asked the interviewees to describe their servitization case and the suppliers' integration characteristics. Moreover, to assess the level

[2] The companies' identification and contacts were provided to the editorial board of this journal in order to assure the transparency of the data collection process.

of intensity of KS (Figure 2), we followed the scale proposed by Le Dain and Merminod (2014) which considers the numbers of KS situations during the collaboration. For the knowledge transfer level, they propose to measure the intensity as the number of existing Boundary Objects (BOs) (i.e. objects such as documents or models used to support cross-boundary discussion with suppliers), as well as the number of iterations on these BOs (i.e. how many times the partners have worked together on the BOs). Knowledge translation can be measured as the number of situations (meetings) needed to prevent misunderstandings and the number of project members involved in these situations. Finally, knowledge transformation can be measured as the number of complex problem-solving situations faced during the project and the time needed to solve such problems.

Since we have had no access to the information systems of the nine companies to obtain the quantitative data on KS intensities, as in Le Dain and Merminod (2014), we adapted the use of this scale. We asked the interviewees to assess qualitatively the KS intensities using the abovementioned scale as a reference (see Table 2). Moreover, we asked them to give arguments and examples to support their estimations about these intensities levels and this information was still contrasted with other qualitative descriptions they provided during the interviews. When any discrepancy was identified, we used a second round of interviews to clarify such differences and to achieve a consolidated understanding about the KS levels. A first version of the research protocol, composed by the questionnaire and the KS scale, was pretested with five researchers from our research group and one experienced manager of a manufacturing company. Moreover, a first interview round in Company D was used as a pilot for the research protocol. We then improved our research protocol (by rephrasing questions that were not clear to the interviewees) and we performed again a second round of interview with this company.

Table 2: Indicative scale to measure the level of intensity of knowledge sharing.
(Source: adapted from Le Dain and Merminod, 2014)

Concept	Variable	Measure (orientation for interviews)	Intensity
Knowledge Transfer	Number of boundary objects (BOs) exchanged: e.g. documents, e-mails, specifications, prototypes, drawings.	- Limited number of BO: < 50 BOs and Limited iterations on BOs (<3 versions in average per BO)	Limited
		- Limited number of BO: <50 BO and numerous iterations on BOs (>3 versions in average per BO) OR high number of BO: >50 and Limited iterations on BOs (<3 versions in average per BO)	Medium
		- High number of BO: >50 and Numerous iterations on BOs (>3 versions in average per BO)	High
Knowledge Translation	Number of situations where efforts are made to avoid sticky knowledge misunderstandings.	- Limited situations to avoid sticky knowledge: <5 and Limited participation of project members (Engineering & Service)	Limited
		- Limited situations to avoid sticky knowledge: <5 and High participation of project members (all or almost all project members) OR Numerous situations to avoid sticky knowledge: >5 and Limited participation of project members.	Medium
		- Numerous situations to avoid sticky knowledge: >5 and High participation of project members (all or almost all project members)	High
Knowledge Transformation	Number of complex problem solving situations which result in the building of a new solution	- Limited number of complex problem solving situations: <5 and problem solved quickly	Limited
		- Limited number of complex problem solving situations: <5 and short problem solving duration OR numerous number of complex problem solving situations: >4 and long problem solving duration	Medium
		- Numerous number of complex problem solving situations:>5 and long problem solving duration	High

3.3 Data collection

For data collection, we used different sources of information to improve reliability of our analysis (Yin, 2009). Specifically, to enhance reliability of data collected from interviews, we interviewed at least three persons that participated directly; in the development of the PSS offering, such as key managers and product, project and service engineers (see **Erro! Fonte de referência não encontrada.**). In all cases, we collected data from the main company side, and this company provided us with information about its suppliers. We did not collect data from suppliers, since the access to them was restricted by the companies because of the strategic and sensitive nature of the information required. Due the complexity of the information demanded, some days before the interview we sent an outline of the research protocol to interviewees, so that they could be prepared and also collect the documentation to support their statements (Voss et al., 2002). The average time of each interview meeting was around two hours. In two cases, the interviews were made by videoconference. During data collection, we used an audio recorder

and written notes to record the impressions and comments from participants. The notes were taken by three researchers, two are authors of this paper and the third is a research assistant: such approach helped to confront impressions from each researcher during the interviews, allowing to obtain a more complete view of each case and also help reducing observers' bias (Yin, 2009). After analyzing the interviews' transcription, we conducted a new round of interviews to the same respondents, aiming to clarify details or questions that remained from the first round. To allow data triangulation, we reviewed companies' documents (mainly internal procedures, business reports and internal slides presentations), information from newspapers and websites (especially to better understand the business activities and new products offered by the company) and scientific papers of other case studies conducted in the same companies (only available for two of the studied companies). The whole process of data collection was conducted from March to August 2015.

3.4 Validity and reliability

As for construct validity, concerning the correct operational measurement of the concepts, we used multiple sources of evidence and followed the indicative scale presented in Table 2 and the list of boundary objects presented by Le Dain and Merminod (2014). In terms of external validity, we conducted the multiple case study and compared evidences on a selection of large companies that traditionally had a manufacturing BM and that recently changed to a BM focused on servitization. Finally, concerning reliability, we used a case study protocol and a final report was developed based on the transcription of the recorded interviews and observations. Some of these procedures were described in Sections 3.1. to 3.3.

3.5 Data analysis

As a first step for the data analysis, the recorded interviews were literally transcribed by the research assistant. After the transcription of all interviews from the same case study was completed, several meetings were conducted between the three researchers involved in the data collection to extract all information from the notes, audio recordings and collected documents. The data was analyzed seeking for evidence from each type of knowledge sharing from Carlile´s (2004) 3-T model (Figure 1). The KS levels were

analyzed based on the criteria established in Table 2, which was used during the interviews. We also reinforced the interviewees' assessment of Table 2 by analyzing the recorded comments and examples given by them to illustrate each evaluation; this was made by applying open coding techniques. These evidences were structured and organized in a final report for each case study. A second round of interviews was conducted to present the report conclusions to the interviewees and to collect feedbacks on our interpretation as well as new information for the cases when convergence was not reached.

After we individually analyzed each case and identified isolated factors and behaviors, we also performed a cross-case analysis to recognize similarities, contrasts and patterns among cases. Finally, we contrasted the results of the cross-case analysis with the literature and we developed a final theoretical framework.

4 Results

Table 3 shows the companies' distribution according to our conceptual framework presented in Figure 3. Some of the companies are repeated in different cells, since these are cases where we considered two different BUs from the same company. These cases are differentiated with an additional letter into brackets. In the next subsections we describe each combination.

Table 3: Companies distribution according to the proposed framework

	Types of service suppliers' involvement		
	White	**Grey**	**Black**
BMI for Product-oriented PSS	Company A [Dental care equipment] Company B[1] [IT infrastructure]	Company D[1] [Telecom hardware]	Company D[2] [TV & Media systems]
BMI for Service-oriented PSS	Company C [Furniture]	Company E [Automation] Company F [Energy]	Company G [Motion systems] Company B[2] [Hardware]

Note: Letters into brackets [1] [2] corresponds to different business units from the same company

4.1 White Box configuration

The White Box configuration in our context of study refers to companies that design almost all PSS offering alone and include the suppliers to collaborate just in the execution phase. Next, we described the White Box cases.

4.1.1 Servitization-driven BMI for product-oriented PSS

4.1.1.1 Dental scanner (Company A)

Company A is one of the global leaders in equipment and diagnosis systems for dental care. In its early years, it was only focused on the development of new products in its R&D department located in the German Headquarter. Aiming to enter in the Brazilian emerging market, the company first tried to operate by means of national distributors. However, the company realized that there was a strong barrier to enter in this market, since the clients' needs were different from the traditional markets where the company used to operate. This is because the equipment users in Brazil are not generally dentists, as in the European market, but radiology technicians from image diagnosis centers. Single dentists are not capable to afford this imported product; therefore, the image diagnosis centers take on such kind of diagnosis by concentrating high levels of demands that justify the investment in such equipment.

Company A started a project to develop a service offering to adapt its dental scanner equipment to the Brazilian market. Services were conceived to be the flexible part necessary to adjust the product to a new way of use and for other kinds of operators. First, this PSS offering is classified as a servitization-driven BMI focused on product-oriented PSS because the equipment did not undergo any change, but the company provided a software service, offered as an additional package through a license of use, which helps to make the equipment user-friendly for the new applications and users. Second, this PSS offering is classified as a White Box because Company A designed all the requirements of this additional service; the software company was involved only at the last stage. As the CEO affirmed: "*I spent almost five months visiting our Brazilian clients to understand how they really use our product*. […] *Since there was only one person in the German HQ that had the knowledge – but not the time – to develop the software, we prospected a regional*

company to develop it according to our specifications". So, the company established a partnership with a software development company to outsource this development and to provide support during the use of this service.

Referring to KS dynamics, the interviewees agreed that a high level of knowledge transfer was necessary between them and the software company. The interviewees presented several evidences of boundary objects used during the PSS development, such as: contracts, documents with specifications of product and service, software prototypes to test the user-friendly interface, draft of the layout to print radiographies from different patients in the same radiography sheet and several e-mails interchanged between actors to clarify little details of software functionalities. About knowledge translation, it was classified as a medium intensity, because even when numerous situations to clarify misunderstandings were necessary, Company A had a low participation during the software development. As the service development engineer from the supplier affirmed: "*we [the software development team] had a hard time at the beginning to understand what they [Company A] needed […]. We had several meetings at the beginning, but after that, a routine of weekly meetings with Company A was enough*".

4.1.1.2 IT infrastructure (Company B)

The second case study was conducted in Company B. We named it Company B[1] because two cases were conducted in the same company. Traditionally, Company B was a computer manufacturer company, but by the end of the 2000s the company decided to innovate its BM by increasing its focus on computer services offering (which today represents approximately 15% of the total revenues). In the PSS offering analyzed, the products were mainly hardware, such as computers and data centers, and the services included in the PSS were mainly restricted to some standardized services. Typically, these services are focused on putting the new system online (e.g. configuration, logistics and data migration) and providing Information Technology (IT) professional services (e.g. consulting for companies' IT optimization or modernization), which are directly related to the equipment selling. Therefore, this BMI was classified as a product-oriented PSS, since the services are adapted to the product, but the product itself does not suffer modifications. The

offered services are sold jointly with the products, as additional licenses and services for a complete care of the IT infrastructure.

This PSS offering was classified as a White Box because all services were developed internally by Company B[1] and service suppliers were involved just in the execution phase. Comparing with case A, this does not happen because of the lack of competence, since in some situations, depending on the geographical location, Company B executes also the service offer by itself. However, in this case the company adopted this strategy aiming to reduce the risk regarding the possibility of losing focus on its core business, which is still the IT infrastructure, as well as to reduce the complexity that involves managing a large number of service technicians dispersed around the world.

Regarding KS, the interviewees agreed that most of the information is shared by a high volume of documents (e.g. hardware and service specifications, manuals, catalogues, training materials, contracts) that are available in a specific internal platform. As the Service Solution Manager 2 affirmed: "*[…] they [service suppliers] have access to our internal platform which is 'full' of specifications about our products […] Commonly, the documents in the platform are enough to support them, but sometimes we have some specialists that receive calls from the technicians when they have some problem*". The interviewees self-assessed their level of knowledge translation as moderated because, additionally to the phone calls, it is mandatory that technical employees from the partner company attend a training course given by Company B to avoid misunderstanding of service and hardware specifications and to guarantee the brand quality standards.

4.1.2 Servitization-driven BMI for service-oriented PSS

4.1.2.1 Customized furniture (Company C)

Traditionally, Company C developed and manufactured off-the-shelf furniture, but in the last decade it engaged in a BMI transition towards customized products, which was the focus of our case study. In the first BMI stage, the company stopped producing furniture in large-scales and focused more on value-added products. In this sense, they changed to a concept of modular design that allows a flexible building of the

furniture, according to the clients' demand (customized products). They invested in front-end activities, such as proprietary stores and trained personnel for furniture design (i.e. employees were trained in the use of software that allows the adaptation of the modules available). However, the company advanced even further: In the second BMI stage, five years ago, the company fully focused on a servitization strategy. They started offering an integrated solution for clients based on a long-term service of "furniture update" program. This service consists in the modular furniture concept previously used, but then focused on a constant adaptation of the purchased furniture, changing it according to customers' family evolution with low cost for adaptation.

This case study was classified as a White Box collaboration because the service suppliers were included only at the final phase. Both service and product are designed by the company and the adaptation service is executed by services companies through outsourcing. Differently from both cases A and B[1], in this PSS offering the product is flexible and can be adapted to the customers' needs, i.e. a service-oriented PSS is designed.

According to the interviewees, the level of knowledge transfer is high since a lot of information is exchanged with partners in written format – mainly contracts, product and service specifications, assemble instructions, client history and e-mails. Additionally, interviewees' self-assessment pointed out a high level of knowledge translation, claiming that they held many meetings with partners to discuss service characteristics and quality patterns. Moreover, they also performed advanced training programs to qualify the service suppliers for a correct execution of services. As the CEO affirmed: "*there are hundreds of furniture companies, […] our differential is the service that we offer […]. During the first semester with us [referring to the service supplier], one supervisor of our company supported most of the service execution […]; this condition is included in the contract they signed*".

4.1.3 Cross case analysis of White Box cases

As shown above, the three cases conform to a White Box configuration because the service providers were included just in the late project phase, where all specifications were already defined by the manufacturing

company. Regarding KS assessment by the interviewees, following Carlile's (2004) classification and Le Dain and Merminod's (2014) scale, KS mainly consists in a high knowledge transfer activity, which can be identified in the intensive exchange of e-mails, manufacturing and services contracts, contractual specifications, manuals and equipment specification, service specification and training materials, among others. However, while similar levels of knowledge transfer were perceived by all interviewees, different levels of knowledge translating emerged according to the companies' BMI focus on servitization. On the one hand, Company C, which experienced a BMI for service-oriented PSS, declared high levels of knowledge translation, which is explained by the fact that this company completely designs the PSS offering where the service is the most important part of the value proposition (solution). Therefore, Company C has to assure the suppliers' understanding about how the service should be provided. On the other hand, Companies A and B[1], which innovated their BM for a product-oriented PSS, showed moderate levels of knowledge translation, since the dominant part of the solution is the tangible good, which can be well defined only by specifications (knowledge transfer). Therefore, based on this first configuration of buyer-supplier integration aiming at servitization-driven BMI, we introduce the following two propositions:

Proposition 1: *White Box collaboration for servitization-driven BMI aiming at a product-oriented PSS requires high intensity of knowledge transfer and moderate intensity of knowledge translation during the knowledge sharing dynamic between buyer and supplier.*

Proposition 2: *White Box collaboration for servitization-driven BMI aiming at a service-oriented PSS requires high intensity of knowledge transfer as well as high intensity of knowledge translation during the knowledge sharing dynamic between buyer and supplier.*

4.2 Grey Box configuration

The Grey Box configuration refers to companies that conduct their servitization-driven BMI through a strong relationship with suppliers by co-designing the central parts of the product-service solution; that is, suppliers are not involved only in the execution phase as in the White Box configuration. Next, we describe the cases representing this configuration.

4.2.1 Servitization-driven BMI for product-oriented PSS

4.2.1.1 Telecom Hardware (Company D)

Company D is traditionally dedicated to the telecommunication industry. In this company we analyzed two different PSS offerings developed with service suppliers: one developed in the company's BU dedicated to telecommunication hardware development and manufacturing, here called Company D[1]; and another in the company's BU dedicated to the development of TV & Media systems, here named Company D[2]. In this section we analyzed the first one.

Company D[1] in the early 2000 had a portfolio composed by around 30% of service and 70% of hardware profits. Thus, this BU had a hardware-driven BM. However, over the last 15 years the company portfolio has been shifting to a service-driven BM, with almost 70% of the profits coming from service offer. Nonetheless, even now that the main profits come from services, these services are adapted according to the already defined product project and, thus, this BU is classified as a BMI focused on product-oriented PSS. The company's changes originated from a necessity of its telecom operator partners which, because of the complexity of this industry, asked for services to rapidly respond to market evolution and support their business shift from network centric to customer centric.

As exposed by interviewees, and also supported by public available reports and some internal documents presented by the management, Company D[1] opted to establish a partnership with some small and medium service companies to satisfy a new demand. As the service sales manager affirmed: "*we were the best in developing hardware and sell it 'as a box', but our client started to demand for complex solutions […]. We were a slow giant, […] without partnerships it would not have been possible to catch up with market speed*". So, they developed together a solution to take full responsibility for the Telco's network, including planning, design and implementation, daily operations and maintenance. Since the interviewees affirm that no two operators are alike, the customized solutions for the client are designed jointly, i.e. representatives from both sides are included in the team in charge of being in contact with the client during the design phase. After this phase, the service companies are predominantly in contact with the client and the service

is controlled by a Service Level Agreement (SLA) based on performance indicators. When the client´s requirements are already identified, there is a joint discussion between the partners about which PSS offering may better satisfy the clients. However, this discussion has the limitation that there is no possibility to modify the hardware already developed by Company D[1], which indicates a BMI focused on product-oriented PSS. Hence, the solution is restricted to the field of the already existing hardware applications. As the senior project manager expressed: "t*he manufacturing way of thinking is still in our veins […], our R&D develops the new products and our customer unit [i.e. service supplier] has to do a big effort to fit the service into the package*".

According to the interviewees, a high volume of written information is exchanged between the BUs, e.g. client's characteristics, client's network utilization documents, specification of service performance indicator, contracts and hardware specifications, among others. Interviewees agree that there is a high intensity of knowledge translation with service suppliers, as reflected by a senior project manager's statement: "*before, our project managers were used to promise a solution to our clients without really knowing how it would be delivered, and this led to high losses in our markup […]. Now, we send to the customers a team composed by hardware engineers, service engineers and project managers from both companies to define the solution*". Because of its high interdependency, this team works jointly during the whole project.

4.2.2 Servitization-driven BMI for service-oriented PSS

4.2.2.1 Robot monitoring (Company E)

Company E is a leading company in automation for manufacturing. The company develops and manufactures robotic solutions for many industries (e.g. assembly lines or processing operations). In this traditional approach, the product was offered off-the-shelf and the clients only chose some configurations based on what they thought they needed. However, in the last decade, the company set the goal of increasing services revenues by 25% in its global portfolio. One of the initiatives launched was the industrial robot monitoring service, which allowed companies to remotely monitor the status of their robots.

Therefore, Company E established a partnership with an Information and Communication Technology (ICT) company to install sensors and modems in the robots and to provide knowledge about data analysis that allows processing information to design, among others, a preventive maintenance program. Both companies worked together for the design and implementation of the solution, thus configuring a Grey Box supplier involvement.

Interviewees indicated high intensity of all types of knowledge sharing. Differently from prior case studies, also high knowledge transformation was indicated by the interviewees. As the regional service manager said: "*a special team of expert engineers was created to analyze market demands […]; they realized that our company did not have all the expertise to leverage this new trend*". This new knowledge was created with the ICT partner, as explained by the senior project manager: "*we have a strong expertise in automation […]; they [ICT partner] know a lot about sensors and Internet of Things*". New products and even a new BU were created to support the development of this PSS offering, indicating a service-oriented BMI and a high intensity of knowledge transformation. To develop this new solution, interviewees declared that both companies exchanged a significant amount of written information about product specifications, client contract and specifications, client's maintenance programs and service characteristics. Referring to knowledge translation, interviewees support their self-assessment arguing that both companies had very specific knowledge and several meetings between project members were necessary to define what parts had to be monitored and why, how it would be done and, additionally, what data would be important to obtain.

4.2.2.2 Energy solutions (Company F)

Company F was traditionally a developer and manufacturer of electrical devices and components, such as circuit breakers, transformers, power systems, among other electrical equipment. The BMI changing to a servitization approach was defined in late 2010, in order to satisfy growing clients' needs to move from buying only energy equipment to purchasing energy solutions. As a result, today services account for around 20% of the company's revenues. The PSS offering which was the focus of our case study comprised

the creation of a stand-alone service BU, named Solution Center, that now offers energy solutions such as engineering studies, field services, projects and modernization, efficiency and sustainability for energy use, among others. Particularly, since the PSS offering to provide energy solutions differs significantly from one client to another, we asked to the interviewees to refer to the most common situation they face. In this kind of project, the service BU is responsible for requirements definition with the client, installation, assembly and service support, while the engineering BU – the company's traditional core activity – is responsible for the provisioning of advanced technical support, i.e. the knowledge of internal product characteristics, engineering project and, whenever needed, the outsourcing of civil constructions. Since both BUs and the other partners need to be involved during all design and implementation phases because their specific knowledge, this is considered a Grey Box configuration.

This BMI can be categorized as a service-oriented PSS because the solutions offered are not restricted to Company F's products, as the service manager's affirmed: "*our clients ask for energy solutions […]. If I need to buy some equipment from my competitors to deliver a complete solution, I do it!*". Because of the complexity needed to deliver solutions that are not restricted to a product portfolio, the interviewees considered that there is high intensity of knowledge transformation in each project. This is illustrated in the words of the service manager: "*each new project is a challenge […]; it is very rare that we know all details at the starting point […]; we all learn from the specific situations that occur during the project*". Also, knowledge translation was assessed by interviewees as high intensity, supported by the fact that engineers of all companies work collaboratively during all project phases, which are coordinated by a project manager from Company F. Finally, a high intensity of knowledge transfer is reflected by the amount of information interchanged between actors, such as contracts, products specification, manuals, standard procedures and even internal forums.

4.2.3 Cross-case analysis of the Grey Box cases

In all cases, the partners collaborate significantly to provide a joint specific solution for the clients, but they also maintain independent traditional business activities. In the three cases, interviewees declared a high

level of knowledge transfer (e.g. product and service specifications, documents, e-mails), and also high level of knowledge translation (e.g. very frequent discussions to avoid misunderstanding about how services and product may perform). Finally, knowledge transformation could be observed only in Companies E and F (service-oriented PSS), but not in Company D[1] (product-oriented PSS). Concerning D[1], this behavior can be explained by its focus on product: since the solution design is restricted to the characteristics of the hardware already developed, there are no innovative solutions created that may demand significant intensities of interpretation and building of common meanings among actors (knowledge transformation). In this case, both sides need to understand the meanings and limitations of both product and service (translation), but the product side does need to go further in terms of unlearning process and new knowledge creation regarding the product. The contrary happens in Companies E and F: given their BMI for service-oriented PSS, the offering is not restricted to the product domain and knowledge transformation can be required in order to rethink the product by adapting it, as well as the service, to a new solution for the client's problem. Finally, it is noteworthy that, in all cases, the interaction among KS levels happens in a cyclical process, until achieving a final solution. Therefore, based on this second configuration of buyer-supplier integration aiming servitization-driven BMI, we introduce the following two propositions:

Proposition 3: *Grey Box collaboration for servitization-driven BMI aiming at a product-oriented PSS requires high intensity of knowledge transfer and translation, in a cyclical process, during the knowledge sharing dynamic between buyer and supplier.*

Proposition 4: *Grey Box collaboration for servitization-driven BMI aiming at a service-oriented PSS requires high intensity of knowledge transfer, translation and transformation, in a cyclical process, during the knowledge sharing dynamic between buyer and supplier.*

4.3 Black Box configuration

For Black Box configuration we refer to manufacturing-based companies that introduce a BMI, changing the BM to a product-service system approach, by outsourcing the service development that will be included in the product-service solution. Next, we describe the cases showing this configuration.

4.3.1 Servitization-driven BMI for product-oriented PSS

4.3.1.1 TV and Media systems (Company D)

For this case study, we analyzed a PSS offering from another business unit of Company D, here named Company D[2]. This BU is dedicated to the development of TV & Media systems. TV and Media is one of the targeted growth areas, which is adjacent to the Telecom core business of Company D. This BU delivers content distribution and services for high-performance video, mobile TV and IPTV consumer services. Company D[2] hence had to look for service partners to rapidly develop new solutions in the growing video content area, in order to fully exploit its already existing network hardware for this new application. To do this, it established a partnership with some small and medium companies with strong experience in this segment, and even acquired some of them, to create a stand-alone service unit. The engineering team of Company D[2] determined, on a high level, only the main characteristics of the solution that was to be offered with its product, constrained by the already existing hardware that they develop; while the complete service design and offering was executed by the service BU or external partners, thus shaping a Black Box configuration. Moreover, the restriction to the use of existing tangible goods denotes a BMI focused on product-oriented PSS.

As assessed by interviewees, a moderate intensity of knowledge translation was necessary before starting the exchange of written information. Several meetings were necessary between projects managers from the service companies (service BU) and engineers from Company D[2] hardware unit, to understand how existing products could be better used in the TV and Media solutions. As described by the product engineer: "*it was a strategic demand from the top management [...], we were not able to start any project without first understanding what TV & Media means*". A moderate intensity is also justified by the limited participation of the engineering team in the developing phase of the solution. A high intensity of knowledge transfer was self-assessed by interviewees based on the high volume of documents exchanged, such as contracts, clients' information, historical records, service specifications, product catalogues and specification as well as e-mails.

4.3.2 Servitization-driven BMI for service-oriented PSS

4.3.2.1 Motion systems (Company G)

Company G is dedicated to Process and Motion Control (e.g. conveying systems, mill chains, steel chains, couplings). In the past, the company was focused only on developing and manufacturing such products, and selling it through dealers. However, because of a clients' demand and when looking for differentiation from its competitors, the company started to offer customized solutions in complex manufacturing processes where the cost of failure or downtime is high (e.g. beverage and food processes). This BMI is characterized as a service-oriented PSS since the products are developed to allow high solution flexibility. For the solutions development, the company established a partnership between the so-called manufacturing BU and another stand-alone BU dedicated to service offer, named Application Engineering. The normal way in which the servitized solutions operated is by a first contact of the manufacturing BU with the client, who is looking for a product according to his needs. Then, if the case is complex, the manufacturing BU offers a consultancy project for process and motion improvement. If the client agrees, the service BU is triggered to develop the solution by using the products of the manufacturing BU. Therefore, the service is outsourced, but the client sees the solutions as a package offered by the manufacturing BU, thus determining a Black Box configuration.

According to the interviewees, the intensity of knowledge translation is low: since the products are mainly standardized in simple parts, only a few meetings between manufacturing engineers and service engineers were necessary to the service BU to obtain explanation about some specific product restrictions or applications. As observed by the sales engineer: "*most of the difficulties are in the identification of the necessities of the client, understanding in which environment our product will work and what will be the demand […]; after the design of the solution, the application engineer will ask for the necessary parts to assemble the solution for the client*". Following this phase, the largest share of knowledge is exchanged in the form of contracts, products specifications, catalogues and e-mails; according to the interviewees, a high knowledge transfer occurred in the process.

4.3.2.2 IT services (Company B)

In this case study, we analyzed a PSS offering from a second BU of Company B (here called Company B[2]), a computer manufacturer. To expand the service share of its whole solution, Company B[2] looked strategically for others services that could show synergies with its products. To do this, Company B[2] acquired a big company already well established in the IT service market and mainly focused in providing IT services for industries such as healthcare, government and banking. The acquired company has worked as a stand-alone service BU, but following high-level specifications set by the core company. This PSS offering can be classified as a Black Box configuration because the complete solution is designed and delivered by the service BU. Moreover, it is a service-oriented PSS, as affirmed by the Service Solution Manager 1: "*the most complex part of the solution is the service delivered by [the service BU] […]; they could use hardware from any of our competitors*".

The interviewees assessed knowledge translation as low intensity. They affirmed that the solution development demands discussions between manufacturing engineers from company B[2] and service managers from the service BU, so as to understand how to obtain a better cooperation between products and services. However, since very simple equipment is necessary to deploy services, e.g. computers, scanners and servers, just few meetings are necessary. After the meetings held to avoid misunderstanding, the interviewees indicated a high level of knowledge transfer related to the information exchange about product and service specifications, contracts, e-mails, among other writing forms.

4.3.3 Cross-case analysis of the Black Box cases

The three cases are characterized as a Black Box configuration because the design, development and execution of the services are mainly performed by a stand-alone service BU or service supplier. The manufacturing BU only defines some high-level specifications for the services, but at an operational level it is still only concerned with the hardware/product offer and support, while the service is outsourced. Regarding the knowledge sharing dynamic, we observed a high transfer among actors in all the cases, mainly involving product and service specifications, but different levels of knowledge translation. On the

one hand, Companies B[2] and G, which conducted a BMI for service-oriented PSS, had shown low knowledge translation, since their products are simpler and standardized. Consequently, the complexity of the solution lays on the service part, which results in a low need of knowledge interpretation by the manufacturing unit. On the other hand, the product-oriented PSS of Company D[2] demands moderate knowledge translation because of the high dependence of the service in the hardware utilization, which requires the service BU to deeply understand the product's characteristics in order to develop the whole solution. Therefore, based on this last buyer-supplier integration configuration aiming servitization-driven BMI, we introduce the following two propositions:

Proposition 5: *Black Box collaboration for servitization-driven BMI aiming at a product-oriented PSS requires high intensity of knowledge transfer and moderate intensity of knowledge translation during the knowledge sharing dynamic between buyer and supplier.*

Proposition 6: *Black Box collaboration for servitization-driven BMI aiming at a service-oriented PSS requires high intensity of knowledge transfer and low intensity of knowledge translation during the knowledge sharing dynamic between buyer and supplier.*

4.4 Summary of the case study propositions and resulting framework

Based on the aforementioned results from our multiple case study observations and propositions, we resume our findings in Figure 4. This figure shows six different KS dynamics in the buyer-supplier integration for servitization-driven BMI, which is the summary of the propositions presented in our results. The framework also shows all the possible combinations for the BMI approaches for servitization and the possible forms of relationship between buyer and supplier. We also highlight the different intensity observed on each level and case by means of different colors in the KS levels.

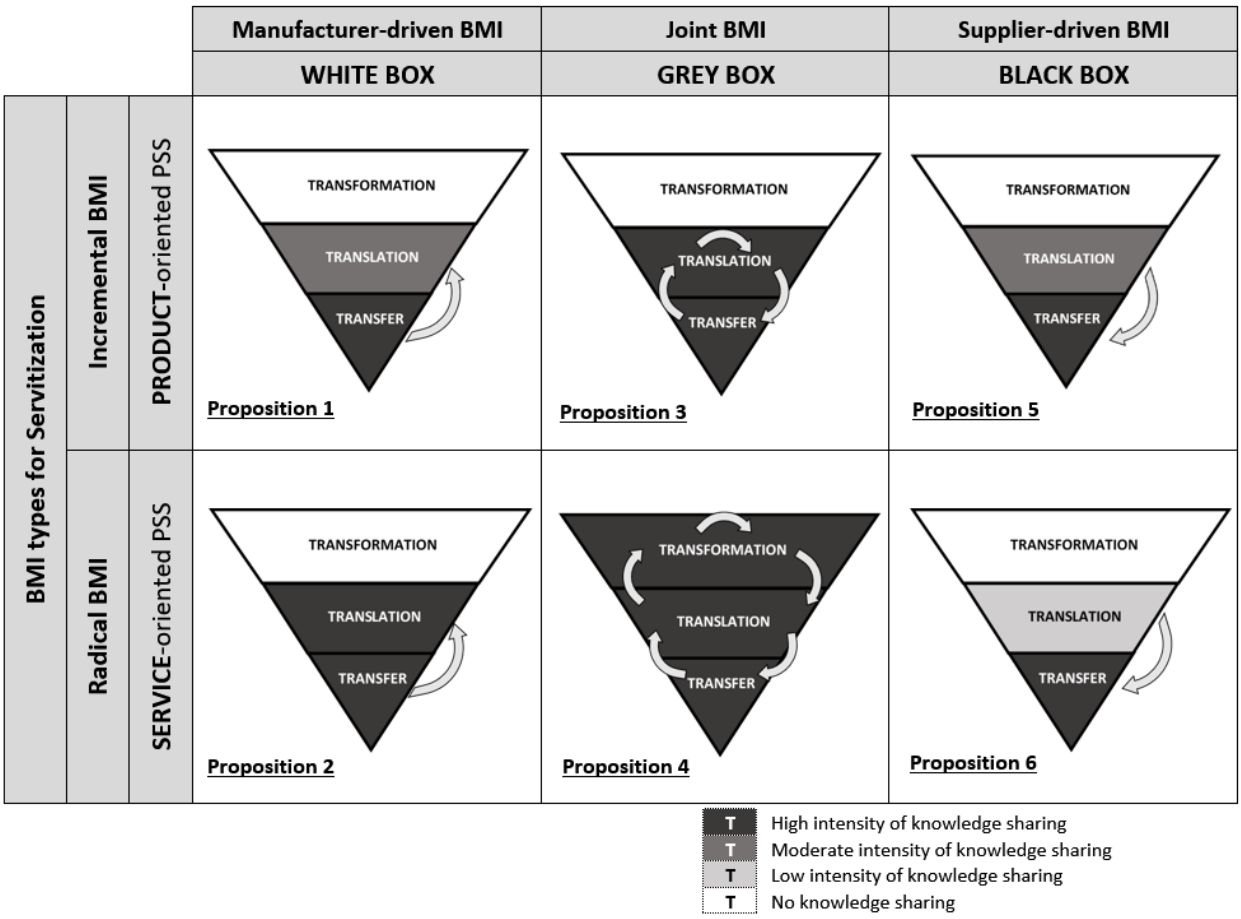

Figure 4 – Overall framework for the knowledge sharing dynamic in the buyer-supplier integration servitization

The results presented in Figure 4 can also be compared across the different types of configurations: for each BMI orientation, this means comparing the differences emerging when the type of relationship with service suppliers changes. For instance, focusing on product-oriented PSS and analyzing both extremes (White and Black boxes), it is possible to observe the same knowledge intensities, but a different direction of the interactions between KS levels. Following such logic, we observe that in the White Box, most of the knowledge is generated and remains in the manufacturing company during all phases of the PSS development. The service company is involved only in the service execution phase. Therefore, the generated documents are shared jointly with products specifications preceding a broader discussion to avoid misunderstanding about the execution of the service. On the other hand, in the Black Box, the manufacturing company first has to share with the service company information on how the product works,

how it is used by their clients, the main characteristics of the users, and other details which are difficult to explain in an explicit manner to a service company. Contrary to White Box, in this case most of this KS happens in the first stages of the development of the PSS offering. When analyzing the service-oriented PSS, we can observe the same behavior; however, some difference exists in the intensity of knowledge translation. Lastly, when comparing the Grey Box configuration with the other configurations for both types of BM orientation, the main difference observed is the cyclical movement between each type of knowledge. In White and Black boxes the process of development of the PSS was in charge of one of the actors, while in Grey Box there is not a main actor, since both actors are building up the solution jointly. Therefore, KS happens in an iterative form.

Additionally, from a BMI theoretical perspective, our resulting framework shows that an incremental BMI occurs when companies follow a product-oriented strategy, while a radical BMI takes place when companies follow a service-oriented PSS strategy for servitization. Considering manufacturing companies in the first group, services have less impact in the innovated business, since their value proposition (the BM's key element of "what" is offered to create value) remains focused on the products; as a result, BMI reflects on changes that are deemed incremental On the other hand, manufacturing companies from the second group (i.e. radical BMI) are those willing to transform their product to better fit the value proposition with the service offering, implying a radical change in the "what", which later propagates to the other BM elements (Mitchell and Coles, 2004); this determines a significant modification of the manufacturers' value architecture (Teece, 2010; Massa et al., 2017). Moreover, our framework illustrates how both incremental and radical BMI levels may appear in each supplier involvement type (White, Grey and Black Box). When the collaboration approach follows a White Box configuration, BMI is driven by the manufacturer, who will centralize the decisions of service design, reducing the dependence of BMI from external actors; such leading role in BMI will require the manufacturing company to internally develop service design resources and capabilities, that may be later used to simply add a service component to the product – as depicted in Proposition 1 – or even leveraged to implement a new service that radically changes how the product is offered – as Proposition 2 illustrates. This finding shows how service design

may become not only a product component, but even a core resource (Barney, 2001) to enable a profound BMI from manufacturing companies towards servitization. On the other hand, when collaboration is based on a Black Box configuration, BMI is supplier-driven. The PSS solution (value proposition) and the resources and activities needed will depend on the service innovation proposed by the supplier. In this case, the service supplier, by leveraging its core resources, assets and know how, will provide novelty to the manufacturer's BM; such novelty will be embedded to different degrees, depending on the manufacturer's willingness to allow its service partner to incrementally (Proposition 5) or radically (Proposition 6) modify also the product configuration the services are attached to. Grey box is a half-way positioning where the joint solution implies also a BMI that is equally driven by the manufacturing and the service firms. In this case, the manufacturer and the supplier will modify internal business dimensions and will influence each other during such change; there is a mutual dependency in aspects like the resources configuration, processes and design activities, and the resulting BMI may show a focus on product (Proposition 3) or service (Proposition 4).

Moreover, based on the case studies, we observed that the more radical the BMI is, the more impact the service supplier will have on the manufacturer's business dimensions in Grey and Black Box configurations.

5 Discussion

The findings of this study shed light on how a combined buyer-supplier KS and BMI perspectives can be valuable to investigate another wider theme in Operations Management, i.e. the servitization of manufacturing companies. Many prior works treated KS as a "item" or a "package" that can and must be exchanged between collaborators in the context of BMI and servitization (e.g. Meier et al., 2010; Storbacka et al., 2013), but this is only the starting point for a broader analysis of the complexity involving collaborations for BMI. As we have shown in our findings, such an understanding about these relationships and the KS dynamic can be expanded by bridging two different streams of research: (i) the BMI stream, and within this stream, the research focused on a specific BMI process called servitization strategy; and (ii) the new product development (NPD) stream concerned with buyer-supplier integration/collaboration. We

showed that by integrating both perspectives it is possible to obtain a more fine-grained description about the levels of KS among the involved actors. If such relationship is only seen from the BMI point of view (and not from the type of collaboration perspective), prior works emphasized different ways of sharing knowledge for product or service-oriented models (Jaakkola and Hakanen, 2013; Lertsakthanakun et al., 2012). On the other hand, when the relationship among actors is considered only from the buyer-supplier integration point of view, the White/Grey/Black Boxes approach allows identifying three main KS dynamics (Le Dain and Merminod, 2014). However, when both perspectives are combined, we showed that six possible dynamics emerge from this phenomenon. These dynamics result from the possible combinations of knowledge among actors, since the type of domain-specific knowledge from each actor directly affects the effort required to cross the boundary knowledge (Carlile, 2004).

Our findings present some differences compared to the buyer-supplier relationship seen from the NPD lenses only, confirming Johnson and Mena's (2008) affirmation that a servitized supply chain has a different behavior than those involving only products. One general aspect is that, in the NPD buyer-supplier, White Box cases seem to happen more naturally than Grey or Black Box ones (Dyer and Hatch, 2004; Huang et al., 2010). In NPD, companies generally start working in collaboration by sending the designed components to be manufactured or adapted by the suppliers. In this case, White Box initiatives are more difficult because the company has, at least, part of the competence that the supplier can offer, even when it is not as advanced as the supplier's (Amaldoss et al., 2000). Therefore, the company first tries to develop its own product components, leaving for suppliers only the less relevant ones (Zirpoli and Becker, 2011). However, thanks to the multiple case study we observed a different trend for servitization-driven BMI. Here, the manufacturing company needs to outsource a service competence, which is generally unknown to the company itself. Thus, Black Box or Grey Box are more likely to happen than White Box, since for White Box the company should first develop a new capability to be able to design the service offering (Baxter et al., 2009; Brax, 2005); hence, the uncertainty and high risk forces the company to look for a stronger help in other business units or companies. White Box, in BMI for servitization, seems to be more likely to happen

when this BMI is simpler, i.e. when the service is not complex or it refers to a very clear problem for the company.

This analysis does not mean that one type of configuration is better than the other, since this depends on the strategic decisions that the company makes (Gebauer et al., 2005; Mathieu, 2001). Black Box appears as a more immediate alternative for companies that need to servitize their BM, since they are outsourcing all the service design and development process, while dropping the chance to internally develop service design-oriented resources. On the other hand, Grey Box configuration can allow the most flexible and, therefore, complete solution, since in this alternative the product can be jointly modified and both product and service-oriented resources and capabilities from buyer and supplier are merged and recombined, possibly generating a more radical BMI. Finally, White Box seems to be an alternative for large manufacturing companies that have the possibility to nurture service-related resources and companies, for instance by hiring people with the necessary abilities to self-design services, but only as long as the market may tolerate a longer time-to-market due to internal development.

Regarding the KS levels, our findings show that in the White Box configuration knowledge translation seems to be more important for BMI aiming servitization than in NPD. This is because a service design is more ambiguous than tangible goods, demanding more discussion to avoid misunderstanding (Aurich et al., 2006; Kapletia and Probert, 2010). However, in this White Box the KS dynamic presents a similar pattern to NPD, where first the manufacturing company provides the product and service specifications (knowledge transfer) and then, on top of it, knowledge translation occurs. Something similar happens in Black Box KS dynamic, were in a general sense there is a similar behavior in BMI for servitization when compared with NPD collaboration according to Le Dain and Merminod's (2014) results. However, for service-oriented PSS, we found that knowledge translation is present, but with a lower intensity when compared with NPD behavior. This is because in our case the value-added offer is centered on the service delivered with the product, which is developed fully by the service supplier. Thus, low levels of translation are needed, only to adjust the PSS offering to be offered.

Still, for the Grey Box configuration, while Le Dain and Merminod (2014) observed that the NPD process requires high levels of all the three types of knowledge and a cyclical dynamic between them emerges, this behavior is not the rule in both types of BMI for servitization. The service-oriented PSS has a similar KS dynamic, since radical new solutions need deep modification of both service and product. However, the product-oriented PSS has a particular behavior in Grey Box, not observed in NPD Grey Box, since we did not identify knowledge transformation. As defined by Carlile (2004), transforming knowledge involves altering current knowledge and creating new knowledge, but this cannot fully happen in this case because of the constraints/limitations to the PSS offering set by the existing product portfolio. Then, KS dynamic is still cyclical, but it concentrates between the phases of knowledge transfer and translation, forcing actors to solve client's problems only with a different combination of the same products, without being able to create totally new solutions and, therefore, not demanding a true knowledge transformation.

As a concluding remark, our analysis from the BMI and KS perspective contributed to previous studies that found difficulties in knowledge management in the buyer-supplier relationship in a servitization context. For instance, Cook et al. (2006) observed that manufacturing companies were worried about service delivery based on service suppliers because it would reduce their capacity to develop efficient solutions. However, when analyzing by a KS perspective, we show that the Grey Box configuration allows both actors to benefit from the generation of new knowledge. Also, Bastl et al. (2012) and Lockett et al. (2011) found in their case studies that the intensity of knowledge exchange was less than they expected, but our work explains this behavior, since we show that the intensity of KS cannot be generalized for all buyer-supplier relationships. This will depend, according to our results, on which of the six types of buyer-supplier configuration and on which of the two different BMI approaches the collaboration is based on. Finally, our study complements Saccani's et al. (2014) conclusions that information exchange between buyer and supplier happens differently, conditioned upon the service type offered in the PSS, since we clarified how the different KS levels are managed for different servitization BM orientation and supplier's involvement configuration.

6 Conclusions

6.1 Theoretical contributions

The research question this study addressed was how manufacturing companies willing to innovate their traditional business model to become servitized integrate knowledge from service suppliers to obtain a joint product-service solution. Strategically, we argued that this is a significant challenge for such companies, since they have to deal with a new competence (based on service knowledge) which is, generally, not part of their knowledge domain; also, they need to innovate their BM to turn it into a servitization BM. Therefore, they need to seek external knowledge based on collaboration with service suppliers. Thus, we show the connection between buyer-supplier collaboration and BMI to understand the impact of such relation on the servitization strategy of the company.

The main theoretical contribution of this study, organized in terms of six propositions, is that we explored the connection between two different fields of research – BMI and buyer-supplier integration in NPD – to provide a comprehensive theoretical framework about possible types of collaboration and levels of KS that can occur in such collaboration aiming for a servitization strategy of the company. Moreover, our study disclosed a relationship between BMI and servitization implementation that is not yet explicit. Our findings showed that viewing the buyer-supplier typologies through the lenses of BMI research (which focuses on the modifications in a company's value architecture – Teece, 2010) can allow gaining a deeper understanding of this research problem. Our study also shows how a manufacturing company's BMI makes the set of interrelated choices explicit within the overall servitized strategy – including the role of collaboration and KS.

Moreover, we also showed different behaviors between the traditional NPD buyer-supplier collaboration and this collaboration in BMI for servitization. We found that KS dynamic depends not only on the type of collaboration, but also on the type of servitization orientation, that is, on whether the BMI is product or service-oriented. Thus, we obtained six forms of KS dynamics for servitization instead of only three as discussed in the extant NPD buyer-supplier literature. Our findings also suggest that only one of the six

configurations involve a high intensity of knowledge transformation (i.e. Grey Box for service-oriented PSS), while all other combinations are restricted to the knowledge transfer and translation levels.

6.2 Managerial implications

As implication for managers and practitioners, our findings suggest that before executives choose one type of collaboration with potential service suppliers, they have to be careful concerning two main aspects. First, they need to evaluate not only the type of collaboration they want to establish, but also the strategic characteristic of the proposed solution's BM, whether it will be product or service-oriented, since this will affect directly the dynamic of the collaboration. Secondly, as a consequence of this first point, they should consider the complexity of the KS dynamic they will have to deal with when choosing one of such combinations. As we showed in our results, Black Box configurations may be more appropriate if managers intend to innovate their BM faster for servitization, since it requires lower levels of KS dynamic with suppliers and the company does not need to develop its own service capabilities. However, trusting suppliers and identifying the right service suppliers can be a barrier for this option. Additionally, the value proposition of the manufacturer's BM becomes more dependent from the service suppliers. On the other hand, we also showed that, if managers want to develop stronger PSS solutions, they may opt for a Grey Box collaboration, but this may require higher intensity of KS with suppliers, especially when the solution is service-oriented, which results in longer times for definition and execution; however, the BMI obtained can be more consistent and performing. Finally, we showed that the White Box option implies to possess internal service capabilities, since the company itself has to develop the service design. Thus, in this case, the KS dynamic with service suppliers is less complex, since they become merely service executers, but the challenge is more on how to internally develop the service competence.

6.3 Limitations and future research

Regarding the limitations of this research, one is that we addressed the proposed research question with a qualitative approach, which may hide observer's biases (Yin, 2009). This is necessary for a first stage of understanding, since we aimed to analyze in depth the KS mechanisms between companies and their

suppliers during BMI for servitization. However, future research can employ a quantitative approach, for instance based on a survey research, to obtain statistical validation for our propositions. Another research limitation is related to the fact that we analyzed some cases with internal BUs collaboration and others with external companies' collaboration. In this sense, we assumed that the fact of considering different BUs from the same company would not affect our analysis, as long as they are stand-alone BUs enjoying a strong degree of delegation and autonomy. Future analysis could complement and expand this first study on KS in BMI for servitization and, when possible, quantitative studies could also test whether internal stand-alone BU against external independent companies can present different performance regarding buyer-supplier integration for BMI aiming servitization.

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