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Component suppliers in the commodity battle: Can digital technology in multi-tier supply chains help to transform liabilities into opportunities?

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Abstract

This conceptual study analyzes how digital technologies can create opportunities for component suppliers in multi-tier supply chains facing the issue of commoditization and it develops a strategic framework based on prior studies. This study finds that modularity facilitates the understanding of the dynamics of commoditization and knowledge sharing. Furthermore, modularization drives the asymmetric distribution of information in a multi-tier supply chain. Finally, digital technologies can offer strategic opportunities for targeting different stages of the value chain. Component suppliers should evaluate the criticality of products in new business models and advanced services to reduce the complexity of the landscape of strategic options and, thus, reduce wrong decisions. Managers should encourage general information sharing and open data exchange in a multi-tier supply chain. They should focus on vertical and horizontal partnerships and collaborations to foster the benefits of digital technologies. Conclusively, component suppliers should cooperate to build a counterweight to original equipment manufacturers in the vertical partnership. This study is the first to integrate the benefits of commodities and digital technologies in a strategic framework. It contributes to the literature on competition in the background of commoditization by outlining the concept of information asymmetry within a multi-tier supply chain driven by modularity. Thus, it advances the literature on digital technology and commoditization.

Keywords: multi-tier supply chain, strategy, modularity, servitization, commoditization, digitalization, knowledge-based view

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1. INTRODUCTION

Manufacturing firms in multi-tier supply chains face highly competitive, rapidly changing, and severe market conditions (Tate, Ellram, Schoenherr, & Petersen, 2014). Furthermore, the standardization of processes and products and the development of interfaces can reduce component suppliers' ability to offer added value (Cabigiosu, Zirpoli, & Camuffo, 2012; Camuffo, 2004). Therefore, component suppliers often lack the opportunity to differentiate their offerings in the light of reduced innovation awareness (Gebauer, Fleisch, & Friedli, 2005; Ulaga & Reinartz, 2011). Specifically, the lack of innovation can lead to an increasingly homogenous offering, with no product differentiation that fosters increased competition (Reimann, Schilke, & Thomas, 2010). Increased standardization within a multi-tier supply setting contributes to commoditization. Commoditization refers to a competitive environment with low product differentiation, which leads to interchangeable products, high price sensitivity among the buyers, low switching costs, and high industry stability (Reimann et al., 2010). Since products become commoditized (even in knowledge-intensive industries) in shorter cycles after investing in new capabilities and production assets, it is challenging to generate sustainable profits (Uehara et al., 2018). Hence, innovation is vital to counteract commoditization and generate new value continuously to ensure sustainable profit and competitive advantage (Gomes & Wojahn, 2017; Martín-de Castro, Delgado-Verde, Navas-López, & Cruz-González, 2013). In this context, firms offer more services to differentiate their offerings (Gebauer et al., 2005; Ulaga & Reinartz, 2011). In the case of manufacturing firms, they switch focus from merely adding services to making services their key offering (Kastalli & Van Looy, 2013; Smith, Maull, & Ng, 2014). A firm's transformation from being solely a manufacturer to a firm offering increased service offerings is called servitization (Baines & Lightfoot, 2014). While many scholars have explored the benefits of servitization, others warn about the disadvantages of generalizing the servitization approach—that is, servitization could lead to reduced profits (Benedettini, Neely, & Swink, 2014; Gebauer et al., 2005). Recent studies have revealed that, to cope with the complexities and risks of servitization, firms are increasingly relying on their ability to leverage digitalization (Parida, Sjödin, & Reim, 2019).

Digitalization has been widely discussed in past research (Baines et al., 2007; Baines & Lightfoot, 2014; Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013; Mathieu, 2001; Yoo, Boland, Lyytinen, & Majchrzak, 2012). Scholars have identified multiple advantages of applying digital technology (e.g., information technology, components such as sensors that generate digital output, and data analytics) to firm operations, including the application of new product or service innovations, utterly novel business models, and options for value creation (Bharadwaj et al., 2013; Hess, Benlian, Matt, & Wiesböck, 2016; Pagani & Pardo, 2017; Svahn & Mathiassen, 2017). However, studies have also indicated the possible challenges of applying digital technologies in multiple domains (e.g., Singh & Hess, 2017; Svahn, Mathiassen, Lindgren, & Kane, 2017). Component suppliers may perceive digitalization as an opportunity to innovate and consider their position within the multi-tier supply chain as a strength for changing the supply chain game in their multi-tier supply chain. Therefore, it is crucial to demonstrate how the described concepts and digitalization can be linked to offer a comprehensive framework for facilitating a competitive advantage for component suppliers.

Prior studies have focused on firms' abilities to innovate and create competitive advantages (Porter, 1985; Sirmon, Hitt, & Ireland, 2007). A manufacturing firm's challenge to leverage knowledge implies the need for a more network-oriented collaboration within the multi-tier supply chain (Adner & Kapoor, 2010; Pagani, 2013). Adner and Kapoor (2010) refer to an ecosystem perspective, comprising all stakeholders affected by innovations. However, despite acknowledging the benefits, previous studies have focused on unilateral relationships (e.g., buyer-supplier relationship, bargaining power, and the comparison of single-tier value creation stages) and neglected the impact of the relationships within a multi-tier supply chain (Adner & Kapoor, 2010). Furthermore, as specified by Vial (2019), prior research has often focused on particular digitalization issues involving comprehensive strategies, innovation strategies, organizational structures, or processes. However, no specific frameworks have dealt with detailed value creation stages. Therefore, no theoretical framework can explain how component suppliers can use digital technologies to escape the commodity battle. A framework for joining the concepts and for appreciating component suppliers' contexts and market settings could enable firms to adopt an efficient approach (e.g., resource allocation) for the strategic development of their current positioning and value creation, thus contributing toward creating competitive development advantages in various market settings.

It is against this backdrop that this study develops a strategic framework for component suppliers to consider digitalization as an opportunity and to realize strategic options in an exemplary manner to foster competitive advantage. First, this study reviews relevant literature in the field of innovation capability, modularity, commoditization, digitalization, and advanced services. Second, it derives a new concept of information sharing in multi-tier supply chains enabled by digital technology. Third, based on these insights, strategic implications are drawn for component suppliers to leverage their position.

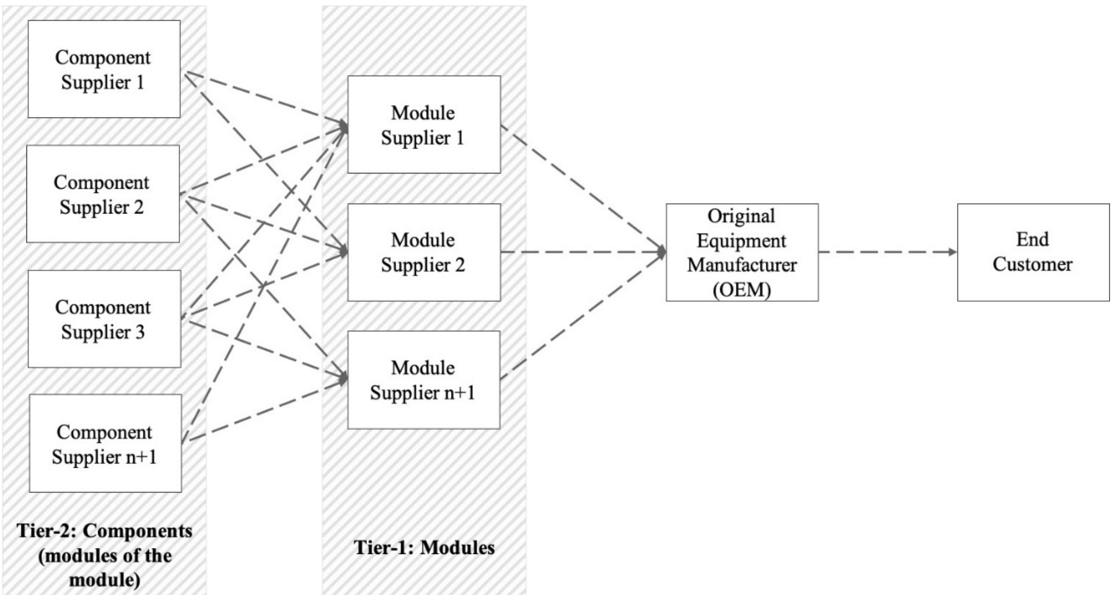
This study focuses on capital- and knowledge-intensive, slow-moving (in terms of technological innovation) industries that feature long product life cycles and the highest safety requirements. Thus, this study presents a multilateral approach, encompassing a multi-tier perspective on innovations (i.e., original equipment manufacturer [OEM], module supplier [tier-1], and component supplier [tier-2] perspectives). First, it extends the management literature to explicitly take account of the strategic implications of digital technologies for component suppliers in a multi-tier supply chain. Second, it improves the understanding and transparency of digital technologies as a source of disruption by clearly showing their impact on the competitive landscape in a multi-tier supply setting (Loebbecke & Picot, 2015; Pagani, 2013). Third, this study sheds light on strategic responses to digital disruption and provides a clear framework for how digital technologies can be considered a risk by increasing commoditization and disadvantaging the companies that want to remain in their established position. It also shows how component suppliers can adjust their strategic orientation to use digital technology to enable a profitable new positioning within the existing multi-tier supply chain. Therefore, this study answers a call for research investigating firms' strategies and information system strategies (Bharadwaj et al., 2013) and how digitalization strategies can be integrated into firms (Matt, Hess, & Benlian, 2015). Finally, it explains why and how firms need to leverage digital technologies to enable new value creation paths by leveraging data in defined networks as a strategic response (Vial, 2019). Component suppliers facing commoditization have to understand the phenomenon's drivers and digitalization benefits in a multi-tier supply chain.

The rest of the study is structured as follows. Section 2 presents the theoretical background of the research. Section 3 describes the fundamental concepts and reviews the literature. Section 4 presents the conceptual implications and an illustrative example that applied the strategic framework in the railway industry, and Section 5 provides the conclusion.

2. THEORETICAL BACKGROUND

Various contextual determinants at the product level and outsourcing initiatives, combined with globally oriented procurement activities, have led to the emergence of more complex multi-tier supply chains (Contractor, Kumar, Kundu, & Pedersen, 2010). A multi-tier supply chain consists of the end customers, OEMs, module suppliers, and component suppliers (Figure 1). End customers are the final product users, OEMs provide the finished products to end customers and source (multiple) modules from (diverse) module suppliers (tier-1 supplier), and module suppliers source the relevant components from tier-2 suppliers (component supplier). Components may consist of further parts, referred to as modules of the module. As a result, firms cooperate in more complex and dynamic networks comprising multiple firms (Carter, Rogers, & Choi, 2015; Pagani, 2013).

Figure 1: Generic schema of a multi-tier supply chain



Prior research has used the resource-based view (RBV) and the knowledge-based view (KBV) as lenses to deconstruct firms' participation and resulting sources of competitive advantage in such multi-tier supply chains (Barney, 1991; Grant, 1996). The RBV is an essential framework for achieving competitive advantage. RBV sees a firm's strategic assets (e.g., resources and capabilities) as the key to gaining sustainable competitive advantage (Conner & Prahalad, 1996; Grant, 1996). The KBV emerges from the RBV and focuses on leveraging knowledge management, knowledge-based resources, and their limitations within a firm (e.g., tangible resources; Gardner, Gino, & Staats, 2012; Gassmann & Keupp, 2007). KBV highlights knowledge as the most important resource fostering competitive advantage (Amit & Schoemaker, 1993; Kogut & Zander, 1992; Spender, 1996). Furthermore, previous studies have demonstrated the link between KBV and innovation, underlining the point that thriving innovators successfully build and manage knowledge within and outside their own firm's borders (Díaz-Díaz, Aguiar-Díaz, & De Saá-Pérez, 2008; Gomes & Wojahn, 2017; Martín-de Castro et al., 2013; Tamayo-Torres, Gutiérrez-Gutiérrez, Llorens-Montes, & Martínez-Loopez, 2016). Particularly, the orchestration of resources and assets may result in competitive advantages (Sirmon, Hitt, Ireland, & Gilbert, 2011). However, the complexity of a multi-tier supply chain has an impact on various economic parameters (e.g., costs). Consequently, firms are constantly striving to reduce complexity, and, thus, improve the efficiency of multi-tier supply chains (Choi & Krause, 2006). Furthermore, confronted by high market uncertainty, competitive intensity, and diverse customer demands, manufacturers try to reduce overall product and organizational complexity.

Previous studies demonstrate that standardized structures enable modularity to reduce product complexity by breaking up complex products into smaller systems, bridging coordination and information exchange needs (Baldwin, 2008; Langlois, 2002; Pil & Cohen, 2006; Sanchez & Mahoney, 1996; Seyoum & Lian, 2018; Sosa, Eppinger, & Rowles, 2003; Worren, Moore, & Cardona, 2002). Standardized interfaces between components and codified knowledge, and reduced interdependencies between modules (loosed coupling), enable modularity (e.g., Campagnolo and Camuffo, 2010) and are vital for outsourcing assets to suppliers and developing hierarchically organized supply chain structures (e.g., multi-tier supply chain; Cabigiosu et al., 2012; Camuffo, 2004; Zirpoli & Becker, 2011). This study demonstrates that standardized interfaces lead to commoditization of modules and components. OEMs increase competitive advantage by focusing on core competencies in a modular environment (Langlois, 2002). OEMs and module suppliers then transfer value and knowledge to suppliers (Doran, Hill, Hwang, & Jacob, 2007). However, only specific information related to the dedicated development-production task is transferred down (Cabigiosu et al., 2012). Thus, component and commodity suppliers are barely involved in the general product development process and receive no general system knowledge vital for innovation and differentiation opportunities, which further drives commoditization (Von Corswant & Fredriksson, 2002; Wynstra, Von Corswant, & Wetzels, 2010). Hence, modularity further impels asymmetric information distribution within the supply chain.

To ensure continued innovation and improve business performance, firms in various fields (e.g., supply chains, sales channels, and processes) should deploy digital technologies (Matt et al., 2015). Recent research and empirical studies have shown the benefit of digitalization in firms' internal and external settings (see Vial ,2019, for an extensive overview). Digitalization enables new business models (BMs; Cenamor, Rönnberg Sjödin, & Parida, 2017), thus driving servitization and advanced services (Baines & Lightfoot, 2014; Cenamor et al., 2017; Parida et al., 2019). Specifically, new BMs enable suppliers to support their customers by fostering innovative activities (e.g., predictive maintenance schemes using sensors for monitoring tasks) built on digital technologies (Baines & Lightfoot, 2014; Jabbour, Jabbour, Sarkis, & Filho, 2017; Nobre & Tavares, 2017). Yoo, Henfridsson, and Lyytinen (2010a) demonstrate that digital technologies allow existing products and services to be combined in order to provide new digital offerings. Adding various digital technologies to the existing product portfolio could offer additional innovation potential or generate new value paths (Loebbecke & Picot, 2015). Further, research often underlines the significance of companies' data analysis ability with regard to developing new BMs and product and service combinations; this is even more the case in the setting of new value paths (Günther, Rezazade Mehrizi, Huysman, & Feldberg, 2017). The ability to analyze data at the product level is the most critical role of advanced maintenance schemes (Bressanelli, Adrodegari, Perona, & Saccani, 2018; Gebauer, Gustafsson, & Witell, 2011). Moreover, in order to offer and use these advanced maintenance schemes, the development of product knowledge—especially the product architecture—is essential (Baines et al., 2017; Cabigiosu et al., 2012; Kapoor & Adner, 2012). That said, one disadvantage component suppliers face is the fact that OEMs primarily define product architecture (Cabigiosu & Camuffo, 2011). However, continuous outsourcing and a multi-tier set-up increase OEMs' challenges in analyzing component data and leveraging it for providing advanced services to customers. Therefore, OEMs are willing to share data and knowledge when offered an added value by the component supplier, thus enabling innovation on the component supplier side (Wang, Sharma, & Cao, 2016). Component suppliers can use the product-specific and far-reaching data for product and service innovation and differentiation.

When referring to the amount of relevant data within a product component, suppliers can occupy various modules within a complex product and leverage the information for future product- or service-specific innovation to gain competitive advantage. Thus, component suppliers can offer vital knowledge regarding various assets at the component level compared to a single module supplier, which further reduces OEMs' coordination efforts. Moreover, digitalization enables the bundling of module-specific components related to operational performance (e.g., remaining useful life), which in a service environment enables component suppliers to integrate forward in the supply chain.

3. THEORY AND RESEARCH CONSTRUCTS

3.1 Knowledge sharing supporting innovation capability

Beginning with the well-known work by Penrose (1959), previous literature began to underline the importance of knowledge that enables competitive differentiation. Over recent years, researchers have investigated how knowledge or information is transferred within companies and beyond their borders through a process that is referred to as "knowledge sharing" (Appleyard, 1996; Darroch, 2005; Loebbecke, van Fenema, & Powell, 2016). Specifically, scholars have emphasized the relevance of knowledge sharing, the improvement of firms' innovation capacity, and the fostering of competitive advantages (Chiu, Hsu, & Wang, 2006; Wang et al., 2016). Scholars have categorized knowledge into explicit and tacit knowledge (Trkman & Desouza, 2012; von Krogh, 2009; Wang & Wang, 2012). Due to its codable and articulated nature, explicit knowledge is transferable (by communication or written documents; Simonin, 1999). Tacit knowledge is non-verbalized, gained by experience, unarticulated, and cannot be easily transferred (Weick & Westley, 1996). Loebbecke et al. (2016) established a detailed approach to knowledge sharing with multiple classifications following Matusik and Hill (1998), who investigated leveraging knowledge to achieve competitive advantage. Nevertheless, this study focuses on general knowledge sharing. The remainder of the study follows James, Guile, and Unwin (2013), who distinguish between individual (e.g., firm-specific) and collective knowledge, private and public knowledge (knowledge owner), component (work element knowledge) and architectural (general process knowledge) knowledge, and tacit and explicit knowledge. No level is exclusive (e.g., architectural knowledge can be private, collective, and tacit; Loebbecke et al., 2016; Matusik & Hill, 1998).

Knowledge sharing, a concept within knowledge management (Foss, Husted, & Michailova, 2010; Ghosh, 2010), is grounded in the KBV (Wang, Wang, & Liang, 2014). Prior studies have considered the knowledge sharing process within and across firm boundaries (Ayala, Paslauski, Ghezzi, & Frank, 2017; Conner & Prahalad, 1996; Loebbecke et al., 2016; Wang et al., 2016) and defined it as a process wherein know-how is transferred (e.g., by communication and interaction) to improve innovation capability and sustainable competitive advantage (Foss et al., 2010; Wang et al., 2016). As products become sophisticated and new digital technology emerges, cooperation becomes a vital corporate strategy (Chen et al., 2017; Feller, Parhankangas, Smeds, & Jaatinen, 2013; Un & Asakawa, 2015). Loebbecke et al. (2016) emphasize the paradox of sharing knowledge with vertical or horizontal partners. According to them, though knowledge sharing may contribute to business opportunities (e.g., new capabilities), it may negatively affect a firm's market differentiation and reduce competitive advantage (Loebbecke et al., 2016). Therefore, firms must focus on both competitive advantages and the disadvantages of partnerships to secure long-term success (Becerra, Lunnan, & Huemer, 2008; Trkman & Desouza, 2012).

3.2 Modularity and the commodity battle

3.2.1 Modularity

Reducing the overall product complexity is possible (Seyoum & Lian, 2018) by breaking up products into modules comprising smaller systems and subsystems (Cabigiosu & Camuffo, 2011). The decomposition of the product design into different modules is a concept known as modularity, which allows further characterization of different product designs (Cabigiosu & Camuffo, 2011). Modularity has been the subject of many systematic investigations (Baldwin & Clark, 1994, 2000; Cabigiosu & Camuffo, 2011; Frandsen, 2017; Sanchez & Mahoney, 1996; Sosa et al., 2003; Ulrich, 1995). Following Simon's (1962) work on nearly decomposable systems, scholars have employed modularity as a general framework to describe different economic phenomena (MacDuffie, 2013; Ponte & Sturgeon, 2014; Schilling, 2000; Sturgeon, 2002) and analyze organizations and processes (Baldwin & Clark, 2000; Sanchez & Mahoney, 1996). Modularity has also been frequently discussed in services and BMs (de Blok, Luijkx, Meijboom, & Schols, 2010; Cabigiosu, Campagnolo, Furlan, & Costa, 2015; Voss & Hsuan, 2009). Studies have proposed several definitions (Baldwin & Clark, 2000; Ulrich, 1995). Ulrich (1995) defines architectures as modular if a one-to-one mapping of functional elements and components exists. Baldwin and Clark (2000) describe modularity as a decomposition scheme that assumes independence across product modules, and high interdependence between the module components characterizes modules. The former concept is referred to as "loose coupling" and posits that changes in one module barely impact other modules within the product (Orton & Weick, 1990; Sosa et al., 2003).

From a practical perspective, modularity adds value by reducing complexity, increasing outsourcing opportunities, and providing design advantages, thus increasing firms' strategic flexibility (Baldwin & Clark, 2000; Ethiraj & Levinthal, 2004; Sanchez & Mahoney, 1996). Specifically, modularity enables firms to respond more efficiently to environmental shifts, increase the range of products and services, and increase the firm's versatility to substitute modules or "mix and match" (Baldwin & Clark, 2000; Cabigiosu et al., 2015; Garud & Kumaraswamy, 1993; Pil & Cohen, 2006; Sanchez & Mahoney, 1996; Worren et al., 2002). Furthermore, by using the same module in different products, firms can employ economies of scale (Baldwin & Clark, 2000). Moreover, modules can be designed independently, which can reduce the specificity of a module (Baldwin, 2008) and lead to outsourcing modular product designs and engineering efforts (Baldwin & Clark, 1997; Schilling & Steensma, 2001; Zirpoli & Becker, 2011). Consequently, Langlois (2002) argues that modular assets reduce buyer-supplier coordination efforts.

3.2.2 Commoditization and the commodity battle

Preliminarily, this study follows Lager and Blanco's (2010) definition that commodity products are interchangeable assets of uniform quality and standard specifications, which exhibit low-level differentiation and are offered by many suppliers. Given the lack of differentiation, firms compete based on price (Greenstein, 2004). The low degree of differentiation leads to an increasingly homogeneous product range and comparatively low switching costs for price-sensitive customers; this circumstance is referred to as commoditization (Reimann, Schilke, & Thomas, 2010). Commoditization thus describes a competitive environment in which the product offerings of many supply alternatives are increasingly aligned from the customer's perspective (Davenport, 2005). This may affect functional products, which Lager and Blanco (2010) define as differentiated assets. Differentiated products have less interchangeability, prices can be set on a cost-plus basis, and suppliers are limited (Lager & Blanco, 2010). Thus, merging both concepts (commodity and functional products) into a process-oriented approach, the commodity battle can be defined as firms' approach to staying competitive by contributing to the product differentiation factors perceived by customers (Lager & Blanco, 2010).

The commodity battle has two perspectives: commoditized products trying to achieve product differentiation or functional products trying to avoid commoditization via continuous innovation (Lager & Blanco, 2010; Linn, 1984). This effort may secure profitability (Matthyssens & Vandenbempt, 2008; Narver & Slater, 1990; Rangan & Bowman, 1992) and address price wars (Davenport, 2005; Guiltinan & Gundlach, 1996; Heil & Helsen, 2001).

3.3 Digitalization leading to advanced services approaches

3.3.1 Business model innovation and servitization

Researchers have increasingly emphasized the importance of business model innovation (BMI) to achieve sustained competitive advantage and increase firm performance (Bashir & Verma, 2017; Bock, Opsahl, George, & Gann, 2012; Bogers, Hadar, & Bilberg, 2015; Chesbrough, 2002; Chesbrough, 2010; Foss & Saebi, 2016; Spieth, Schneckenberg, & Ricart, 2014; Wei, Yang, Sun, & Gu, 2014). BMI is a novel BM or changes to established critical principles and architecture of a BM (a product or service; Bock et al., 2012; Foss & Saebi, 2016). Furthermore, BMI is a conceptual configuration wherein firms employ new ideas (e.g., technologies for product or service development) regarding established ways of doing business (Baden-Fuller & Haefliger, 2013; Osterwalder, Pigneur, & Tucci, 2005). Thus, it encompasses major trades and BM novelties, including innovative technology (Chesbrough, 2002, 2010; Foss & Saebi, 2016) or the foundation of innovation itself (Snihur & Wiklund, 2019). Moreover, by adding services to their established BMs and product portfolios, many firms innovate in direct response to customers' needs to achieve differentiation (Kowalkowski & Brehmer, 2008).

Servitization as an approach necessitates that firms relate services directly to their products to extend their traditional product portfolios (Baines et al., 2007). There has been an increase in research focusing on service-dominant business logic (Vargo & Lusch, 2016). Scholars have discussed servitization characteristics with regard to the synergies of these characteristics (Baines & Lightfoot, 2014; Lenka, Parida, & Wincent, 2017; Mathieu, 2001; Oliva & Kallenberg, 2003; Parida, Sjödin, Wincent, & Kohtamäki, 2014; Tukker, 2004). Mathieu (2001) builds his topology via two key variables (organizational focus and service specificity), and Tukker (2004) develops his theory via eight so-called product service systems (PSSs; e.g., ranging from asset use to performance). Although Tukker's (2004) PSS approach is acceptable (Baines et al., 2017; Bocken, Short, Rana, & Evans, 2014; Reim, Parida, & Örtqvist, 2015; Smith et al., 2014), an arguable weakness is the generalization of the categories (Parida et al., 2014). Thus, this study employs Oliva and Kallenberg's (2003) service-oriented categorization for servitization, an impact-oriented view on whether firms offer customized services or service supported products that address customer services. The company providing the service may either offer a combination of products and services or directly impact customers' business processes (Kowalkowski, Gebauer, & Oliva, 2017; Kumar & Reinartz, 2016; Reim et al., 2015; Ulaga & Reinartz, 2011). Accordingly, the primary goal is to achieve customer process integration to enable the highest possible differentiation.

Servitization offers many benefits to manufacturing firm performance via differentiation, creating value by addressing customer needs, and achieving sustainable competitive advantage (Baines, Lightfoot, Benedettini, & Kay, 2009; Gebauer et al., 2011; Oliva & Kallenberg, 2003; Parida et al., 2014). However, it is no panacea for solving the firm's business challenges. Specifically, scholars discuss the interrelation between service-oriented BMI and performance decline (e.g., reduced profit) of the service provider (Benedettini et al., 2014; Visnjic, Wiengarten, & Neely, 2014). Studies refer to this interplay as the "servitization paradox," and the associated risk is called the risk of servitization (Benedettini et al., 2014; Cenamor et al., 2017; Fang, 2008; Gebauer et al., 2005; Kastalli & Van Looy, 2013). Although many studies recognize the importance of conceptualized service approaches, a generalized approach to successfully implementing servitization is missing (Coreynen, Matthyssens, & Van Bockhaven, 2017).

3.3.2 Digitalization, advanced services, and platforms

Many scholars acknowledge that digitalization's benefits enabled servitization approaches to overcome the servitization paradox (Ardolino et al., 2018; Kindström & Kowalkowski, 2014; Rymaszewska, Helo, & Gunasekaran, 2017). This study defines digitalization as the "use of digital technology (e.g., sensors) to enable BMI and contribute to a firm's value proposition via digitized product information" (Gobble, 2018; Parida et al., 2019; Roblek, Meško, & Krapež, 2016). Accordingly, as defined in this study, digital technologies suit the SMACIT acronym (social, mobile, analytics, cloud, internet of things) coined by Sebastian et al. (2017). However, it is not limited to one field of technology in an operational setting but rather a combination of technologies or applications (Bharadwaj et al., 2013). Scholars refer to the need to apply digital technologies in an operative setting (Loebbecke & Picot, 2015). Firms can combine digital technologies with existing products and services to enable new offerings (Yoo et al., 2010a). By focusing on services (Barrett, Davidson, Prabhu, & Vargo, 2015), firms may offer digital services by implementing digital technology, which may extend their service portfolio (Coreynen et al., 2017; Dalenogare, Benitez, Ayala, & Frank, 2018; Vendrell-Herrero, Bustinza, Parry, & Georgantzis, 2017) and monitor product conditions and health on a digitally accessible and shareable system. Thus, firms may receive real-time information from monitored data (e.g., usage, status, location; Ardolino et al., 2018; Baines & Lightfoot, 2014; Spring & Araujo, 2017), resulting in increased customer proximity (Rymaszewska et al., 2017) to bypass the OEM. Furthermore, service suppliers could use this customer-specific information to leverage their situation "from bargaining to communication" (Baines & Lightfoot, 2014; Bressanelli et al., 2018; Lenka et al., 2017; Rust & Huang, 2014). Thus, firms can derive useful life and apply maintenance schemes via specific asset information (e.g., condition-based maintenance; Baines & Lightfoot, 2014; Jabbour et al., 2017; Nobre & Tavares, 2017).

Oliva and Kallenberg (2003) add to the literature above by referring to service suppliers' development from services supporting a product to more advanced services and solutions (e.g., flexible maintenance schemes). Given digitalization (Lenka, Parida, Sjödin, & Wincent, 2018; Rönnberg Sjödin, Parida, & Kohtamäki, 2016), scholars define advanced services as "a capability delivered through product performance, adding critical value to customers' business processes, and often featuring; relationship over extended life cycle, extended responsibilities, and regular revenue payments" (Baines & Lightfoot, 2014, p. 13). Incentivized contracting set-ups (e.g., power-by-the-hour) support advanced services (Baines & Lightfoot, 2014), where the service supplier assumes responsibility for customer availability or asset uptime. Scholars have examined the positive impacts of a platform approach on advanced services (Bask, Lipponen, Rajahonka, & Tinnilä, 2010; Cenamor et al., 2017; Voss & Hsuan, 2009), where digital technology (based on a modular architecture) enables firms to flexibly use modules to increase their offerings and keep complexity to a minimum (De Reuver, Sørensen, &

Basole, 2018; Sawhney, 1998; Thomas, Autio, & Gann, 2014; Yoo et al., 2012; Yoo, Henfridsson, & Lyytinen, 2010b). The ability (i.e., knowledge) to analyze extensive data using analytics and pronounced analysis for justified decision-making is the most critical (Bressanelli et al., 2018; Gebauer et al., 2011). As digitalized products become increasingly complex, manufacturing firms have to develop new capabilities, engage in external cooperation, and share information to leverage advanced services (Hakanen & Rajala, 2018; Leminen, Rajahonka, Wendelin, & Westerlund, 2019).

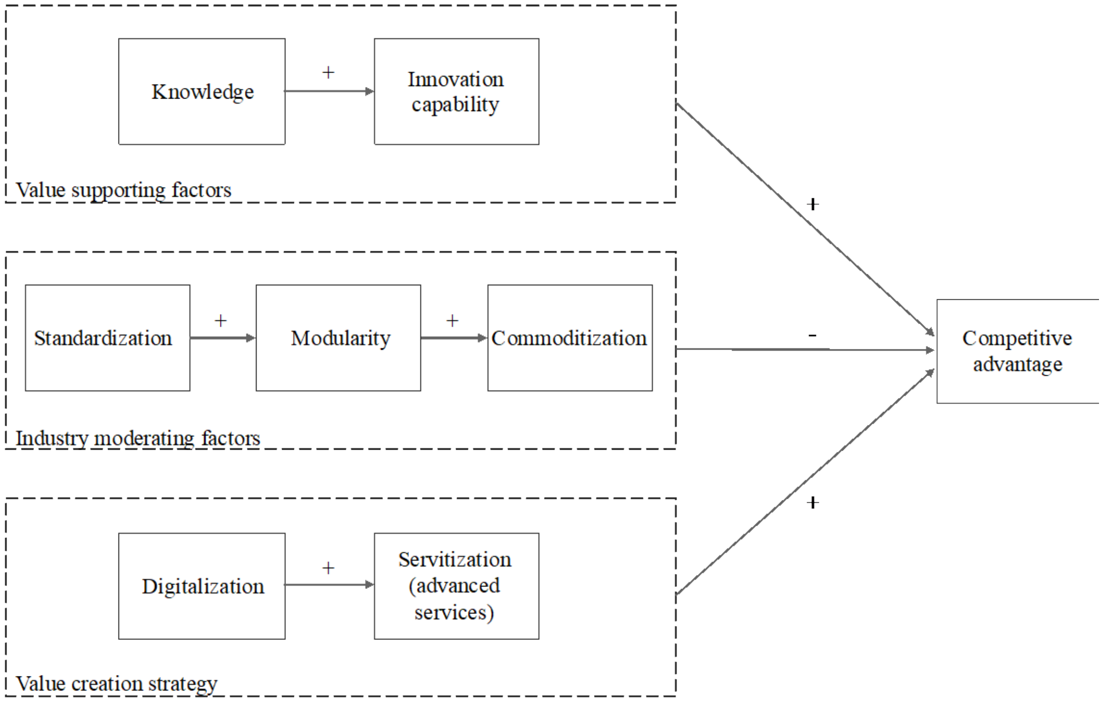
Cenamor et al. (2017) posit that platforms should escape the servitization paradox by integrating digitalization with the general ecosystem approach. Platforms form the basis for exchanging digital products and services regardless of the value-added stage or industry. This gives them a strong influence on the existing market model (Tiwana, Konsynski, & Bush, 2010). More specifically, Lusch and Nambisan (2015) underline the relevance of service platforms for increasing the flexibility of resources, allowing an efficient exchange of services to enable further innovation. However, firms need to develop integrative capabilities, as multiple actors from multiple industries and value-creation stages participate in platforms (Jacobides, Cennamo, & Gawer, 2018). Hence, in this network of multiple stakeholders from different industries and stages of the value chain, different relationships and interests need to be managed to offer the customer added value (Li, Su, Zhang, & Mao, 2018; Tan, Pan, Lu, & Huang, 2015).

Scholars have identified specific value-adding roles in this field: front- and back-end units (Cenamor et al., 2017). Front-end units are responsible for offering services to the end customer. Back-end units cater to the operational development (e.g., design, development, and production) of a service (Cenamor et al., 2017; Gebauer & Fleisch, 2007; Grönroos, 2011; Oliva & Kallenberg, 2003). Parida et al. (2014) specify communication between the two roles as vital for servitization success. Likewise, studies on platforms distinguish between two distinctive actors: the orchestrator and the offering builder (Aarikka-Stenroos & Ritala, 2017; Bask, Lipponen, Rajahonka, & Tinnilä, 2011; Thomas et al., 2014). The orchestrator (defined as the platform owner, designer, and provider) coordinates interactions within the platform network and is responsible for end customer offerings (Cenamor et al., 2017; Ikeda & Marshall, 2019). The offering builder assumes the back-end unit's role and adds value to the offerings (Cenamor et al., 2017). This study employs platform roles as a construct for inter-firm cooperation based on digital technology.

As noted above, manufacturing firms can improve their competitive advantage via servitization. However, operating within an established multi-tier supply chain, actors (e.g., OEM and tier suppliers) need to defend their current position, face the competition (horizontal or vertical), offer advanced services, and dominate the new network (Dijkman, Sprenkels, Peeters, & Janssen, 2015; Kiel, Arnold, & Voigt, 2017; Vendrell-Herrero et al., 2017). Thus, firms' strategies on networks, partnerships, and external factors should be highly prioritized and defined ex-ante (Kiel et al., 2017; Tee, Davies, & Whyte, 2019).

Emerging studies on servitization focus on the specific benefits of digital technology tools (e.g., sensors, remote monitoring, cloud computing, big data, and predictive analytics; Ardolino et al., 2018; Bressanelli et al., 2018; Grubic, 2014). However, the connection between both servitization and digitalization has garnered little attention. Furthermore, previous studies have neglected commoditization and its significant effect on competitive advantage. Thus, this study contributes to the literature by integrating these concepts and deriving key implications for a conceptual framework. Moreover, scholars have considered value co-creation with customers enabled by digital technology, which might lead to an unclear allocation of roles and responsibilities within a supply chain and ambiguities between actors, requiring role flexibility (Lenka et al., 2017; Rönnberg Sjödin et al., 2016). Thus, using the theoretical model provided in Figure 2, this study contributes toward understanding servitization and platform roles by further describing the interactions between actors offering advanced services to end customers.

Figure 2: Theoretical model

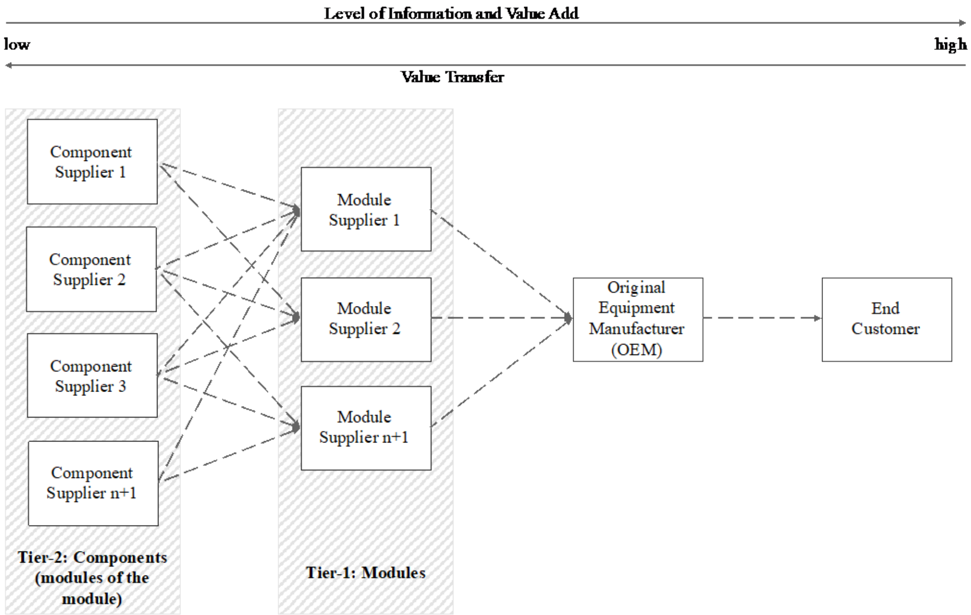


4. IMPLICATIONS FOR COMPONENT SUPPLIERS: DIGITAL TECHNOLOGY IN MULTI-TIER SUPPLY CHAINS

4.1 Digital technology: The window of opportunity to reduce the information asymmetry in a multi-tier supply chain

Megatrends and diverse, rapidly changing market conditions that are contributing to diverse customer needs have resulted in high-level complexity for manufacturing firms in knowledge-intensive industries. By leveraging the benefits of modular concepts, OEMs focus on the primary managerial purposes of modularization: managing complexity, parallel development, production, and the flexibility to react efficiently to variable market needs (Baldwin, 2008; Baldwin & Clark, 2000; Frandsen, 2017; Zirpoli & Becker, 2011). Standardized interfaces and design structures provide innovative ways to outsource modules, thus reducing overall complexity, increasing firm flexibility, and reducing coordination efforts between suppliers in the multi-tier supply chain (Pil & Cohen, 2006; Sosa et al., 2003; Tee et al., 2019), which results in a low exchange of knowledge between each level. Furthermore, studies have highlighted suppliers' low involvement in the general product development process, further reducing the product and system knowledge of component suppliers (Von Corswant & Fredriksson, 2002; Wynstra et al., 2010). Since knowledge fosters innovation capability for gaining competitive advantage, firms are reluctant to share knowledge (especially tacit knowledge) with suppliers (Le & Lei, 2018; Wang et al., 2016). Thus, each multi-tier supply chain level only shares minimum information. However, by outsourcing defined modules and products, specific production-value stages transfer production value and knowledge to subsequent value-creation stages (Doran et al., 2007). Hence, there is asymmetric dissemination of information regarding the product and its surrounding systems within a multi-tier supply chain (Figure 3).

Figure 3: Multi-tier supplier structure, product view



By offering services, firms strive for increased customer proximity and direct customer feedback (Rymaszewska et al., 2017). Component suppliers can benefit from first-hand user feedback, which enables and fosters specific knowledge exchange. Digitalization enables the integration of more products with digital technology for product-specific data. Component suppliers may efficiently deal with information asymmetry and secure profitability, focusing on information exchange. However, customers demand comprehensive solutions by few stakeholders to ensure reduced complexity, which induces the need for single monitoring technology in emerging service solutions that monitor multiple modules. This highlights the necessity of an overall monitoring approach with fewer interfaces at the product level. Specifically, OEMs with general product responsibility and direct customer contact can best offer monitoring solutions. Monitoring solutions enable firms to gain real-time knowledge of product usage, status, and location (Baines & Lightfoot, 2014; Lenka et al., 2017; Rust & Huang, 2014). Furthermore, data can be analyzed at the module and component levels. OEMs possess holistic real-time information about products, enabling suppliers in a multi-tier supply chain to offer diverse functionalities (Bressanelli et al., 2018). Sharing such knowledge with participating firms in the multi-tier supply chain increases system and product transparency and fosters future innovation. Hence, digital technology offers the potential to counterbalance information asymmetry within a multi-tier supply chain.

4.2 Leveraging digital technology: Initiate knowledge exchange and achieve competitive advantage

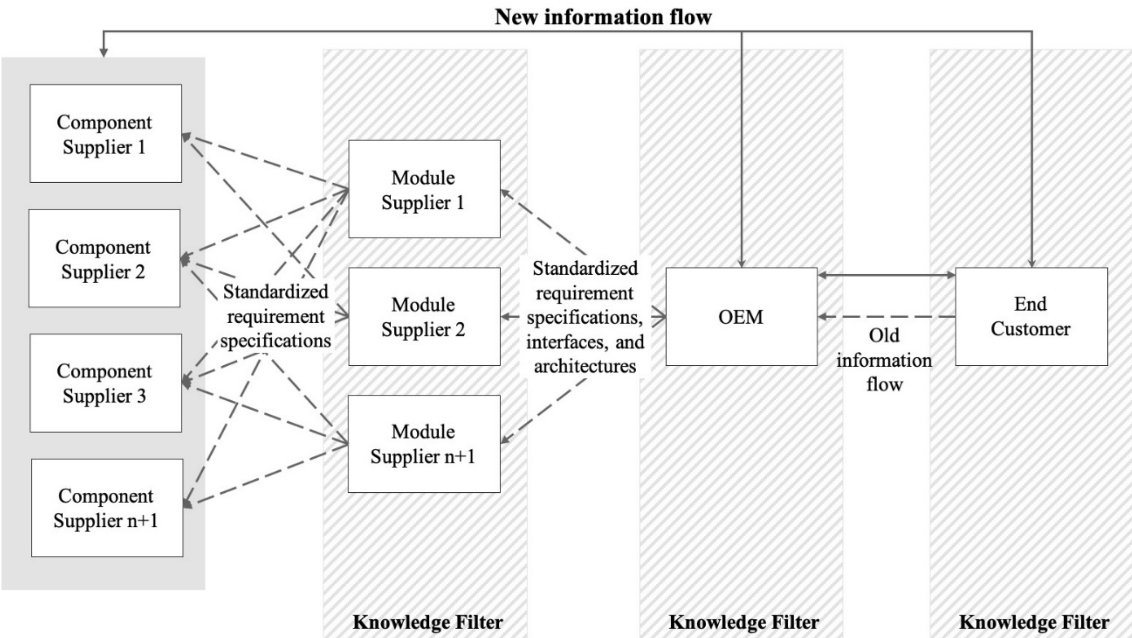
4.2.1 Knowledge exchange fostered by digital technology

Manufacturers can track and gain information to evaluate product usage and health via digital technology (Baines & Lightfoot, 2014). Scholars have considered many benefits and applications of such information to monitor products in real-time (Baines & Lightfoot, 2014). Bressanelli et al. (2018) provide a good summary of the functionalities driven by real-time monitoring, ranging from product-specific improvements to BMIs and process optimizations. Furthermore, Porter and Heppelmann (2014) refer to the new strategic choices utilized for promoting smart, connected products. More specifically, they present new value-creation opportunities with new and existing partners, thus enabling the development of a competitive advantage. By building on these ideas and using a case study approach, Lerch and Gotsch (2015) explore how digital technologies can optimize various processes within a firm and between firms and—more importantly—how they can optimize resource allocation. Creating complex and knowledge-intensive products and services requires comprehensive industry knowledge, which offers a high entry barrier for new competition. However, containing knowledge in one firm is challenging; thus, firms rely on suppliers (Zirpoli & Becker, 2011). Since product-level knowledge is vital for enabling competitive advantage (e.g., Martín-de Castro et al., 2013; Gomes and Wojahn, 2017), it may lead to an (inter-firm) social dilemma (Bornstein & Ben-Yossef, 1994; Zeng & Chen, 2003).

Moreover, OEMs and each value chain stage maximize their self-interests and pay-offs (Razmerita, Kirchner, & Nielsen, 2016). Given the modularization and outsourcing options, knowledge sharing may be unilateral for a customer to prompt suppliers to deliver products and services in formalized agreements (Ko, Kirsch, & King, 2005; Loebbecke et al., 2016; Oshri, Kotlarsky, & Gerbasi, 2015). Hence, knowledge exchange remains restricted to explicit knowledge, and comprehensive tacit knowledge remains withheld for competitive advantage. Component suppliers need to motivate higher-ranked value chain stages (e.g., end customers or OEMs) to make knowledge sharing bilateral and obtain general information via digital monitoring technologies. Suppliers can foster bilateral knowledge exchange by improving a firm's competitive market position (Marabelli & Newell, 2012; Razmerita et al., 2016). Compared to the unilateral inter-firm relationship, the bilateral knowledge exchange resembles an inter-firm R&D collaboration instead of a hierarchical buyer-supplier relationship, demonstrating increased knowledge exchange (Van de Ven, 2005).

Firms leverage digital technology and rely on critical component information to ensure reliable conclusions (e.g., the remaining useful life of modules) by offering advanced services and new BMs to end customers. OEMs lose this vital ability and, thus, have to cooperate with component suppliers (Lincoln, Ahmadjian, & Mason, 1998; Zirpoli & Becker, 2011). Furthermore, module suppliers receive requirement specifications with a standardized architecture as OEMs influence product design (Figure 4), and profound component knowledge and analytical capabilities are reserved for component suppliers. Hence, by receiving monitoring information and knowledge, component suppliers contribute analytical and vital knowledge capabilities to the BM of the OEM or the end customer's profitability, thereby contributing to direct offerings, enabling innovation, and fostering competitive advantage. Thus, firms are motivated to practice direct bilateral knowledge sharing (Figure 4).

Figure 4: Old and new information flow within a multi-tier supply chain; dotted lines describe old information flow (i.e., without digital technology), and solid lines, new information flow (i.e., direct inter-firm knowledge exchange of monitoring data). OEM=original equipment manufacturer.

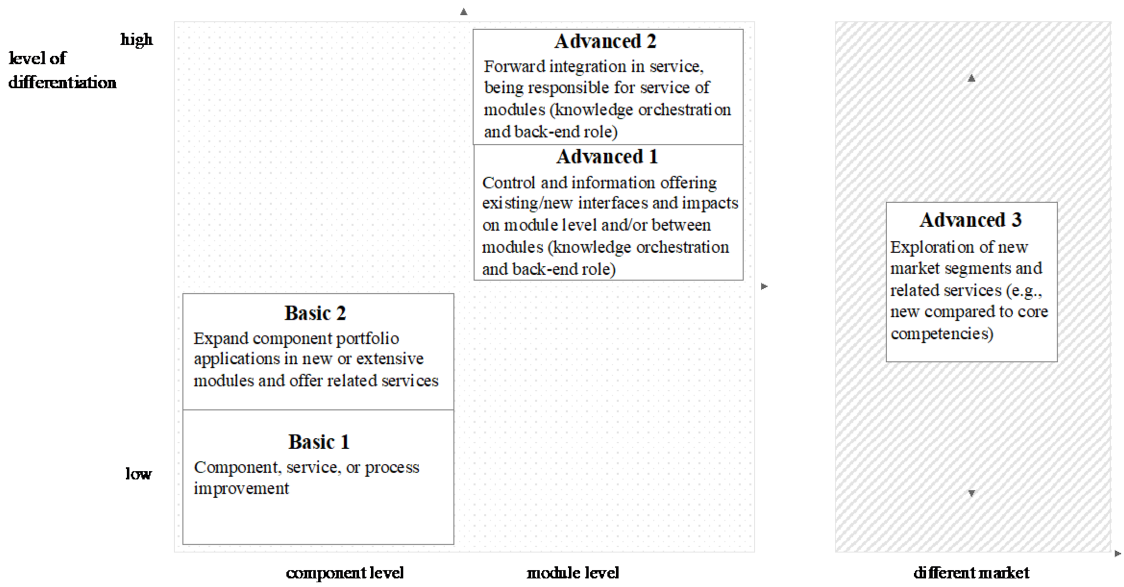


4.2.2 Leveraging monitored data, information, and knowledge: Strategic implications for component suppliers

Component suppliers can gain insight and capitalize on information regarding product performance in different appliances and real-time usage via digital technology and different strategic options. The strategic options differ in the value-creation stage of the multi-tier supply chain and its ability to enable a perceived differentiation level (Figure 5).

The first option (Basic 1) is the overall improvement of products, related services, and component suppliers' portfolio processes, enabling differentiation between firms within and outside the direct information exchange loop. However, this offers lower-level differentiation, as several competitors can utilize this strategy. An example is the real-time monitoring and exchange of material for product application from which a component that can better withstand real loads was made.

Figure 5: Strategic implications for component suppliers



Particularly with regard to the second option (Basic 2), gaining comprehensive product knowledge enables component suppliers to analyze the behavior of multiple modules inside the product. Moreover, formerly tacit knowledge can be decoded by analyzing the monitored data to simulate the component performance in other modules or gain information about how another component performs in a given module and enable portfolio extension. However, this step is open to multiple competitors; thus, differentiation may differ according to the number of firms. Since Basic 1 and 2 are within the competencies of multiple component suppliers, differentiation opportunities, which OEMs drive, are obtainable for several firms. Thus, the number of competitors taking a favored position in leveraging shared information should remain high to improve OEMs' competitive advantage.

To further improve the level of differentiation and efficiently face the commodity battle by themselves, component suppliers need to increase their responsibility. Accordingly, this study develops three different strategic opportunities for component suppliers. Advanced 1 employs comprehensive product knowledge and assumes a back-end unit's position, thus integrating several modules' analyses and responsibilities, including its components. It focuses on contributing an idiosyncratic benefit toward the front-end unit. Bundling several applications is a unique position and reduces overall complexity; thus, this strategy improves differentiation compared to competitors in various value-creation stages. Moreover, the commodity type can offer multiple value additions through the ability to control and analyze multiple modules using their critical components. They define the general performance of a product, as OEMs and module suppliers cannot judge component health and future performance. Hence, component suppliers' leverage increases by the number of components in varying modules within a product. Furthermore, component suppliers offer in-depth knowledge of interfaces and impacts between modules and components based on the monitored information on the product level. OEMs then push suppliers to take more risks on products and module levels to increase value. Thus, component suppliers may offer services for modules, including their products.

Module-specific information can analyze the surrounding environment, interfaces, and impacts on the module. Being responsible for the module and key component services enables component suppliers to reduce the overall complexity. Moreover, the additional value increases with the number of modules that component suppliers oversee. Furthermore, component criticality advances with the ability to map accurate data (Advanced 2). Given the design and engineering outsourcing and the pressure to establish competitive buying set-ups by relying on OEM specification sheets, module suppliers cannot reliably judge component health, enhancing their competitive advantage, compared to single module suppliers. However, this step may include higher risks, and firms need to develop capabilities and increase investments. To allow component suppliers to explore new segments in markets (Advanced 3) currently unrelated to their portfolio or core competencies but which may be concerned with diverse target customers (e.g., different industries), monitoring and analyzing product use information may help. This facilitates the highest differentiation, compared to the established commodity business.

4.2.3 Leveraging monitored data, information, and knowledge: An exemplary case of utilizing the developed strategic framework in the railway sector

This study focuses on capital-intensive, knowledge-intensive, and slow-moving (in terms of technological innovation) industries, and it features industries with long product life cycles and the highest safety requirements. The railway sector is one exemplary sector that exhibits these industry characteristics in a multi-tier supply chain (Esposito & Passaro, 2009). Accordingly, this study described the strategic implications (Figure 5) from the perspective of a bearing supplier (component supplier) within a rail vehicle, particularly a motor bogie (product level). The essential modules that contain bearings within a motor bogie are the wheelset engine and transmission. Digital technologies can be used for monitoring product data in real-time (Baines & Lightfoot, 2014). Such digital technologies can also be used for monitoring the relevant modules and their health. Using the example of a wheelset bearing, the obtained data can be utilized to improve the product itself (longer service interval). Alternatively, it is important to assess the health of modules and related components and justify the maintenance of the modules and components through continuous monitoring during product use, thus avoiding unplanned failures (Basic 1). The second development option at the component level (Basic 2) can be demonstrated (e.g., by monitoring a gearbox and the corresponding data exchange). As discussed previously, because of the acquisition of comprehensive monitoring data, conclusions can be drawn about other components within the module. Specifically, such data enable comparative analyses and enable a bearing supplier to derive the requirements for other components within the gearbox. Furthermore, this enables a bearing supplier to expand his product portfolio on the component level (e.g., designing and producing gears) and helps him offer related services. By using digital technology to monitor the specific modules (Advanced 1), comprehensive module knowledge can enable component suppliers to offer comprehensive analysis information for 1) a dedicated module or multiple models and 2) their relationships. Following these lines of thoughts, bearing suppliers can take responsibility for one or multiple models (e.g., gearbox, motor, and wheelset). This newly gained orchestration position of the bearing supplier allows for the addition of an increased added value toward the front-end unit (Advanced 2). Such monitoring—for example, that of wheelset bearings—enables the acquisition of additional data and information. Because the wheelset bearings are located close to the wheels, data from the infrastructure can also be collected and analyzed. This enables the bearing supplier to evaluate the condition of the infrastructure (e.g., rails or switches) and this helps the supplier to enter a new market segment to offer related services—from rail cars to infrastructure-related products (Advanced 3).

Based on the example of bearing suppliers in the railroad industry, the application of the strategic framework shows that digital technologies enable various strategic development scenarios. Bearing suppliers can continue to develop on the component level, which offers a lower potential for differentiation. However, digital technologies can enable bearing suppliers—for example, an orchestrating positioning within the existing multi-tier supply chain. Digital monitoring technologies can also enable development into new markets, such as from the vehicle market into the infrastructure market, with varying differentiation potentials.

5. DISCUSSION AND CONCLUSION

This study aimed to develop a strategic framework to help component suppliers consider digitalization as an opportunity and to realize strategic options in an exemplary manner in order to foster competitive advantages. The basic assumption was that digital technologies and the position of component suppliers within a multi-tier supply chain would break new ground in terms of value creation.

In line with prior research, the present study's strategic framework demonstrates the importance of digital technologies in enabling new value-creation paths (Bharadwaj et al., 2013; Pagani & Pardo, 2017). Following these findings, this study considers the added value of digital technologies beyond information and knowledge flow improvement (Bressanelli et al., 2018) and the facilitation of successful servitization (e.g., Baines et al., 2007) or advanced services (e.g., Baines & Lightfoot, 2014) in the existing value chain. The alignment of organizational and information system strategies is especially crucial for successfully leveraging digital technologies (e.g., Bharadwaj et al., 2013). Specifically, new value creation is facilitated by combining analytical capabilities, digital technologies, and existing product and module knowledge. This corresponds to the findings of current studies, which have shown the added value of digital technologies (Vial, 2019). Unlike prior research, this study considered commoditization not as a risk but as a contextual factor that not only supports repositioning (e.g., as an orchestrator) but also facilitates it in the application of digital technologies. By doing so, this study argues against the view that digital technologies hinder the generation of competitive advantages for well-established firms (Kahre, Hoffmann, & Ahlemann, 2017). Following this view, this study expanded research and understanding regarding digital technologies as a source of disruption, which could change roles and value chains on a business domain level (Parviainen, Tihinen, Kääriäinen, & Teppola, 2017). A prime example of the enabling character of digital technologies is Pagani's (2013) work, which demonstrates different roles in a so-called value network enabled by digital technologies and modular product architecture. The position of the value orchestrator could become the most valued business skill in the future (Pagani, 2013). This study shares this view; however, it expands this perspective by highlighting the point that an orchestrator's position allows for further development in new markets (e.g., integration of modules or new products). However, existing research has failed to develop a dedicated strategic framework for achieving this orchestration ability and position. Firms may benefit from a more practitioner-oriented view. This conceptual work thus attempts to fill this knowledge void by appreciating the benefits of digital technologies and paying close attention to the contextual factors of component suppliers in multi-tier supply chains. Therefore, it extends the current studies by providing a clear roadmap for leveraging digital technologies and the benefits of commodities in a strategic framework designed to create competitive advantages.

5.1 Theoretical contributions

This conceptual study sheds light on the question of how component suppliers in multi-tier supply chains can leverage digital technologies to escape the commodity battle. It enquires into the factors and dynamics that foster or inhibit the strategic transformation of component suppliers. This study also investigates modularization to identify and rate its impact. Specifically, critical aspects like design and engineering outsourcing, which affect competencies and knowledge within and between the firms of a multi-tier supply chain, were considered. It differs from prior studies, which have focused on either the benefits or risks of modularity. Given the advantages of modularity for component manufacturers, this study analyzed how digital technologies, combined with servitization, enable strategic options for component suppliers.

Four contributions address the call for frameworks regarding organizational behavior, strategy research, and digital innovation (Bressanelli et al., 2018; Cenamor et al., 2017; Le & Lei, 2018; Loebbecke et al., 2016; Martín-de Castro et al., 2013; Razmerita et al., 2016; Sosa et al., 2003; Un & Asakawa, 2015; Zirpoli & Becker, 2011). First, by integrating vital elements of modularity and commodity concepts, this study identified an asymmetric allocation of product-specific information within a multi-tier supply chain. This contributes to studies that focus on modularity and commoditization as isolated concepts. Specifically, it offers a more balanced view of modularity's benefits and risks for multiple value-creation stages. Second, the study contributes to knowledge exchange discussions by outlining digital technologies' benefits and integrating them with established knowledge sharing approaches in multi-tier supply chains. Since knowledge is vital for innovation and drives competitive advantage, firms face the paradox of sharing knowledge by evaluating the risk exposure against the potential benefits of knowledge sharing. Thus, the discussion suggests that servitization fosters a more favorable environment for sharing information, as component suppliers play a vital role in facilitating advanced services. Third, by considering servitization, digitalization, and commoditization in a holistic approach and analyzing the benefits of knowledge sharing in multi-tier settings, this study advances the understanding of motivational factors of knowledge sharing in a multi-tier supply chain (Seyoum & Lian, 2018; Sosa et al., 2003; Zirpoli & Becker, 2011). Finally, this study contributes to studies exploring strategies in contradicting fields of research by analyzing the mechanisms of commoditization, modularity, and digitalization in a multi-tier supply chain (Cabigiosu & Camuffo, 2011; Cabigiosu et al., 2012; Schilling, 2000; Smith et al., 2014).

Since modularity and digital technologies offer a new context for strategic opportunities pursued by component suppliers, this study suggests five strategic options as to how component suppliers can leverage digital technology to differentiate and increase competitive advantage. The strategic initiatives give scope for integration, and firms with different levels of value-addition can integrate several strategies in different industries and applications to improve flexibility. Thus, the study highlights component suppliers' differentiation opportunity via monitored data and information to innovate at the product level or increase responsibility toward modules or new market segments. Furthermore, the market only transfers risk to component suppliers if they can manage it better than the module supplier. However, digital technologies cannot be applied due to higher business risks, which have to be considered when deciding on future business development.

Component suppliers may improve their current product, service offerings, or internal process efficiency by applying diverse functionalities enabled by digital technologies. Thus, they may employ general product information to expand their portfolio in new or extensive modules. This step may foster a competitive advantage by increasing their product share, the ability to decrypt previously encrypted or withheld knowledge and information between modules and components, and the ability to provide perspective to the data. Hence, the differentiation level is a function of the number of components applied in varying modules. An increased differentiation level can be achieved by playing a predominant role as a back-end unit. Therefore, component suppliers may use their knowledge to extend their responsibility by moderating interfaces between modules and components. This effect is positively related to the overall number of components in different modules of the product.

By analyzing general information on modules and key components, component suppliers leverage vital knowledge to provide reliable module health feedback. Thus, they can extend responsibility further by offering module related services. Finally, by analyzing product data, component suppliers may explore new market segments, which may be interfaces between modules outside firms' core competencies and differentiate more, compared to the existing competitive scenario.

From a digital technology perspective, business strategies rely on monitoring systems. However, contributing to advanced services by enabling and assuming responsibility for accurate statements on critical and safety-relevant components (e.g., extending remaining useful life) is a high-risk action. Thus, digital technologies provide the basis for reliable analysis and decisions to minimize risks for component suppliers.

5.2 Managerial implications

This study provides a proper understanding of the role of modularity in the context of commoditization. Specifically, this study's framework shows how mutual knowledge sharing fosters innovation and how digital technology generates differentiation, thus enabling competitive advantage. Hence, managers may use the framework to design a strategic roadmap for gaining competitive advantage via digital technologies. Furthermore, this study highlights the need for leveraging digital technologies in order to focus on transforming value-creation and capture processes (Vial, 2019).

This study's framework highlights multiple new options for establishing new BMs in multi-tier supply chains enabled by digitalization. For instance, this study explored how digital technologies and the status of component suppliers can facilitate new value propositions, thus enabling new positioning opportunities in a multi-tier supply chain (e.g., orchestration in a network). Thus, along with the digitalization of products and services, managers should also consider various new positioning options within a multi-tier supply chain in future strategic decisions and investments.

Despite the advantages, pursuing the strategic framework suggested in this study is a challenging task. First, through an orchestrating and, thus, a more accountable role in the value chain, the focal firm's current customers could become its competitors. On the one hand, customers could terminate the existing business relationship, leading to a loss of sales. On the other hand, the focal firm's clients could also try to implement the same strategic approach. In this context, it is essential to understand which company is better positioned (i.e., has the strength to orchestrate and provide the desired value). In addition, end customers also make decisions based on potential new costs and risks when adapting the supply chain (e.g., switching or transaction costs). Internal processes in this particular case could leave component suppliers to orchestrate multiple products or modules. Internal processes and procedures can be implemented efficiently over several years, especially in the capital-intensive, knowledge-intensive, and slow-moving (in terms of technological innovation) industries that feature long product life cycles and the highest safety requirements (e.g., service processes such as the reconditioning of products). Adapting these would lead to a higher amount of effort and risk. Furthermore, new coordination and learning processes would have to be initiated between the companies. This could prevent end customers from actively supporting the new position of component suppliers (orchestration) and could lead them to deviate from the new model.

Another hurdle in implementing the framework could be the employees themselves. Employees would need to possess the relevant skills to deal with extensive technologies during the adoption of the framework and, in most cases, would have to assume greater responsibility. Previous research has also pointed to the issue of employee resistance to the introduction of digital technologies (Wiesböck & Hess, 2020).

5.3 Limitations and future research directions

This study has a few limitations. Given the conceptual nature of the framework, the implications may not be empirically supported or generalizable. Thus, future research could employ quantitative methods to analyze the framework. A case study based on the theoretical framework may also be presented to evaluate this study's findings. Furthermore, this study focuses only on capital-intensive and slow-moving industries, which have a long product life cycle. Future research could examine other industries with shorter product life cycles.

The concept of modularization focuses on the product level but may also be adapted to the BM level. Future research may evaluate the role of modules of suppliers in advanced services. This research did not differentiate between the knowledge sharing among different firms in the supply chain. Specifically, it did not differentiate the knowledge exchange between end customers and component suppliers or OEMs and component suppliers. Further, the framework considered only a few digital technologies. Advanced technologies like additive manufacturing, cloud computing, or technologies enabling digital tracking may have different strategic impacts. Additionally, future empirical work could further explore the concept of inter-firm platform roles, which could address the impact of strategic opportunities on the circular economy. In conclusion, the proposed strategic options refer to various levels of risk-taking by component suppliers. Thus, the monetary risk of the investments in innovation or accrued liabilities for module responsibility may lower each strategy's attractiveness, thereby contributing to another paradox. Hence, future research could investigate the monetary benefit of digital investments for component suppliers relative to the level of differentiation and the value chain stage.

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