The value of Big Data in servitization

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1. Introduction

Service oriented strategies in manufacturing are much older than the most widely used terms like servitization (Vandermerwe and Rada, 1988)and product–service system (Tukker, 2004). Manufactur-ing enterprises began to combine goods with services as far back as the year 1850 (Schmenner, 2009). 'Servitization' is the most high-level term for service-oriented strategies, and will be thus used throughout this article. Servitization is omnipresent in manufacturing enterprises in mature economies (Neely, 2007). It can be an extremely successful differentiation strategy for undergirding competitive advantage and for avoiding the commodity trap, which pressures from the economies with lower production costs. However, manufacturing enterprises in such countries are also servitizing, where the level of penetration is proliferating sharply, e.g. in China from 1% of servitized enterprises in 2007 to 20% in 2011 (Neely et al., 2008). This indicates that manufacturing enterprises that start out with servitization will soon have the onus to design a further strategic step after servitization or one that is complementary. Thus product–services (P–S) could become a necessary, but not sufficient, condition for the sustained success of manufacturing enterprises in mature economies.

The question is, thus, what is the next step strategic step after servitization, i.e. how to derive more value from servitization and, among others, to avoid the service paradox (Gebauer et al., 2005). When trying to answer this question and to analyse the servitization practices of manufacturing enterprises, the data perspective arises. Today's servitization differs greatly from the one a century ago, mostly due to the technology that can support the creation and delivery of P–S. Many services are supported or enabled by ICT solutions, e.g. by providing software in addition to the product, ICT technology to support the technological needs of a car adapted for car sharing, or a TV set with a pay-per-view movie portal. Such technologies enable data about the use of the service to be collected, as eBay is doing by selling blinded transaction data to interested third parties (Ferguson et al., 2005). In P–S, this potential is based among others on the ubiquitous concept of the Internet of Things (Kopetz, 2011), where the concept of smart products plays a representative role (Kortuem et al., 2010; Welbourne et al., 2009). Furthermore, ICT has been introduced, not only in the delivery and execution phase of the P–S, but also in the ideation and creation phase of P–S. Based on the concept of Service Engineering (Bullinger et al., 2003; Sakao and Shimomura, 2007), it enables all the relevant intangible and tangible assets (I/T assets) of a manufacturing enterprise to be identified and virtualized. They are represented as data with which new P–S are composed and managed. Furthermore, since

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manufacturing enterprises do not own all the necessary expertise and ideas for designing and delivering a service, they collaborate with each other and form a Manufacturing service Ecosystem (MSE) in order to obtain others' resources and to retain and develop their own resources by combining them with those of others (Das and Teng, 2000). Evidently, servitization has been demonstrated to be a process with new distributed sources of unstructured and structured data with a high level of variety, while ensuring relative veracity and needed velocity. Servitization can be thought of as a data intensive process. With new virtualizations of assets, new P–S compositions and, especially, through P–S usage, the volume of these data increases exponen- tially. Thus, the "5Vs" can have the characteristics of Big Data (Beulke, 2011).

The purpose of this article is thus to help manufacturing enter-prises that servitize within an MSE to manage and exploit Big Data related to servitization in order to increase the level of competitive advantage. As this work is novel, the following hypothesis has first, to be investigated: "The generation and exploitation strategies of Big Data related to servitization constitute the next basis for competitive advantage after a manufacturing enterprise has servitized its products within a Manufacturing Service Ecosystem". In order to scrutinize this hypothesis, a Big Data Strategy framework in servitization is conceptualized that depicts Big Data generation and exploitation strategies integrated into the process of servitization within an MSE. This article elucidates, from a Big Data perspective, how a manufacturing enterprise that is servitizing within an MSE can use the four Big Data stratums (Volume, Velocity, Variety and Veracity) in order to create a link with the fifth stratum, Value. Albeit the "buzz" around Big Data, only a few IT executives have reported that their organizations were succeeding at generating significant business value from their data (Beath et al., 2012). Accordingly, this article will enable managers of manufacturing enterprise that are servitizing products to unveil the fifth "V", Value, represented as an additional layer of added-value hidden in servitization.

The argument goes as follows. The main concepts are introduced in the first section. It starts with servitization and its related sub-concepts MSE, Service Engineering and Informatization. The next main concept is Big Data. Conceptual simulation of the Big Data Strategy framework in servitization is treated in the second section, where its relevance is scrutinized. In order to evaluate the impact of the newly designed Big Data Strategy framework in servitization, it is benchmarked against existing relevant frameworks in the fields of Big Data and of servitization. In the same section it is explained how the fifth "V" Value is created through the application of a Big Data Strategy in servitization. The last section depicts the impact of the Big Data Strategy framework on the competitiveness of manufacturing enter-prises, first through an evolutionary perspective and secondly through a theoretical lense of the Resource Based View (RBV) (Peteraf, 1993; Wernerfelt, 1984) and dynamic capabilities (Prahalad and Hamel, 1990). The article ends offers a short discussion and paths for future research.

2. Concepts

The concepts upon which the conceptual simulation of the Big Data Strategy framework in Servitization for manufacturing enterprises is based are presented. The synergies of the following concepts and their related ICT tools and procedures are utilized—(a) the service oriented strategy servitization, (b) the specific service engineering ICT tools and procedures facilitating servitization within an MSE (virtualization procedure of assets and their management in terms of deletion, addition, sharing and composition within an MSE) and (c) the process of informatization. The advancement in the field of these concepts is briefly depicted.

2.1. Servitization

In an extensive literature review, Beuren et al. (2013) conclude that, given the growth in the number of publications on product–service systems (PSS) in recent years, there has been increased interest in the subject. Furthermore 20% of enterprises have already integrated some kinds of services (Santamaría et al., 2012). A wide terminology for service oriented strategies exists, such as servitization (Vandermerwe and Rada, 1988), servicizing (Rothenberg, 2007), PSS (Tukker and Tischner, 2006), functional sales (Markeset and Kumar, 2005) and even full-service contracts (Stremersch et al., 2001), etc. However, the two most pervasive concepts are servitization (Vandermerwe and Rada, 1988) and PSS (Goedkoop et al., 1999; Tukker, 2004). The latter is defined as a combination of products and services in a system that provides functionality for consumers and reduces environmental impact, while servitization is defined as a market package or bundles of customer-focussed combinations of goods, services, support, self-service and knowledge. As the two concepts overlap at some points, Baines et al. (2007) proposed a solution by making a synthesis of both terms. A P–S is defined as an integrated combination of products and services that deliver value in use. The servitization definition is refined by encompassing the PSS approach. Hence, in this paper, the term servitization will also be used for service oriented strategies. Many other definitions also exist (Harmon et al., 2011; Mont, 2002; Sundin et al., 2009; Wong et al., 2011), but servitization is conceptually the widest one. According to the framework from Thoben et al. (2001) servitization has more than four main levels of servitization, going from pure product to providing pure functionality that can be detached from the product itself. Servitization is applied, not only to the final product of the manufacturer, but also to specific parts of the supply chain that are used to provide the final product (Opresnik et al., 2013b).

By achieving better price discrimination, helping to save costs, and preserving the power to deter a potential entrant (Sheikhzadeh and Elahi, 2013), servitization is used as a foundation for a compe-titive manufacturing strategy (Olivia and Kallenberg, 2003; Slack, 2005). Hilti International provides such an example, when one of its competitors came onto the market with a product with similar specifications, but at a lower price (Johnson et al., 2008). Hilti International reacted by servitizing its product; the drilling machine was no more the object of the sale, but its functionality, with a "pay per hole" model. Taking into account the trends, it can be deduced that servitization will be used even more by manufacturing enter-prises to create additional and more secure revenue streams, since global competition is increasing while margins are lowering. How-ever, despite the fact that P–S can be very promising, there are also many challenges. The three most important ones for this article can be listed (Martinez et al., 2010): (a) the delivery of integrated offering (e.g. expectation gap between the P–S provider and consumer, multi touch points with the customer); (b) the need for the acquisition of new capabilities that enable the organisation to compete in new service spaces, since there is a lack of tools and techniques for use for assessing the internal capabilities of organisations to design and deliver P–S offerings; (c) the need for much stronger cooperation with partners within the manufacturer's supply network of the P–S. In order to contribute to solving those challenges, the concept of service engineering and its related ICT tools is introduced.

2.2. Service engineering within a manufacturing service ecosystem

Many enterprises do not have the processes and corporate structure to enable P–S to be developed efficiently and launched onto the market, thus a structured approach called service engineering is used, based on which models, methods and tools for the composition of new innovative P–S are developed (Bullinger et al., 2003). This article takes into account the advantage of the power of this discipline, and introduces formal semantics in order to transform all the key real world assets of a manufacturing enterprise into their virtual representations, i.e. data. Those can be managed operationally, i.e. added, deleted, shared and composed, by the enterprise that is part of the MSE. Two main types of assets exist – Tangible Assets (TA)(e.g. machines) and Intangible Assets (IA) – that are defined as key drivers whose essence is an idea or knowledge and whose nature can be defined and recorded. In order to operationalize the management of I/T assets, a dedicated virtualization procedure (Hirsch and Opresnik, 2013) has been developed. It is framed within software processes that facilitate the population of the data warehouse and are commonly known as “Extract-Transform-Load” processes (Vassiliadis and Simitsis, 2009). Starting from real-world in-/tangible assets like human skills or physical resources, the virtualization method provides a systematic approach to transfer these assets into a data base and has five main steps—identification of key assets, population of the P–S ontologies, definition of rules, deployment, and maintenance (Hirsch and Opresnik, 2013). The outcome of this process is data about the assets of the manufacturing enterprises that are collabor-ating in the process of servitization.

2.3. *The manufacturing service ecosystem and data*

Servitized supply chains are different from their production counterparts and need to be more responsive, relying on real-time information (Johnson and Mena, 2008). Furthermore, a tighter collaboration between partners is essential in delivering P–S (Martinez et al., 2010). The importance of relationships between enterprises for increasing competitive advantage has been emphasized (Dyer and Singh, 1998) and collaboration between enterprises shown to be one of the key elements of enterprise competence development (McEvily et al., 2003). From the strategic management perspective such a phenom-enon could be termed, according to its function, as a “strategic factor market” (Barney, 1986), defined as a market where the resources necessary to implement a strategy are acquired. Such dynamic networking, as well as collaborative engineering for innovation, can be facilitated by Future Internet (FI) architectures as well as by information and communication technologies (ICT). Consequently, since we are dealing solely with manufacturing enterprises that are collaborating in order to provide as efficiently as possible an innovative P–S on the market, the term Manufacturing Service Ecosystem (MSE) is used to depict an organized collaboration in the process of servitization. Within such MSE, the partners' key assets are virtualized. Each MSE partner has access to this repository. From an employee perspective, when one is inserting data about assets such as compe-tence and skills, it could work similarly to LinkedIn, where the users insert their professional Curriculum Vitae from distributed locations. However, those asset are structured on a dedicated MSE ontology, ena-bling prices and other market conditions to be added, thus providing information relevant for the MSE partners. By adopting such a structured approach to P–S, the enterprise already gains a competitive advantage, as the value of resources and their related skills and competences is greater than the sum of their assets, due to the complementary effect (Amit and Schoemaker, 1993). Furthermore, by using such dedicated ICT tools and procedures, a manufacturing enterprise can acquire external competences and skills, which among other things decreases the force of the path dependent enterprise development (Quélin, 1997), enabling more freedom in innovation. Once the P–S is composed from different assets owned by multiple MSE partners, it can be managed from an assets perspective.

Although the P–S represents the nucleus of the value of servitization, it is not only factor. During servitization another layer of added-value arises, the information layer that is nascent due to a process called informatization (Opresnik et al., 2013a). By showing that servitization is a data intensive process and by offering procedures to exploit them, such data, that are collected from consumers during the P–S usage and then exploited on an ecosystem level, could represent a new revenue stream for manufacturing enterprises. Thus, informatization starts by collecting and storing data during a P–S usage. One possibility is to do this through the smart-products. Second, the data are analysed using business intelligence techniques, where the newly generated information serves as an input for a new innovative P–S or to incrementally innovate the existing one. Alternatively, those information, or simply raw data, can be resold to other entities; for instance to marketing agencies in need of longitudinally accurate behavioural data, that are extremely hard to obtain, or to other manufacturing enterprises with complementary products, or to independent service providers wanting to design a new service. However, the data exploitation phase would be much more efficient if organized within an ecosystem of partners interested in data exploitation—the information ecosystem. Thus, the transactions could be closely managed, ensuring privacy policies and enhancing trust.

2.4. *Big Data*

The term Big Data refers typically to the following types of data (Dijcks, 2013): (a) traditional enterprise data, (b) machine-generated / sensor data (e.g. weblogs, smart meters, manufacturing sensors, equipment logs), (c) social data. Given the mass of data generated through those channels, information overload is going to be the biggest problem for coming generations, as also the biggest oppor-tunity related to data for enterprises (Renee, 2013), as it is opening new exploiting opportunities. Every day Google alone processes about 24 petabytes (or 24,000 terabytes) of data (Davenport et al., 2012), a single jet engine can generate 10TB of data in 30 min, while Smart meters and heavy industrial equipment like oil refineries and drilling rigs generate similar volumes of data (Dijcks, 2013). The increased volume and velocity of data in production settings means that organizations will need to develop continuous processes for gathering, analysing and interpreting data (Davenport et al., 2012). “Smart Products” are also gaining importance, especially with the rise of the Internet of Things, e.g. for performing predictive main-tenance of a refrigerator (Cassina et al., 2007). As there is also an explosion of different types of data, of unstructured data and sources (Beath et al., 2012), volume is not the only major characteristic of Big Data. Thus, there are five Big Data characteristics (Beulke, 2011):(a) volume—e.g. from machine generated data; (b) velocity, increas-ing due to frequency and speed of transactions; (c) variety—increase of structured and unstructured data number of data sources;
(d) verification—tackling the issue of data quality and security levels;
(e) value—enquiring into how value is being extracted from existing data. Consequently, from the perspective of a manufacturing enterprise, after having increased its data Volume, Variety and Velocity, while struggling with Verification, the question that is posed is how a manufacturing enterprise can exploit those data, so that added value can be created. According to Zhu and Madnick (2009), there are two ways an enterprise can increase the value of its data: first sell the “private” data (currently not publicly accessible) or, secondly, to become a data re-user. These strategies are very well known in the software industry. One such case is the online auction site eBay, which uses data in at least two manners; first as data reuse, with the data about the behaviour of millions of its customers it drives analytics at every level of the organization (Boucher Ferguson, 2013). Second it has already begun selling blinded transaction data to interested third parties (Ferguson et al., 2005), thus exploiting them, not only for internal use, but also as a new “product” generating an additional revenue stream, which is data sell. This case indicates not only the strategy of data reuse, but also of “data re-purposing”, which can be part of both previously depicted strategies and simply indicates the possibility to reuse data differently.

In conclusion, a manufacturing enterprise, in order to stay competitive, must servitize in collaboration with others within an MSE. The ICT tools and procedures that support service engineering generate numerous additional volumes of data with a high level of variety and velocity. Due to the software and hardware that support the provision of a P–S (e.g. remote maintenance), there is another source of data available—the P–S during its usage. Consequently, a manufacturing enterprise in mature markets, which is falling into the commodity trap, has new opportunities to increase its long term competitive advantage, by exploiting the Big Data that have become available due to servitization within an MSE. The methodological background of the article is demonstrated in the next section.

3. Methodology

Conceptual simulation is used to design the Big Data Strategy framework in servitization and to simulate the related opportunities. The term is also called "what if" reasoning. It is used in situations of informational ambiguity and may be used to help scientists resolve that uncertainty, especially when attempting to develop a general, or high-level, understanding of a system (Trickett and Trafton, 2007). The latter is the case in this article of trying to develop a Big Data System within a certain level of information ambiguity. Furthermore, Brown and Fehige (2011) proposed a three-step process of first, visualizing a situation, secondly, applying a certain operation on it, and thirdly, observing so to omit or admit causal relations. This framework serves as the research design of this article:

- Visualization of the situation—a process of servitization of a manufacturing enterprise within an MSE.
- Performing an operation on the situation. Big Data generation and exploitation strategies are applied on servitization of a manufacturing enterprise within an MSE. The two main operations can be applied: one being data reuse (in regards to composition of the new P–S and/or analysis of data), while the second is resell of the data generated during P–S usage.
- Observation of causal relations—the effects of the operations from the previous step are analysed in regard to the level of competitive advantage, using RBV and dynamic capabilities.

The concept of the Servitization Big Data System is being designed in the first two steps. It is based on System thinking theory in order to recognize and analyse the relation between the components and the effect on the whole system (Pan et al., 2013). More precisely, by adopting the General System Theory, the system model becomes an important means of controlling and instigating the transfer of principles from one field to another, and it will no longer be necessary to duplicate discovery of the same principles in different fields isolated from each other (Von Bertalanffy, 1950). Thus, the system of the Big Data Strategy framework in servitization simulates the interrelations between the integrated concepts from a data flow perspective, depicting two main points; first how the data are generated and secondly how they are exploited. However, in order to evaluate the findings, the results of the proposed framework have been integrated and benchmarked against established ones in both fields—Big Data and servitization. Furthermore, in the third step, in order to increase the validity of the conceptual simulation onto competitiveness, the results are analysed through an evolutionary perspective and also using the RBV and dynamic capabilities perspectives. The former was chosen, since servitization in the conceptual model is based on Service engineering, which uses assets as a basis, like RBV that uses resources. The latter one was chosen because market needs are dynamic and not static, as advocated by the RBV (Eisenhardt and Martin, 2000) and consequently the firm needs to possess distinctive capabilities to make better use of its resources (Penrose, 1959), which are the dynamic capabilities.

Thus, in this article we investigate whether the Big Data generation and exploitation strategies really undergird the competitive advantage of a manufacturing enterprise that has servitized its product within. Consequently, the Big Data exploitation strategies are independent variables, while the level of competitive advantage is the dependent one. The results can be generalized for a manufacturing enterprise in mature economies that have servitized their products successfully within an MSE. In the following section, the data flow simulation during such servitization is depicted and concrete opportunities for Big Data dedicated exploitation strategies of manufacturing enter-prises in such an environment pinpointed.

4. Conceptual simulation of the Big Data Strategy framework in servitization

The data related to servitization are first analyzed to determine whether they can be treated as Big Data. The first two steps from the research design are applied, which means to conceptualize the framework and then to apply the Big Data generation and exploita-tion strategies.

The servitization related data may appeared to be, *prima facie*, in small amount, well structured and, possibly, quite static. However, when considering the servitization and informatization processes in parallel, this is not necessarily the case. The first of the "5Vs" (Beulke, 2011) is Volume, which can be augmented in two ways. The first is in the process of virtualization, in which the data used by service engineering tools from partnering manufacturing enterprises are loaded into the MSE database. The second way is by the automatic generation and collection of data from smart products during P–S usage. For instance the data generated by a car (e.g. speed, location, tyre pressure), when it is driven, are sent to the manufacturer for further exploitation. The second "V" is Velocity, where the number of transactions and their frequencies are increasing, especially when ideating, composing and testing new P–S; the data must be updated and easily accessible to all partners involved so that they can perform the required service engineering operations. The velocity of availability of different kinds of data from multiple users constitutes one essential advantage of knowledge sharing within an ecosystem of manufacturing enterprises. The third "V" is Variety, which is escalat-ing due to the extremely large number of different types of data, particularly in the form of unstructured data that are being transformed and, due to the increasing number of data sources as servitization is performed among multiple partners with numerous employees, which creates a certain level of complexity. Furthermore, this "V" is important for knowing how to create synergies or new knowledge using data generated through the usage of multiple P–S. The variety of data can increase considerably. For example a partaker could obtain access to data generated from a washing machine, car and mobile phone. The fourth "V", Verification, can represent a challenge in service engineering and servitization, as it is hard to control and ensure the required level of data quality in all aspects. It is handled by integrating different access rights and enhancing trust between partners. The four Vs represent a challenge to manufactur-ing enterprises, and also boosts costs, so that management of such data requires sound business objectives in order to be able to create the last "V", Value, with which this article deals most. Thus, positioning the generation of Big Data in the business context of servitization enables the Big Data in question to be exploited in such way that they create Value. The first four "Vs" represent a more or less technical challenge, while the present article focuses on the last "V", which is a challenge in combining a pervasive business strategy in manufacturing with cutting edge ICT approaches.

The second part of this section deals with visualization of the context, which is also the first step in the research design. The model conceptualization follows a process perspective. The boundaries are defined by the business strategy of servitization within an MSE, using collaborative service engineering approaches to support and spur the process in question. The process of collaborative servitization is divided into four main steps. The first consists of setting-up the MSE before starting with the actual composition of P–S. It is necessary to access the data of the partners cooperating in servitization, thus to identify the data relating to the most relevant assets in each manufacturing enterprise and to load them. After establishing the necessary collaborative and data related infrastructure, the second step consists of the ideation of a new P–S based on the previously virtualized data about the partners' assets; following that, the testing and approval of a certain composition is performed and, finally, the P–S deployed on the market. As each partner should have the right to ideate and deploy P–S, the previously virtualized data must be shareable across the entire MSE. In an environment where multiple business partners are required to deliver a solution, such an organization, based on a service engineering approach can, besides increasing the innovative potential also minimize transaction costs and reaction time. The composition of the P–S contains, not only data such as a classical "bill of material" of the P–S, but other crucial business information like price and availability. These composed data also enable their partial or full reuse by other partners in some later servitization scenarios. Furthermore, as those assets can have price labels and can be dynamically adjusted, it could theoretically allow managers to trade them within their MSE, encapsulating the logic of "buy low, sell high", inclining to creation of a parallel assets market. In the third servitization step the P–S is on the market and in use by consumers. In this step the process of informatization is introduced into servitization. Data are collected from the usage of each P–S on the market and collected by the manufacturer. This step constitutes the second source of data in this process, in addition to data virtualization about the assets of the collaborative enterprises in servitization. In the fourth servitization step, the P–S in question is being improved, relying on continuous innovation. This step sees the beginning of the Big Data exploitation strategy, in which the data are first analysed and then used to innovate existing P–S and ideate new ones. This way manufacturers are not detached from their consumers and can very quickly sense changes in the latters' behaviour. However, the data serving as input into the P–S innovation process constitute only one possibility in exploiting the Big Data previously generated. The second possibility is to sell the generated and collected data on the market to other business entities (e.g. marketing agencies, manufacturers and service providers).

Until now, the Big Data Strategy has been presented from the perspective of the business strategy of servitization. However, the same strategy can also be depicted from the Big Data perspective. In the framework, two main steps are present—first, Big Data genera-tion and, secondly, Big Data exploitation. These two frames help determine in which part of the servitization the data are being generated and whether they are exploited. It can be seen that the virtualization and the management of individual assets merely generate data, while informatization is also valuable for data exploi-tation. Thus, the step of Big Data generation encompasses the first three steps in servitization described previously: (a) setting-up an MSE, (b) P–S ideation and prototyping and (c) P–S usage. These three servitization steps constitute two sources of data: the first comes from the virtualization of the assets of the manufacturing enterprises collaborating in servitization; the second arises from the extraction of data from the P–S during its usage. The four main servitization steps are depicted in Fig. 1, using vertical grey dashed lanes, while more detailed tasks in servitization are represented by horizontal lanes. While the Big Data generation and exploitation strategies are represented in red and blue.

To analyse further all the processes from the Big Data perspective, data exploitation strategies are utilized (Zhu and Madnick, 2009): (a) sell the "private" (i. e. not publicly accessible) data, (b) to become a data reuser. The relationships between the servitization and the Big Data exploitation strategies are shown in Table 1. It shows which steps contribute to which part of the strategy in order to generate Big Data and to create value from them. Data reuse can be a very powerful concept, as already Tim Berners-Lee, inventor of the Web,

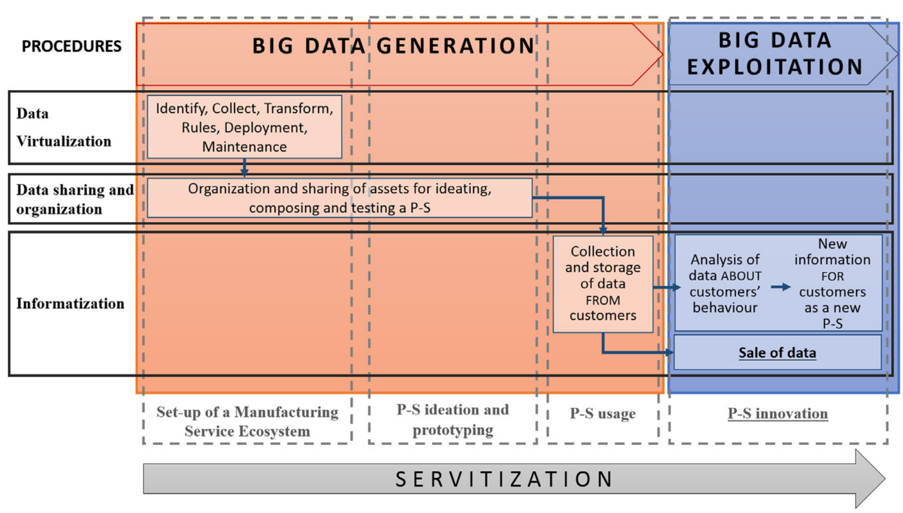

Fig. 1. Big Data Strategy within the context of servitization. (For the colored version of this figure, the reader is referred to the online version of this article.)

Table 1
Relations between servitization and Big Data Strategy.

Big Data Strategies		Virtualization	Org. and sharing	Informatization			
				Collection	Analysis	Sell	Data and/or info as input for new P–S
1. Generation		x	x	x	x		
2. Exploitation	**Reuse**		x		x	x	x
	Resell					x	

said in an interview published in Technology Review in 2004, "the exciting thing is serendipitous reuse of data: one person puts up data there for one thing, and another person uses it another way" (Zhu and Madnick, 2009). The same goes for the assets and their comp-osition within an MSE, where one manufacturing enterprises pub-lishes its assets and another one uses them to compose a completely new P–S. Data reuse is thus also present during the composition of, possibly, multiple P–S; hence, the data is reused. Furthermore the data that are being collected during P–S usage can be used a new input when designing or improving a P–S or simply resold to others. Both possibilities enable data reuse. Thus, in the introduced frame-work, data can be reused for different purposes (i.e. innovation and ideation of a P–S or resell) by the same organization providing them or by other organizations, which is means that those data are first sold to them and then used. Data resell can also be possible by selling them directly, which is being done extensively by the software industry. Table 1 depicts the relationships between the tasks in servitization with the Big Data strategies.

5. Big Data Strategy framework positioning

The previous section depicted the main conceptual model of this article. With the aim to position the framework in question in the fields of Big Data and servitization, some of the most representative frameworks have been chosen to be benchmark against our proposed framework or to scrutinize it through their perspectives. We first address five Big Data frameworks, in three cases we perform a direct benchmark, while in the other two cases we integrate our Big Data Strategy into their framework with the objective to obtain a new perspective. In the second subsection, we then position the proposed Big Data Generation and Exploita-tion strategies within the process of servitization. The objective is to position the proposed Big Data Strategy framework into the literature of servitization as also to emphasis the impact of the Big Data Strategy onto the process of servitization, moreover on the added-value created for the manufacturer.

5.1. Positioning servitization in Big Data theory

Miller and Mork (2013) proposed a Big Data framework called the Value Chain for Big Data based on Porter's value chain, which is process based. Among others, the proposed framework aims to manage data from their generation to the exploitation point where are present the consumers of information. It also presumes data collection from various stakeholders and establishing a portfolio-management approach to maximize the value of the data. Their value chain has three main steps: data discovery (i.e. collect and annotate, prepare and organize data), data integration (i.e. common representation of data), data exploitation (i.e. analyse, visualize and make decision). The Big Data Strategy framework in servitization conceptualized in this article takes up a similar approach. However, compared with Miller and Mork's (2013), our framework do not have an individual second step of Data Integration, but it has been merged with the third phase Data Exploitation. Such integration is need, because the representation of the data must be made according to the objective of data usage, however, in the Big Data Strategy, the consumers of information are unknown until the last step, thus making Data Integration infeasible previously. Furthermore, when benchmarking against the framework of Miller and Mork (2013), one can notice that the Big Data Strategy framework is already focusing on a sectorial application—the application of Big Data on the process servitization within manufacturing enterprises. Consequently, the additional novelty is the actual conceptual application of the concept of Big Data on a specific field, which in this case is manufacturing, moreover servitization. As the application is field specific, our Big Data Strategy framework generates new opportunities for manufac-turing enterprises. Namely, the value of servitization does not solely reside in the P–S itself and in the relationships with customers, but also in the data that are generated during this process. Hence the Big Data exploitation strategy increase substantially the added-value generated from servitization and increase also the number of revenue streams, making servitization an even more profitable and reliable strategy for manufacturers.

A second Big Data framework for benchmarking the Big Data Strategy framework is based on servitization and is called the Big Data Analysis Pipeline (Zheng et al., 2013), describing the perspec-tive of analysis of Big Data with five main steps: (a) acquisition,(b) extraction and cleaning, (c) integration and representation,(d) analysis and/or modelling and (e) interpretation. The frame-work per se do group the steps from a value perspective as our framework or the one from Miller and Mork (2013). Nonetheless, the sub-steps of the framework are then quite similar. Our frame-work would include their first two steps into the data generation phase, while the last three would be in the Big Data exploitation phase. This framework, does not however stipulate multiple users of the data generated from the Big Data analysis.

A third Big Data framework deals with its application for cons-umers, proposing to show how a mathematical topology and Markov chain theory along with co-occurrence analysis can be applied in obtaining useful information to the analysis of various kinds of data in consumer world (Thi Thi Zin et al., 2013). It is a framework constituted of three main blocks: data organization layer, analysis and modelling layer and predictive and inference layer. This framework describes from a technological perspective the data flow, while our framework positions the Big Data flow within a managerial perspec-tive, similar to the Value Chain of Big Data. Therefore, the value of this framework resides in providing extremely concrete and advanced methodologies and tools to extract value, while the value of our Big Data framework relies in providing different modes to generate data from multiple sources, while also providing opportunities to exploit those data.

A forth Big Data framework proposes a Big Data architecture and framework aiming to captures all the stages of a Big Data application (Tekiner and Keane, 2013) consisting of three stages: (a) acquisition and filtering of data, (b) data analysis and modelling, (c) data orga-nization and interpretation, while providing seven layers constituting the Big Data architecture. This framework also focusses on the application of Big Data and adds another level of details being the Big Data architecture. While our Big Data Strategy framework relates the value chain of Big Data with a pervasive business strategy in manufacturing.

As for the fifth and also the last presented Big Data framework in this article, proposes to classify each data set into so called "5Ws" data dimensions. Those stand for "what" the data is, "where" the data came from, "when" the data occurred, "who" received the data, "why" the data occurred and "how" the data was transferred (Jinson and Mao Lin, 2013). This framework was employed to test the Big Data Strategy presented in this article. The value of this integration lies in increasing the understanding this strategy. Hence, in Table 2 the value of the Big Data generation and exploitation strategy is depicted from this perspective also.

5.2. Positioning Big Data in servitization theory

While the previous sub-section depicted the impact of integrating the process of servitization into diverse Big Data frameworks, the following section in turn depicts the opposite, the impact of the Big Data strategy onto servitization. The objective is to scrutinize the added-value of the Big Data strategy for manufacturers.

By offering relevant benefits to customers, the product created a certain amount of added-value, however not only for consumers,

Table 2
Big Data Strategy characterization.

Big Data Strategies	Big Data	What	Where	When	Who	Why
Generation	CVs and Human resources data sets	Text, knowledge items	Human resource department, individuals in the enterprises	As part of preparation for P–S design, thus as part of virtualization	The manufacturing enterprise designing or managing the design of a P–S	To ideate and design new innovative P–S more rapidly using service engineering
Exploitation	Data extracted from a P–S	Items, amounts, text	From the P–S in use	During usage of a P–S	The manufacturer or the organization in charge of exploiting data coming from different P–S of different manufacturers.	Obtain information that can be useful to a set of partakers as wide as possible (e.g. marketing agencies, universities)

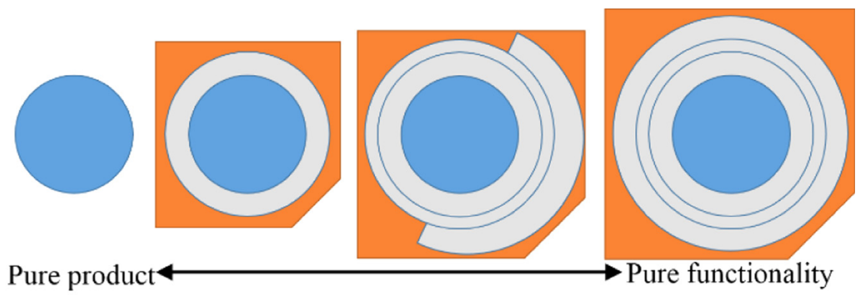

Fig. 2. The added-value of Big Data in servitization.

but also for the manufacturer in terms of profit. After time, when the product's profit margin were decreasing regardless on product innovation, manufacturers had to uptake other growth strategies, among which, one extremely pervasive is the integration of services into the customer offering, resulting into a P–S offering. Thus, insofar, manufacturers had two basis for creating added-value, profit—one was the product and the other was the service. In this article a third layer of added-value is introduced based on data, moreover Big Data. The impact representation is based on Thoben's et al. (2001) seminal representation of servitization and of the informatization process (Opresnik et al., 2013a). In Fig. 2 four combinations of P–S are depicted (Thoben et al., 2001), from a pure product to a customer offering providing a pure functionality called in certain case also product as a service. The inner circles in each phases represent the added-value generated by the product and remains the same through all the four phases. While the services are introduced in the second phase and their added-value increases in each phase and is depicted by grey circles. The novel and third layer of added-value for manufacturers represents the generated data during servitization and is depicted by orange rectangles. This layer is present in all the phases where services are also present. This is because it is presumed that data extraction can be undertaken only in relation to a service (e.g. remote maintenance). This novel layer of added-value, represents a new revenue stream, thus it represents a new Value, which is the fifth "V" among the "5Vs". Consequently, it means that when Big Data are generated through servitization, the most important "V" among all, is being generated also. Namely, one of the biggest challenge in Big Data is the fifth "V"—how to create Value out of data.

The limitation of the representation in Fig. 2 is that the size of the generated added-value is not dependable upon the phase of servitization, but mostly upon the Big Data exploitation strategy and on the type of servitization (e.g. the more services are ICT supported, the more automatically data extraction can be undertaken). However, those two dimensions are not visible here, as such level of details requests additional studies.

The objective of this section was to additionally evaluate the proposed Big Data Strategy framework though the lenses of established frameworks in the Big Data literature as also in the servitization literature. The integration of our proposed solution into existing frameworks as also direct benchmarks gave the opportunity to emphasize the differences and novelties of the proposed framework in regards to both disciplines, servitizaiton and Big Data.

6. Impact of the Big Data Strategy in servitization on competitiveness

This section represents the third and last research design step, it evaluates the impact of the Big Data Strategy framework on the competitiveness of manufacturing enterprises. This evaluation is divided into two main parts. First, a general evaluation is performed through the evolution of the competitive advantages of manufacturers. Then in the second part, the evaluation of the impact of the Big Data Strategy framework is performed through two established theoretical frameworks - RBV and dynamic capabilities. Though there introduction is gradual in order to avoid potential fallacies in causality between the effect of servitizing within an MSE and the introduction of Big Data exploitation strategies based on the Big Data Strategy framework. Thus, this section is, contextually, divided into two main subsections.

6.1. The impact of the Big Data Strategy in servitization on competitiveness—An evolutionary perspective

In order to understand the position and expectations of a Big Data Strategy, it has first to be positioned in the context of the evolution of the core competitive capabilities of a manufacturing enterprise. This will make it clear what should be the role of integrating such a strategy and, moreover, who should or could integrate it. The main findings are depicted in Table 3. It presumes three core steps in the evolution of the competitive advantages of manufacturing enterprises. First, the core of the main competitive strength is the product. Until the 1960s, demand was in many cases higher than supply, so high profit margins were inevitable. However, as competition intensified, manufacturers were forced to

Table 3
Evolution of the competitive advantage of manufacturers.

Competitive advantage	Potential benefits	Type of environment
Product	• Through product innovation, an increase in revenues and profit margin	• Products still enjoy an adequate level of profit margin, thus the market is still not saturated
Product–service	• A second revenue stream (usually with a higher margin and a more stable stream) • Closer interactions with consumers and higher customer retention rate	• The targeted market is saturated, competition is strong, customers are demanding (lowering prices, shorter PLC phases), and the previously satisfactory profit margin has now been eroded • Thus, the need to differentiate strongly against competitors and to retain this competitive advantage longer than the one arising from product innovation. It also involves entering new, niche, markets
Big Data Strategy *(based on product–services)*	• A third revenue stream that could be so disruptive in terms of business model as to enable the manufacturer to drastically decrease the price of its P–S • Continuous P–S innovation based on the extracted data indicating consumers' behaviour	• Customers are no longer willing to pay a relevant price premium for services, but start to take them for granted, as part of the P–S offering • Thus a significant number of competitors have already servitized their business to a certain, "safe", level, meaning that the differentiation based upon service integration is slowly disappearing and indicating that, because of the service profit margin decrease, the service paradox is becoming an even greater threat • A need for a new hard to imitate basis for competitive advantage is needed, being data exploitation • A parallel market is created—an information market • Reaction to customers' needs turns into their prediction

innovate or find new markets to apply their existing products. However, product innovation alone also reached its limits over time, as consumers demanded more flexible offerings, but that was hard to fulfil based solely on products. Thus, manufacturing enterprises had to find new ways to satisfy consumers' needs and to differentiate against competitors, since pure products, even though they were improved, were no longer enough to keep one nose ahead of the competition. Among other factors, customer retention was low and expansive (e.g. the white goods industry) though, on the other hand, market growth was expansive to achieve due to a high market saturation rate.

Therefore, one alternative to these strategic and operational problems, that has proved itself to be extremely successful, was the integration of services into product offerings. This gave manufacturers the opportunity to increase their profit margins, to create a new revenue streams or "just" to increase the customer retention rate (that can be problematic and costly in some cases). However, this strategy that was introduced officially at the end of the 1980s (Vandermerwe and Rada, 1988), and is today already pervasive around the globe, even in countries with a still significant industrial growth and in not yet mature economies. Consequently, more and more types of services are slowly becoming commoditized and are turning into a necessity, rather than a basis for competitive advantage, similarly to quality management that was a basis for competitive advantage from appro-ximately the 1970s onward, but today is present in every manufactur-ing enterprise. The same thing goes for servitization.

Thus, in response to the upcoming need for a new basis for competitive advantage, a new business strategy that exploits the existing competitive advantage of product–services is being introduced—the Big Data Strategy. On the one hand, it builds upon the existing P–S infrastructure and market, while on the other it is building up a new competitive advantage that is even harder to imitate. In theory, it could disrupt existing business models of manufacturing enterprises and their markets. In this case it would generate significant revenues from data exploitation generated during the P–S usage, since it would allow the actual price of the P–S to decrease. In this case, consumers would also benefit, as would other participants in our society, like research centres and policy makers. The limits set in this evolutionary representation exclude other strategies minimizing manufacturing costs, like delocalization, wage reduction, introduction of a "flexible" labour market, etc. Such strategies are considered, unfortunately, to be evident.

6.2. *The impact of the Big Data Strategy in strategy on competitiveness–A Resource Based View and Dynamic Capabilities*

The second part of the section deals with scrutinizing the Big Data Strategy through the theoretical frameworks of RBV and its dynamic capabilities. Since this article is dealing with assets and service engineering, the RBV (Peteraf, 1993; Wernerfelt, 1984) and the dynamic capabilities perspective (Teece et al., 1997) have been chosen to convey the effect of the Big Data System Model. Although RBV does not currently appear to meet the empirical content criterion required of theoretical systems, it does not mean that conceptual work initiated from a resource perspective is not a theory (Barney, 2001). Furthermore, RBV has already shown itself to be a robust and integrative tool (Peteraf, 1993). According to Barney (1991), RBV presents a basis for sustained competitive advantage only when four conditions are met. This is when the enterprise resources are: (a) valuable—these enable strategies to be conceived or implemented that improve efficiency and effectiveness, (b) rare, (c) imperfectly imitable—valuable and rare organizational resources can only be sources of sustained competitive advantage if enterprises that do not possess them cannot obtain them; (d) non-substitutable—there must be no strategically equivalent valuable resources that are themselves either not rare or imitable. Manufacturing enterprises have access to a wide pool of potentially valuable, rare and hard to imitate assets through data virtualization. These data could not have been obtained otherwise, outside the MSE. Hence, based on the RBV, such a manufacturing enterprise, by joining an MSE, has increased its competitive advantage over other enterprises that are servitizing outside the MSE. In addition to the changes to those factors that occur when a manufacturing enterprise enters an MSE, there are other opportunities. Such factor markets would enable the manufacturing enterprise to diminish information asymmetry, thus minimizing its assets price, while maximizing the quality of such assets. This means that "factors markets" of I/T assets are key in an enterprise's strategy. This is novel, as RBV has not been applied systematically to strategic alliances (Das and Teng, 2000), such as ecosystems.

However, it appears that the RBV is not enough to support a significant competitive advantage, since the winners in the global marketplace have demonstrated timely responsiveness and rapid and flexible product innovation, coupled with the management capability to effectively coordinate and redeploy internal and external competences (Teece et al., 1997). Therefore, dynamic capabilities are introduced as another perspective on competitive advantage. Teece et al. (1997) defined "dynamic capabilities" as follows. The term "dynamic" refers to the capacity to renew competences so as to achieve congruence with the changing business environment. The term "capabilities" emphasizes the key role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences to match the requirements of a changing environment. To delineate the difference between RBV and dynamic capabilities, Wang and Ahmed (2007) hierarchical depiction of competitive advantage is used. It is stated that Resources (assets) are the foundation and can be a source of competitive advantage when demonstrating the four necessary conditions for sustaining competitive advantage. However, in dynamic market environments, such resources do not persist over time and hence cannot be a source of sustainable competitive advantage. Therefore, there is a need for "capabilities", which are to result in improved performance, when firms demonstrate the ability to deploy resources to attain a desired goal and also for "core capabilities", which are the ones that are strategically important to the enterprise. Though, when the core capabilities become obsolete due to the changes in the environment, it can create a competency trap (Levitt and March, 1988). Hence, dynamic capabilities are introduced as a constant pursuit of the renewal, reconfiguration and re-creation of resources and capabilities to address the environmental change and are seen as the "ultimate" organizational capabilities that are conductive to long-term performance.

As already seen, servitizing within an MSE has a positive effect on an enterprise's competitive advantage. The output of the Big Data Strategy framework in servitization comprises data and information which, from the RBV perspective, represent, for a manufacturing enterprise, new assets and resources, which can potentially have the four characteristics needed for sustained competitive advantage. Data are generated by the virtualization procedure, by management of I/T assets and by automatic collection during the P–S usage. Some of those I/T assets will be used to compose new P–S, where some core assets will be owned by only one specific MSE partner and, due to factors like causal ambiguity (Reed and Defillippi, 1990), will be imitable only with difficulty and, finally, where there is otherwise no direct substitute for such an asset. The information generated during the exploitation phase, as the result of data analysis, also constitutes new assets. Compared with a manufacturing enter-prise that is servitizing without generating and exploiting the Big Data, it has greater potential to sustain competitive advantage. However, the Big Data Strategy framework does not provide only static assets, but also processes to constantly generate new assets and to exploit them, hence to give them value. The need to compose a new P–S or to ideate or simply to reconfigure an existing P–S can come from the analysed information that has been collected during the P–S usage. This means that the manufacturing enterprise can quickly predict and sense the changes in consumption habits, needs or simply optimize its P–S to maximize revenues. Consequently, the Big Data Strategy framework undergird the dynamic capabilities of a manufactur-ing enterprise to reconfigure, more quickly and more efficiently, its capabilities (core or non-core) in congruence with the need of a dynamic environment. However, reaching congruence with the environment does not indicate that a manufacturing enterprise must solely follow the existing needs of the market, thus innovating incrementally and being too path dependent. Hence, from a Schumpeterian perspective, a manufacturing enterprise should also innovate radically in order to create new needs and not just follow existing ones. The MSE, in relation with the informatization process, provides to each partner the possibility to combine different resources with different needs, thus improving the possibility to step out of path dependency.

7. Discussion and paths for future research

Generating profit from P–S is not self-standing, especially if taking into account the servitization paradox (Neely, 2008). Nonetheless, more and more manufacturing enterprises are servitizing their products and in the future there will be a need for a new evolvement of the servitization strategy. One such possibility is proposed herein. Through the article we have shown that the hypothesis of this article is accepted, meaning that Big Data exploitation can be the next step of the value creation after a manufacturing enterprise has servitized its products within an MSE. Understandingly, it does not mean that servitization and the exploitation strategies as integrated within the Big Data Strategy framework exclude each other, but conversely they do reinforce each other. The more a manufacturing enterprise servitizes its products, the more users they have, the more data can be collected and information exploited through resell and/or reuse. Thus, a novel hierarchy of bases for competitive advantage, from a servitization perspective, is proposed: (a) a manufacturing enterprise servitizes standalone or with ad hoc partners; (b) servitization within an MSE; (c) servitization within an MSE applying a Big Data Strategy framework. This means that a manufacturing enterprise do not differentiate itself solely d on the basis of its products, nor of the services that are related to the products (P–S), but foremost on the type of Big Data exploitation strategies and their efficient incorpora-tion into the servitization process, so to spur the most important of the Big Data's five "Vs"—Value.

In terms of future research, it would be complementary to operationalize the concept of a "factor market" for data/information resell. Such an information ecosystem would gather interested parties in exploiting data derived from the P–S usage. Furthermore it would interesting to assess and offer concrete solutions to practitioners in terms of business analytics. Each manufacturing enterprise does not hold within itself the ability to analyse such a volume of data in a dynamic manner. One possibility would be to make data analysis available as a service within the information ecosystem. Finally, such a new strategic opportunity of Big Data exploitation in relation to servitization could enable the manufacturer to revise business models that are based on the idea to sell as many products as possible, hence not being adequate in terms of sustainability (Garetti and Taisch, 2012).

The limitations of this work are at least twofold. First, although some parts of the Big Data Strategy framework in servitization have already been operationalized successfully within industry, the entire model still rests a conceptual one. To avoid potential fallacies, rigorous theories have been employed and conceptual simulation performed in stages. Second, one of the most relevant impediments for effective utilization of Big Data for supporting decision making arises from "organizational silos", meaning that data are connected to certain organizational functions and are often not made available to the other departments within the organization. If there is a problem in the data flow inside an enterprise, than the question is how the flow of Big Data would behave between multiple partakers and organizations. Strict regulations and governance would have to be put in place, however this perspective is not within the scope of this article.

8. Conclusion

As the servitization level in markets with lower production costs is sharply on the rise (from 1% in 2007 to 20% in 2011) (Neely et al., 2008), manufacturing enterprises in mature economies will have to obtain a new basis for competitive advantage that goes one step beyond servitization. However, until now no such strategy has been offered to complement servitization. A new basis for competitive advantage following servitization has therefore been proposed. The servitization procedure has been scrutinized to form a data perspective, where the data have the characteristics of the Big Data. Although Volume, Variety, Velocity and Verification represent technical challenges in some situations, the main issue with Big Data related to servitization is focused on the fifth "V"—Value. We have inferred that servitization can become a process in which data are the quintes-sence of servitization. This, in turn, has been shown to generate many new business opportunities. It has been hypothesized that operationalization in servitization of the two main data exploitation strategies (Zhu and Madnick, 2009), data reuse and data resell, through the Big Data Strategy framework, is one of the possible next steps in creating new revenue streams and new added-value in a manufacturing enterprise that has already servitized its products within an MSE. To assess this, a three step research design (Brown and Fehige, 2011) was utilized. First, the context was set up, being the process of servitization within an MSE from a data flow perspective. Second, the Big Data perspective was applied enabling a conceptual simulation of the data flow to be depicted. In the third step the effect of the conceptualized Big Data Strategy framework was scrutinized, first using RBV and, secondly, using dynamic capabilities, which extends the resource-based view argument by addressing how valuable, rare and difficult to imitate and imperfectly substitutable resources can be created in changing environments (Ambrosini and Bowman, 2009). Thus, the data from servitization could become one of the nexus of competitive advantage, which can in turn offer a valuable insight on a certain market that competitors do not have or can represent a new product, which is sold separately. Hence, the Big Data Strategy for manufacturers thus represents the possibility to create a new product or service, depending on the perspective.

Collecting and analysing data has, until now, been more in the domain of the software enterprises and not so much of manufacturing ones. The software giants have started providing products to complement their services and obtain even more data. Manufacturing enterprises are already providing services to complement their products (P–S) through servitization, but are still not exploiting the possibilities arising from collection and exploitation of potential data. Lessons could be learned from industries that are rising sharply in terms of innovation and revenues.

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