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Platform-based servitization and business model adaptation by established manufacturers

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ABSTRACT

Digitization is receiving a lot of interest in recent servitization research, but the use of platform-based Industry 4.0 technologies to boost product-service innovation (PSI) is less covered. This study aims to explore how companies successfully leverage platforms for servitization in an Industry 4.0 context. Building on theories of PSI, platform leverage and business model adaptation (BMA), we use longitudinal and interpretive research methods to conduct an exploratory study of the servitization pathways of four Chinese textile and apparel manufacturing companies. Results reveal companies' roadmaps in undertaking digital and smart servitization strategies enabled by platform leveraging, and show the implementation approaches for related BMA. Further analysis identifies platform-based servitization destinations and pathway dynamics. This study constructs a theoretical basis and a typology for explaining platform-based servitization.

1. Introduction

Industry 4.0 and servitization are two prevailing trends that jointly transform the manufacturing industry (Frank et al., 2019). Industry 4.0 refers to the use of emerging technologies, such as the Internet of Things (IoT), Cloud Computing (CC), Big Data (BD) and Artificial Intelligence (AI), to add value to manufacturing processes (Ardolino et al., 2018; Matthyssens, 2019). Servitization, also known as "service infusion" (Kowalkowski et al., 2017a), is mainly focused on the addition of services to manufacturers' core product offerings to create additional customer value (Raddats et al., 2019; Vandermerwe and Rada, 1988). The competitive advantage of companies today increasingly stems from enhancing product-service innovation (PSI) (Gomes et al., 2019; Rabetino et al., 2018), and as companies change their market strategy from providing products to services, they often rely on others to help innovate their offerings (Polova and Thomas, 2020) and even take over certain activities (Visnjic et al., 2018). The simultaneous acceleration of Industry 4.0 and servitization in 2020 during the COVID-19 crisis has created an unprecedented opportunity for manufacturers to adapt to new business models of quickly translating customer needs into specific products and service (Paiola and Gebauer, 2020; Zambetti et al., 2020) and redesigning the way offerings are delivered (Seetharaman, 2020).

Digital platforms are adopted by companies to connect network actors and their resources in a more intelligent and value-adding manner (De Reuver et al., 2018; Perks et al., 2017; Tian et al., 2021), creating new opportunities for advanced service offerings (Cenamor et al., 2017; Eloranta and Turunen, 2016). Companies that leverage the power of platform business models have grown dramatically in size and scale over the past decade (Evans and Gawer, 2016). For example, Apple, Microsoft and Amazon have become some of the most valued companies in the world today (Cusumano et al., 2020; Reillier and Reillier, 2017). At the same time, many manufacturers are considering how they can leverage platform thinking (Lager, 2017) to sustain their competitive advantage (Constantinides et al., 2018). For instance, General Electric's Predix platform creates a digital twin of customers' physical assets and products, connects them to the Cloud and uses advanced BD analytics to continuously improve customers' business processes (Weber, 2017). More recently, Rapaccini et al. (2020) reported several cases of Italian manufacturers leveraging digital platforms to remotely monitor and control operating machines, which make them less dependent on human

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interaction, to respond to the COVID-19 crisis.

Exploiting the opportunities of digital platforms requires a better understanding of the different technology pathways that manufacturers follow to advance service (Coreynen et al., 2017; Tongur and Engwall, 2014). Confronted with the present opportunities and challenges of Industry 4.0 and Industrial IoT (IIoT) in particular, established manufacturers are forced to transform their business model from being a relatively independent player in the value chain to a value co-creator (Ardolino et al., 2018; Frank et al., 2019; Kiel et al., 2017). Oftentimes, the transformation toward a service business model is considered a smooth, unidirectional process along the product-service continuum (Oliva and Kallenberg, 2003), yet this view is increasingly being questioned (Brax and Visintin, 2017; Kowalkowski et al., 2017b). Prior studies have shown that manufacturers only incrementally change their business model (Laudien and Daxböck, 2016), that they often struggle with service innovation (Visnjic et al., 2016), and that there are not one but different ways to leverage technology for servitization purposes (Coreynen et al., 2017; Jovanovic et al., 2019). The servitization literature therefore recently stressed the need for further insights in manufacturers' transition process toward platform-based service business models (Kohtamäki et al., 2019).

The aim of this study is to increase our understanding of how platforms enable servitization in an Industry 4.0 context. We address the following two research questions. First, how do manufacturers leverage platforms to stretch the boundaries of digital servitization? To use an analogy: If servitization is the destination, how can platforms be the engine for companies' transition journey? Specifically, we are interested in uncovering different platform leverage logics (PLLs) that manufacturers apply to create and deliver increasingly digital and ultimately smart services. Second, continuing the analogy, what are the different pathways that manufacturers follow to reach their final service destination? Do they embark on a single, smooth journey, knowing their final destination from the start, or do they gradually move toward smart servitization through trial-and-error by exploring and combining different pathways? With this second question, we want to better understand the dynamics of platform-enabled servitization by investigating companies' unique business model transitions.

To address these questions, we first build upon a review of the literature on (1) servitization and PSI (e.g., Kohtamäki et al., 2019; Rabetino et al., 2018); (2) platform leveraging (e.g., Eloranta and Turunen, 2016; Thomas et al., 2014), and (3) business model adaptation (BMA) (e.g., Landau et al., 2016; Saebi et al., 2017). These key theoretical lenses are then used to construct a conceptual framework that visualizes different platform approaches for the purpose of servitization. Next, we adopt an interpretive methodology to describe the unique, platform-based service transitions of four manufacturers. Finally, we plot the cases onto the framework to uncover different platform-based pathways for reaching increasingly digital and smart service levels.

This study contributes to the current body of literature by theorizing about the transition process of manufacturers toward platform-based service business models. Past studies have already shown the potential of platforms for servitization (e.g., Cenamor et al., 2017; Eloranta and Turunen, 2016) and provide several typologies of digital service business models (e.g., Frank et al., 2019; Gebauer et al., 2020a; Kohtamäki et al., 2019), yet the literature remains ambiguous about how manufacturers actually transform their business model toward platform-based servitization. Therefore, we integrate prior knowledge on digital and smart servitization (Kamp et al., 2017; Paschou et al., 2020), platform leveraging and BMA to establish the foundation of a new theory that suggests multiple transformation pathways.

For the context of this study, we move to China's textile and apparel industry. In the age of IIoT, platform-based systems are often found in so-called "smart factories". The smart factory concept is mostly used to describe the future of manufacturing (Radziwon et al., 2014) and it is characterized as "a self-organized multi-agent system assigned with big data-based feedback and coordination" (Wang et al., 2016, p. 158). It also connects manufacturers and their suppliers to provide better-integrated service packages for customers (Zheng et al., 2018). In China, smart factories are a core component of the Made in China (MiC) 2025 plan, which aims to enhance innovation and productivity through the integration of industry and information (Li, 2018; Tao and Qi, 2019). As a key sector of the MiC 2025 plan, the Chinese textile and apparel industry is pushing its top-performing companies to reconstruct their business according to a smart manufacturing philosophy (Wübbeke et al., 2016). On top, the COVID-19 crisis has severely affected the whole manufacturing industry, including the textile and apparel sector (Cai and Choi, 2020; Zhang and Watson IV, 2020). Some companies in South Asian countries, such as Pakistan, minimized their operations or temporarily had to shut down due to the shrinking demand and other supply chain disruptions (Majumdar et al., 2020), while other companies, from China, utilized this crisis to further shift their focus to online trade and transform their manufacturing capacity to produce personal protective equipment (e.g., face masks, protection gowns and even respirators) at a large scale to curtail losses (Shafi et al., 2020). Therefore, the Chinese textile and apparel industry provides an interesting setting for this study.

2. Theoretical development

2.1. Servitization and PSI theory

Servitization, the process of manufacturers adding services to their product portfolio (Santamaría et al., 2012; Vandermerwe and Rada, 1988), is of significant importance for companies to differentiate their offerings from that of the competition and meet more heterogeneous market needs (Matthyssens and Vandenbempt, 2008; Parida et al., 2015). Yet despite the ample strategic and financial benefits associated with servitization (Baines et al., 2009; Crozet and Milet, 2017), many companies struggle with mastering the PSI transition (Kohtamäki et al., 2020; Parida et al., 2014). One of the main reasons is that servitization not only affects the way manufacturers innovate products and services, it ultimately also transforms how they create, deliver, and capture customer value (Garcia Martin et al., 2019). On the one end of the product-service spectrum, manufacturers mainly offer value to customers through tangible goods with services only as add-on, while on the opposite end, the main source of value lies in the service itself and products are viewed as mere carriers of services (Oliva and Kallenberg, 2003). Servitization thus not only has consequences for the way manufacturers innovate their offerings but also for how they maintain relationships and co-create value with customers and suppliers (Kamalaldin et al., 2020; Saccani et al., 2014). In short, servitization disrupts companies' entire business model (Annarelli et al., 2019) and revenue model (Witell and Löfgren, 2013).

In recent years, servitization research has focused on how manufacturers adopt technology for the purpose of digital and ultimately smart servitization (Kohtamäki et al., 2020; Martín-Peña et al., 2018; Paschou et al., 2020). *Digital* servitization refers to the use of digital technologies to create and seize value from product-service offerings (Kohtamäki et al., 2020; Vendrell-herrero et al., 2017). Here, technology can be an enabler for servitization (Coreynen et al., 2020; Lenka et al., 2017). For instance, manufacturers implement software (e.g., for program optimization, system integration) in the back-end to enable scalability in product customization, or they upgrade front-end customer channels (e.g., websites, online applications) to reach new, untapped market segments (Coreynen et al., 2017; Sklyar et al., 2019). Technology can also be integrated into the offering by embedding digital components and software in the physical product (Kohtamäki et al., 2019; Vendrell-herrero et al., 2017). In both instances, the manufacturer still mainly provides value through tangible products supported by additional digital or digitally-enabled services, such as online support and remote monitoring.

Smart servitization involves a further shift toward more connected, intelligent and autonomous product-service systems (Chowdhury et al., 2018; Kamp et al., 2017). Here, companies leverage advanced manufacturing technologies (AMTs), such as IIoT and CC (Qu et al., 2016; Simeone et al., 2019), to improve not only their own back-end processes but to better align with those of customers and suppliers as well (Kamp et al., 2017). They also create smart, connected products, such as equipment systems (e.g., for farming, mining) that work independently without much need for human intervention (Porter and Heppelmann, 2015), and use them as front-end carriers for offering advanced, smart services, such as automatic upgrades and predictive maintenance solutions (Kamp, 2018).

Currently, researchers try to understand how manufacturers can take a robust and future-proof servitization approach in an Industry 4.0 context (Ardolino et al., 2018; Frank et al., 2019). So far, several frameworks have been introduced to help us better understand the connections between different service levels and Industry 4.0 technologies. For instance, Kohtamäki et al. (2019) present a framework that combines three dimensions—customization, pricing and digitalization—to better differentiate the characteristics of different digital servitization business models. Also, Frank et al. (2019) consider the connections between three types of services—smoothing, adapting and substituting services—and three levels of digitization—low, moderate and high—resulting in a classification of nine service offering types. Though these frameworks offer useful insights in different technology-based service business models, they do not explain how manufacturers in practice leverage Industry 4.0 technology to move the frontiers of servitization forward. The servitization literature often describes the "destination", but the different "engines" of digital and smart servitization still remain unexplored. In the following section, we discuss how digital platforms create numerous incremental and radical innovation opportunities for manufacturers, both in the back- and the front-end of the organization, as a foundation for servitization. To continue our analogy: We will lift the hood of the car and take a closer look at the engine for digital and smart servitization from a platform leverage lens.

2.2. Leveraging digital platforms for servitization

The industrial innovation management literature is increasingly paying attention to the potential of digital platforms for industry (De Reuver et al., 2018). Platforms can be "products, services, or technologies that act as a foundation upon which external innovators, organized as an innovative business ecosystem, can develop their complementary products, technologies, or services" (Gawer and Cusumano, 2014, p. 417). From a manufacturing engineering perspective, platforms as technological architectures enable economies of scope in supply and innovation. From an economics perspective, they enable economies of scope in demand as markets (Gawer, 2014). In the future, it is expected that more and more companies will leverage both types of platforms for both innovation and transaction purposes, and that technological advances (e.g., in BD, AI) will turbocharge innovation, leading to a wider range of product-service applications (Cusumano et al., 2020).

Also within the servitization literature, the topic of platforms is attracting attention (Paschou et al., 2020). Cenamor et al. (2017) explained how intra-firm platforms (i.e., inside the company) enable manufacturers to pursue both customization and operational efficiency, and Eloranta and Turunen (2016) showed how inter-firm platforms (i.e., between companies) manage and orchestrate complex relationships with customers, suppliers and even competitors. These and other studies (e.g., Kamalaldin et al., 2020; Sklyar et al., 2019) demonstrate that platforms cover a wide range of application areas, both in the back- and the front-end as well as inside and outside of the organization. Gebauer et al. (2020c) indicate that the network effects inherent in platforms stimulate industrial companies to transform their business toward digital servitization. Eventually, platforms can become a separate form of business model, whereby manufacturers provide platforms-as-a-service (PAAS) to connect various suppliers and customers, collect and analyze data to generate new business opportunities, and thus strengthen their market position (Kohtamäki et al., 2019).

Establishing a typology that explains different rationales to effectively leverage platforms for servitization purposes may be considered useful at this point. Previous literature has stressed the importance of different platform leverage logics (PLL) (Thomas et al., 2014). In this study, we define PLL as strategies executed by companies adopting platforms to maximize resource utilization and create the best possible value for customers and business partners. We build a PLL typology based on two popular platform dimensions. A first dimension is based on a company's business operations – focus meaning where the platforms are applied to be used to connect with actors in either the back- or the front-end. For instance, Gawer (2014) explained how platforms can serve as a device to coordinate suppliers or buyers. Also Thomas et al. (2014) discussed two platform leverage rationales: a production rationale (focused on bringing together different suppliers and manufacturers) and a transaction rationale (focused on bringing together manufacturers and customers). This first dimension has already been applied in servitization research (e.g., Cenamor et al., 2017). A second dimension is based on the platform's degree of digitality. For instance, De Reuver et al. (2018) explain how platforms vary from non-digital platforms to low-level, pure-technical platforms and ultimately high-level, IoT-based platforms. As platforms become increasingly digital, they allow companies to better manage and capture data as well as innovative ideas coming from outside the firm (Eloranta and Turunen, 2016; Gawer and Cusumano, 2014), enabling both incremental and radical service innovation opportunities (Johansson et al., 2019; Myhren et al., 2018).

In summary, platforms stimulated by Industry 4.0 technology can be leveraged in two application areas—the productional back-end and the transactional front-end—and in both areas, the degree of digitality opens incremental to radical innovation opportunities. Hence, based on these two dimensions, we suggest four main types of PLL: a back-end incremental (BI), a back-end radical (BR), a front-end incremental (FI) and a front-end radical (FR) logic.

First, a BI logic relates to manufacturers leveraging *digital* manufacturing platforms as a foundation for incremental innovation with suppliers. Following this logic, manufacturers focus on improving efficiency in production and logistics by integrating their own processes with those of suppliers. Examples from the literature are supply chain (production) platforms such as created by Ford and Volkswagen (Muniz and Belzowski, 2017). For instance, Volkswagen's platform enabled the integration of its production process, increased the flexibility of its production network and, over time, was used to better connect with supply chain partners (Volkswagen, 2020).

Second, a BR logic refers to manufacturers further leveraging *smart* (i.e., IIoT-enabled) manufacturing platforms to radically innovate, and thus fundamentally rebuild, industry-wide supply chains. This logic enables the creation of smart, autonomous product-service systems (Chowdhury et al., 2018; Kamp et al., 2017) while further comprehensively reducing production and logistics costs (Cenamor et al., 2017). Here, the manufacturer maintains architectural control of key elements (Thomas et al., 2014). Examples from the literature are industry ecosystems (Gawer, 2014; Kohtamäki et al., 2019). For instance, the smart manufacturing platform that provides an event-driven, shop-floor management foundation to monitor and control the dynamic production (Tao and Zhang, 2017). Rapaccini et al. (2020) illustrated a case of Italian manufacturer who used a cloud-based platform to achieve high systemic coordination and remotely control factory operations.

Third, the FI logic concerns the use of *online* transaction platforms to incrementally upgrade front-end operations. When manufacturers implement online customer channels, they can monitor and satisfy customers' content and service needs more efficiently while also creating new opportunities for value co-creation (Constantinides et al., 2018; Eloranta and Turunen, 2016). Examples from the literature are e-commerce platforms and products upgraded with digital sensors (Coreynen et al., 2017; Porter and Heppelmann, 2015). For instance in consumer electronics, device manufacturers have been reported "platformizing" their products by using an open Application Programming Interface (API) that provides them access to customer data and which is later used to develop new applications (Basaure et al., 2020).

Fourth, a FR logic refers to manufacturers leveraging *connected* transaction platforms, such as smart, autonomous products and Industry 4.0 service platforms, to transform front-end customer relationships from single to continuous interactions. This logic enables a quantum leap in value co-creation and significantly supports manufacturers in creating tailor-made, integrated solution packages (Constantinides et al., 2018; Teece, 2018). For instance, Gebauer et al. (2020a) reported a case of an equipment manufacturer who created digital platforms to integrate and process data on the entire customer manufacturing system in order to develop solutions for their customers. Following the FR logic, Bosch established an IoT Suite software platform for IoT developers that later became the technical foundation for a broad range of connected solutions, consisting of hardware (e.g., sensors and industrial gateways), software and services for the manufacturing, mobility, energy and smart home sector.

To recapitulate: In the previous section we introduced PSI and showed two servitization "destinations": digital and smart servitization. In this section, we constructed a PLL typology that distinguishes between four platform logics—BI, BR, FI and FR—as "engines" of innovation. In the next section, we draw from the business model dynamics literature to describe different "pathways" that companies follow to adapt their current business model toward platform-based servitization.

2.3. Dynamics of business model adaptation for platform-based servitization

Business modeling has received increased attention in research on business relationships and industrial networks (Bankvall et al., 2017). A business model describes the design or architecture of a company's value creation, delivery and capture mechanisms (Teece, 2010). It is a useful construct to explain how companies' business operations change over time, even leading to new dynamics in industry competition (Willemstein et al., 2007). Particularly in the age of Industry 4.0, technology puts tremendous pressure on manufacturers to adapt their business model in order to stay competitive (Kiel et al., 2017). Business model adaptation (BMA) refers to the efforts of adjusting and reconstructing existing business model components to better fit external environment changes (Landau et al., 2016; Zott et al., 2011). In practice, established manufacturers usually adopt IIoT to transform their own internal infrastructure first, before moving on to finding better ways to manage their partner network and finally developing new value propositions for customers (Kiel et al., 2017; Lager, 2017; Laudien and Daxböck, 2016). The recent work by Gebauer et al. (2020a) displayed how B2B manufacturers were adapting their strategies and business step by step to achieve the advanced, service-oriented business model. Therefore, continuous BMA is considered a key dynamic capability in sustained value creation and capture (Achtenhagen et al., 2013; Dottore, 2009).

Also in servitization, the transition of manufacturers toward services has often been described as a form of business model transformation (e.g., Frank et al., 2019; Kastalli and Van Looy, 2013). Originally, servitization was considered a smooth, unidirectional evolution whereby manufacturers steadily move from one end of the product-service continuum to the other (Oliva and Kallenberg, 2003), yet this assumption is increasingly being questioned (Kowalkowski et al., 2017b; Raddats et al., 2019) and more complex interpretations of servitization have been proposed. First, manufacturers are observed to gradually expand into service by further building new, more advanced services on top of simple services (Parida et al., 2014). They often hold multiple positions along the product-service continuum, for instance by providing basic, product-oriented services to one customer segment and more advanced customer-oriented services to another (Kowalkowski et al., 2015). Second, instead of moving along the continuum, companies can also strengthen their current service position by focusing on standardization, which is necessary for scale and repeatability (Kowalkowski et al., 2015; Matthyssens and Vandenbempt, 2010). Despite these more shaded insights in manufacturers' service transition, the literature offers only limited insight on how manufacturers actually move toward digital services in an Industry 4.0 context (Frank et al., 2019; Paiola and Gebauer, 2020). Therefore, a better understanding of how manufacturers adapt their digital service business model is still considered a research priority (Kohtamäki et al., 2019).

On the basis of the existing literature on business model dynamics (Gebauer et al., 2020a; Willemstein et al., 2007), business model adaptation (Landau et al., 2016; Saebi et al., 2017), servitization (Kowalkowski et al., 2015), and digital servitization (Frank et al., 2019; Kohtamäki et al., 2020), we argue that companies can follow two main BMA strategies: a deepening and a complementing approach. First, when the current business strategy has a positive impact on performance, companies will further *deepen* (i.e., strengthen) their strategy to expand its positive influence. For example, manufacturers may leverage IIoT and CC to standardize previously customized solutions and promote scalability in production and service delivery (Ardolino et al., 2018; Kowalkowski et al., 2015). Also, they may upgrade existing products with sensors to better monitor and service products remotely (Coreynen et al., 2017; Porter and Heppelmann, 2015). Second, a company attempting to create new value offerings and find untapped sources of revenue might *complement* its current business strategy by adding a new strategic course to seize those opportunities. Examples are manufacturers that already provide product-oriented services, such as remote monitoring or repair, and choose to expand into the adjacent customer activity chain by also offering data-based services, such as advice and outsourcing (Gebauer et al., 2010).

The presented BMA approaches are not suggested to happen in a specific order. A company may focus on one strategy, seek combinations or sequence steps to adjust its business model to fit the competitive and technological landscape. This choice—to adapt their business model either through a deepening or complementing approach—often depends on the drivers for change. For instance, Saebi et al. (2017) show that companies are more likely to adapt their business model under perceived threat than under perceived opportunity. As long as the business model fits the environment, a deepening strategy might be more profitable as it builds upon already successful pathways. If not, and companies fail to adapt in a timely manner, they may suffer negative consequences (Corbo et al., 2018). For example, in the battle of market dominance, companies gain platform control by being the first, while followers favor more distributed forms of control (Den Hartigh et al., 2016). Alternatively, Saebi et al. (2017) found that firms with a strategic orientation toward market development rather than domain defense are more likely to adapt their business model. Here, combinations of adaptation strategies—either sequential or simultaneous—may enable companies to learn from past efforts and perhaps even suggest areas for further improvement, to the extent such new opportunities can be pursued (Geissdoerfer et al., 2018).

2.4. A conceptual framework for platform-enabled servitization pathways

Based on our review of the literature, we found that no study so far has considered how manufacturers adapt their business model by leveraging different types of platforms for the purpose of digital and smart servitization. The literature on BMA paths is still a work-in-progress, particularly in the area of Industry 4.0, and the convergence of platforms and digital servitization may not be very clear. Though some companies may have outlined a clear strategy for platform-enabled servitization, others evolve rather through trial-and-error by applying different platform logics, either in combination or sequentially. Hence, based on the consulted literature, we posit a new framework to be used as a map to plot our cases' unique business model transitions and theorize about platform-based servitization pathways. Fig. 1 illustrates the BMA framework for platform-based servitization. We divide the framework into a back- and front-end focus, representing two distinct organizational areas where companies can leverage increasingly digital platforms for incremental and radical service innovation purposes:

- On the horizontal axis, we make a distinction between three production platform stages that are salient in the back-end when companies upgrade their manufacturing systems, from analogue (i.e., non-digital, traditional manufacturing) over digital (i.e., IT-enabled manufacturing) to finally smart (i.e., autonomous manufacturing systems based on IoT, CC, and AI).
- On the vertical axis, companies move through three transaction platform stages in the front-end as well when managing customer relationships, from being offline (e.g., traditional sales, shops) over online (e.g., e-commerce) to ultimately staying connected with customers (e.g., smart products, service platforms).

To gain further insights in the drivers and pathways of platform-enabled servitization, we present four cases from China's textile and apparel industry. Next, we first explain this study's methodological approach.

3. Methodology

3.1. Research design and sampling

Given the limited amount of literature on platform-based servitization, we chose an exploratory approach, and more specifically a longitudinal research method (Aaboen et al., 2012) based on multiple case studies (Eisenhardt, 1989; Yin, 2013). This approach enables us to draw evidence from more than one unit of analysis and map relevant changes over time of companies' platform strategies (van de Ven and Huber, 1990). Additionally, we apply an interpretive methodology in data analysis, which is recommended for uncovering new relationships among key dimensions of relatively unstructured, dynamic market strategies (Matthyssens and Vandenbempt, 2003; Pettigrew, 1990).

For the empirical data, we focus on large companies specialized in textile and apparel manufacturing and services located in the east coastal areas of China. Because the textile and apparel industry is characterized by labor-intensive manufacturing and a relatively high degree of environmental pollution (Jia et al., 2020), it is one of the most targeted sectors to apply digitization and servitization (Haseeb et al., 2019; Küsters et al., 2017), transitioning from a "low-tech" sector toward a new technology-enabled, disruptive one (Mendonça, 2009). Recent studies find that companies from this sector that utilize IoT and/or transaction platforms to meet Industry 4.0 requirements actually have a higher chance of survival (Cai and Choi, 2020; Hynes et al., 2020). Also, as this industry holds many specialized SMEs, a better integration of the network is expected to bring significant benefits (Huang et al., 2013; Moeuf et al., 2018). Large textile and apparel companies have already taken a series of platform steps to continuously re-conceive front- and back-end relations with customers and suppliers, leading to better collaboration between stakeholders and considerably higher economic value. Because China has "the largest textile factory industry with the complete industrial chain and is also the largest textile exporter in the world" (Lin et al., 2018, p.859), we focus on Chinese cases for this study. The major textile and apparel production and trading centers are located in the east coastal areas of China (Shen, 2008), such as Jiangsu, Zhejiang, Guangdong and Shandong province, having more than 80 percent of total output value of the textile and apparel industry (Chuang, 2008). The selection of cases has been based on purposeful sampling (Welch and Patton, 1992), using the following criteria:

- Larger textile and apparel companies with over 1000 employees or an annual total revenue of more than CNY 400 million (USD 57 million)[1];
- Companies that responded to the MiC 2025's call to move from traditional, non-digital factories to "Smart Factories" to offer better-integrated service[2];
- Companies that have a strong platform-type configuration in industrial manufacturing and service provision settings; and.
- Companies that, over time, have demonstrated characteristics of BMA activities.

These criteria have been checked during preliminary contacts with the companies that were initially selected for a broader "Trends in Textile and Apparel" study and in consultation with sector experts. The basic characteristics of the four companies are presented in Table 1.

Four cases of textile and apparel companies active in yarn manufacturing, fabric manufacturing, fabric dyeing, and apparel manufacturing were selected. The textile and apparel industry has a long value chain that comprises many processes, including raw material (e.g., cotton, linen and wool) harvesting, fiber developing, fabric manufacturing, apparel manufacturing and retailing (Adhikari et al., 2020; Danskin et al., 2005). We select four companies in the textile and apparel value chain: Huaxing, Ruyi, Huafang and Baoxiniao. The four cases cover separate processes of the textile and apparel value chain (see Fig. 2).

The four selected companies have developed their businesses in the textile and apparel clusters of Shandong and Zhejiang. Over the last few decades, as a result of China's "opening-up policy", these provinces have benefited from the substantial restructuring of local industrial resources and linking with global manufacturing and trade networks (Brun et al., 2002; Yeung, 2001). Faced with the opportunities of Industry 4.0, our cases combined a smart manufacturing and servitization philosophy to reconstruct their business. They used a rich set of platform strategies,

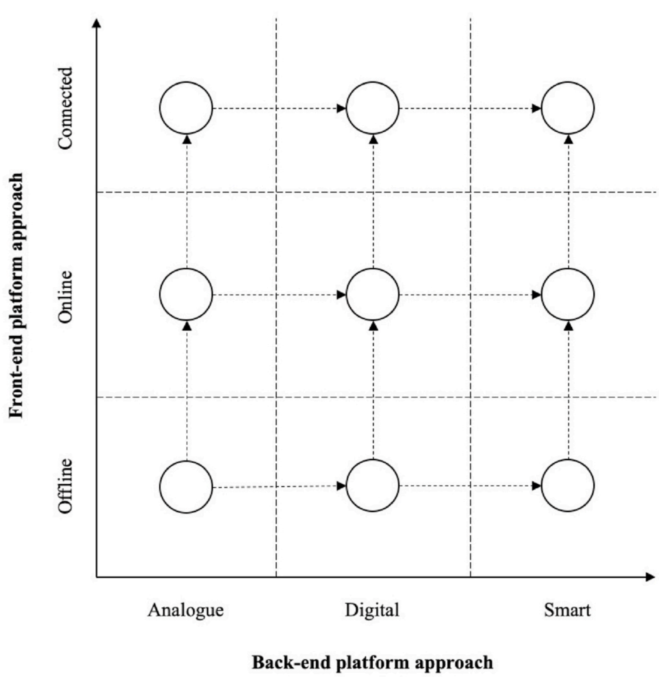

Fig. 1. The PSI transition framework.

[1] We followed the definition of large companies given by the Ministry of Industry and Information Technology (MOIIT) in China.

[2] Companies were either selected in the national programs, such as "Experiment and Demonstration Pilot Project of Intelligent Manufacturing" and "Experiment and Demonstration Pilot Project of Industrial Internet of Things Platform" issued by MOIIT, or rewarded the national prize, such as "China Industrial Awards" issued by China Federation of Industrial Economies (CFIE).

Table 1
Profile of four textile and apparel companies.

	Huaxing	Ruyi	Huafang	Baoxiniao
Main industry	Yarn manufacturing	Fabric and apparel manufacturing	Fabric printing and dyeing	Apparel manufacturing and branding
Number of employees (+/−)	1000	3000	4000	8000
Turnover in 2019	¥ 973 million	¥ 1.2 billion	¥ 3.1 billion	¥ 3.3 billion
	($ 143 million)	($ 172 million)	($ 444 million)	($ 472 million)
Creation date	1987	1972	1976	1996
Headquarters	Shandong	Shandong	Shandong	Zhejiang
Ownership	Private company	Listed company in Shenzhen	Listed company in Shanghai	Listed company in Shenzhen

covering all four PLL types and representing different combinations of BMA activities (i.e., deepening and complementing), to realize their transformation from labor-intensive manufacturers to digital, interconnected suppliers and extend their offerings from standard products to customized product-service portfolios. On top, the COVID-19 crisis has created a major challenge for the global economy, in particular the textile and apparel industry (Cai and Choi, 2020; Zhang and Watson IV, 2020). The implementation of platform-based smart servitization enabled our cases to further adapt to new business models, from offering online ordering and home delivery services to collaborating with supply chain partners to create a flexible production chain for new, customized offerings (e.g., specialized face masks).

As an illustrative study, we want to offer real-life cases that illustrate the implementation mechanisms of a platform-based PSI system (Siggelkow, 2007). We start by reviewing how each company in the case initiated its platform strategy, what BMA activities they applied as a response to external and internal changes, and how their relationships with platform partners (e.g., suppliers, customers, research agencies and industrial institutes) changed, ultimately becoming *servitized* manufacturers.

3.2. Data collection

The data for this study stems from three rounds of fieldwork. A variety of data gathering methods were used, which ensured construct validity through triangulation of data (Beverland and Lindgreen, 2010; Harwood and Garry, 2003; Jack and Raturi, 2006). First, we consulted seven industry experts from local Chinese universities and regional industrial associations specialized in textile and IT. Before the start of the study, the experts helped in identifying best-practice cases by sharing their views on Industry 4.0 and servitization developments within the Chinese textile and apparel industry, and by grasping how the selected companies changed their offerings and transformed their business models over time. During the study, we also briefly met with some of the experts informally at different occasions (e.g., industry conferences, gatherings) as a sounding board. They helped us update our views, evaluate the accuracy of what we have learned from respondents on industry trends and company developments (i.e., member checks), get access to additional respondents within companies to address specific questions, etc. Table 2 shows a brief summary of the consultation data.

Second, prior to interviewing the cases, we collected secondary information on the selected companies by scrutinizing their websites, annual reports, promotion materials and consulting other available information such as news articles and online videos. This allowed us to construct an essential timeline of the case companies' critical events, which provided further input for the identification of platform strategies and business model changes.

Third, to better understand their strategic developments, we conducted multiple in-depth interviews with the case companies' representatives. Data was collected through group interviews and panel discussions with the case companies' top management, marketing, production and the technology departments. Additionally, company reports, observations during our visits to the case companies, and senior managers' presentation slides from joint meetings were utilized. For issues requiring further clarification and conformation, we contacted the respondents at a later date through email, telephone discussions and instant messaging. The overview of data is displayed in Table 3.

The interviews were conducted following a semi-structured questionnaire with open questions (Patton, 1990). Each interview targeted

Table 2
Overview of data collected through expert consultation.

Organization	Expert position	Work experience	Consultation length	Date
Yangtze Delta River Creative Economy Cooperation Committee	Vice Secretary	>15 years	2h	Nov. 9, 2016
	Director of research center	>10 years	1.5h	Apr. 12, 2017
	Director of enterprise center	>10 years	1.5h	Apr. 5, 2017
Donghua University	Professor at textile college	>15 years	1h	Nov. 25, 2016
	Professor at apparel college	>15 years	1.5h	Oct. 23, 2017
	Professor at textile college	>15 years	1h	Oct. 23, 2017
	Professor at textile college	>10 years	1h	Oct. 23, 2017

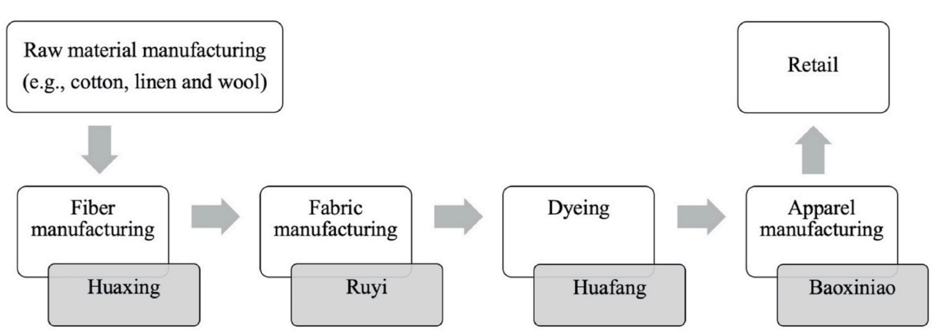

Fig. 2. Selected cases and their position in the textile and apparel value chain.

Table 3
Overview of collected company data.

Case	Data source	Participating respondent	Date
Huaxing	Company visits, interviews and company reports	Managerial representative of the intelligent spinning division (HX1), technological representatives of the intelligent spinning division (HX2, HX5), and managerial representative of the marketing and sales division (HX6)	17–19 Nov. 2016
	Conference presentation with slides	CEO (HX3)	Nov. 25, 2016
	Telephone discussions	Vice President in charge of intelligent operations management (HX4)	Sep. 1, 2020
	Panel discussions (face-to-face)	HX1, HX3 and HX6	Sep. 25, 2020
	Emails and instant messages	HX3	2016–2020
Ruyi	Company visits, interviews and company reports	Managerial representative of marketing and sales division (RY1, RY3), spokesperson of manufacturing division (RY2), and managerial representative of technology division (RY5)	28–30 Aug. 2013
	Conference presentation with slides	Vice President and Chief Engineer (RY4)	Nov. 25, 2016
	Panel discussions (face-to-face)	RY4 and RY5	Sep. 24, 2020
	Emails and instant messages	RY4 and managerial representative of technology division (RY6)	2016–2020
Huafang	Company visits, interviews and company reports	Vice President in charge of IT management (HF1), officers of technology division (HF4, HF5), and spokesman of manufacturing division (HF6)	17–19 Nov. 2016
	Conference presentation with slides	HF1	Nov. 25, 2016
	Panel discussions (online)	General Manager (HF3), HF1 and HF4	Oct. 9, 2020
	Emails and instant messages	HF1, HF3, HF4, HF5 and officer of marketing division (HF2)	2016–2020
Baoxiniao	Company visits, interviews and company reports	Managerial representative of technology and research division (BX1), spokesman of manufacturing division (BX2), and manager of customization division (BX3)	Dec. 10, 2019
	Panel discussions (online)	BX1, BX2 and BX3	Oct. 9, 2020
	Emails and instant messages	BX1, BX2 and BX3	2019–2020

Note: The senior managers of the case companies (i.e., CEO, vice president and general manager) all have over 15 years of working experience. The junior managers of the case companies (i.e., managers and representatives of manufacturing, technology and marketing) have five to 15 years of working experience. The interviews with senior and junior managers were conducted through face-to-face and/or virtual meetings. Each of the company interview lasted about 30–60 min. Extensive notes were taken during these interviews.

the content, process, and context (De Wit and Meyer, 1994; Matthyssens and Vandenbempt, 2003; Pettigrew, 1992, 2012) of the case companies' platform strategies and BMA activities. The interviews included questions on companies' Industry 4.0 strategy drivers and barriers, product-service innovations and solutions development, platform strategy and business model changes, and outcomes and key success factors (see Appendix 1). The interviews provided an understanding of the turning points of companies' platform-enabled servitization development.

Extensive notes were taken during these company interviews. After each interview, the interviewers exchanged and reported the gathered information in a joint debriefing meeting and jointly made a verbatim of each interview based on their individual notes. The Chinese version was translated into English short notes by university assistants proficient in both English and Chinese and specialized in the marketing field.

3.3. Data analysis

Analysis of the data started by delineating the platform-based servitization BMA processes case-by-case. The analysis formulated the timeline of case companies' platform strategies and business model evolutions (e.g., in 2012 Huafang initiated the "digital Huafang" program, and in 2015 the company built a digital dyeing and HFCPS platform), which provided the baseline for identifying how the servitization transition of each case was initiated and evolved. This practice is in line with the longitudinal philosophy which suggests to capture processes as the central focus to achieving better content (Aaboen et al., 2012; Fu et al., 2017; Pettigrew, 1990).

A qualitative coding analysis was carried out to reflect the relationships among platform strategies, BMA activities and servitization dynamics at each stage. Following the content analysis approach (Mayring, 2000), the interview transcripts and notes were analyzed using the qualitative coding software Atlas. ti. The software was used to enhance the preciseness of data analysis outputs and increase efficiency in the analysis process (Bell, 2013). In a first step, open coding was implemented to associate particular notes with relevant concepts drawn from the literature. Every sentence was analyzed by applying the Auto Coding Dialog tool of Atlas. ti, and all the keywords linked to platform strategies, BMA activities and servitization dynamics were automatically identified and coded. To ensure the accuracy and reliability of the coding process, the software-generated codes were manually checked by two researcher coders.

Next, using a pattern matching logic (Beverland and Lindgreen, 2010), a cross-case analysis was carried out to identify common themes and compare the emerging differences regarding strategic changes and servitization outcomes among the cases. The data analysis focused on the changes of PLL and BMA activities as units of analysis, exploring how servitization evolved as patterns (Appendices 2-8 display the data structure and examples of supporting quotations from the case companies). Finally, a pattern of platform-based servitization trajectories was derived. Four servitization destinations and two pathways, which have been matched and compared with relevant research on digital servitization, emerged from the analysis. Two of the authors constantly compared, discussed and refined the pattern during this process. This practice made sure that the empirical data is linked to the theory, while also highlighting new ideas and connecting different concepts (Williamson et al., 2018). The overall quality of data analytic process was assessed (Wagner et al., 2010) by one scholar reviewing and challenging our interpretations of the data and results and through triangulation (incl. member checks). A final analysis report was sent to each case company for control of accuracy. Each top management confirmed their consent to the content.

4. Findings

Since 2000, the four companies have been focused on establishing a platform business to strengthen their competitive position in the market. Facing the challenges of the ever-shrinking labor supply and especially the global 2007–2009 financial and economic crisis, they invested time and efforts in platform settings. Huaxing, Ruyi and Huafang adopted a platform approach in back-end units reconstruction to coordinate supply chain members and improve operational efficiency. In the case of Baoxiniao, the company focused on the front-end and started developing online sales and service channels to stimulate growth.

In the early 2010's, a progressive expansion of platform business models was undertaken by the four companies. Due to the network effects, companies decided to scale-up their platforms and involve additional stakeholders and resources into the network. Huafang and Baoxiniao emphasized front- and back-end complementarity to reach digital servitization, while the two companies located in the upper side of the value chain and running business at a smaller scale—Huaxing and Ruyi—proceeded to extend and deepen relationships with one side of platform stakeholders to assure a successful launch of digital production.

In late 2010's, partly inspired by the MiC 2025 plan, companies refined their platform-based business model by adopting close interactions between technical optimization of the back-end and new offering development in the front-end. Baoxiniao managed to leverage platform-based business for customized products and advanced service delivery. In the meantime, Huaxing, Ruyi and Huafang decided to sell platform-based business knowledge and technical expertise to SMEs to create additional source of revenue.

During the COVID-19 crisis of 2020, the four companies quickly reconstructed their production lines to meet the requirement of customized orders, such as face masks and protection gowns. The production platforms efficiently coordinated manufacturing resources to offer protective products. Also, the online platforms enabled transactions with minimal physical contact and safely. Thanks to the rising local demand, especially in the online markets, the platform sales of Huafang and Baoxiniao increased in the third quarter of 2020.

Figs. 3–6 provide an overview of the key findings of each case.

4.1. Huaxing

Facing the overall economic slowdown of the 2007–2009 economic crisis, Huaxing began the exploration of digital manufacturing (see Appendix 5, HX5). In a first step, Huaxing collaborated with software suppliers to design a modeling platform to manage the whole yarn production on a digital database. Huaxing started the transformation from the roving process which was considered as the bottleneck to yarn manufacturing (see Appendix 5, HX5). In practice, Huaxing optimized its workshop with sensors implanted in roving units and collected the tremendous roving data together through the platform to monitor, analyze and forecast the status of its roving units (see Appendix 2 and 5, HX2). As such, the platform enabled Huaxing to achieve highly efficient optimization with reduced labor consumption in the bottleneck roving process.

Next, the company applied the platform-enhanced roving knowledge in other process units and in 2014 developed a smart spinning workshop (see Appendix 3, HX4). Facilitated by an integrated cyber-physical system (ICPS), the smart workshop enabled Huaxing to improve the utilization rate of the raw materials and utilize new material to update product offerings (see Appendix 6, HX1). In addition, the smart workshop shortened the overall spinning process, which enables Huaxing to save electricity and labor costs and reduced the environmental impact of the spinning process.

In a next stage, Huaxing expanded its reach by integrating spinning SMEs into its manufacturing platform. In 2015, Huaxing decided to initiate the "1 + 100" program. As exemplified by the CEO (HX3): "Digital transformation is the trend for manufacturers while it's not easy to achieve. We intended to help about 100 spinning companies by teaching them to use our ICPS platform. We would like to share our knowledge and invite platform users to share their manufacturing resources in terms of operation data, product data and so on." In an effort to implement the "1 + 100" program, Huaxing invested in further enhancing the ICPS platform. To address the issues of product data privacy, security, ownership and traceability, Huaxing set up a database center in the Cloud and several decentralized databases in user companies (see Appendix 4, HX3). As such Huaxing created a way to secure platform-based manufacturing collaboration.

In 2020, the COVID-19 crisis initially severally impacted Huaxing's business, but the platform-enabled production capacity helped Huaxing quickly expand its product portfolio. For instance, when the production resumed in February 2020, Huaxing implemented mask production facilities and aggregated supply chain partners to the industrial mask manufacturing chain. Thanks to the digital platform, the company quickly installed new production bases for protective masks and clothing (see Appendix 6, HX4). In the future, Huaxing plans to develop more market-appealing products and explore new ways to better integrate online channels with back-end units to respond even more quickly to new market requirements.

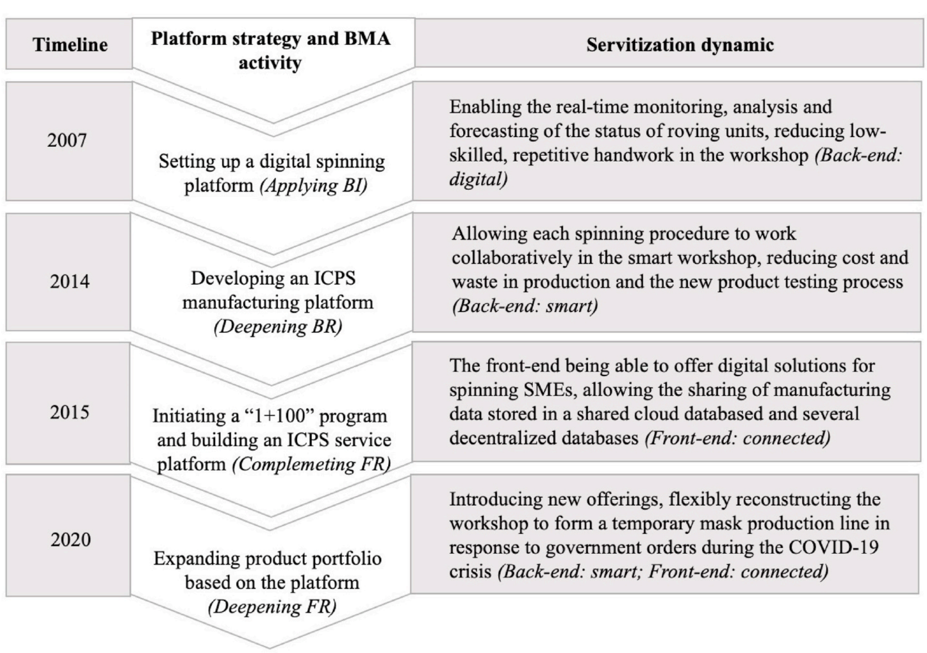

Fig. 3. Huaxing's platform-based servitization journey.

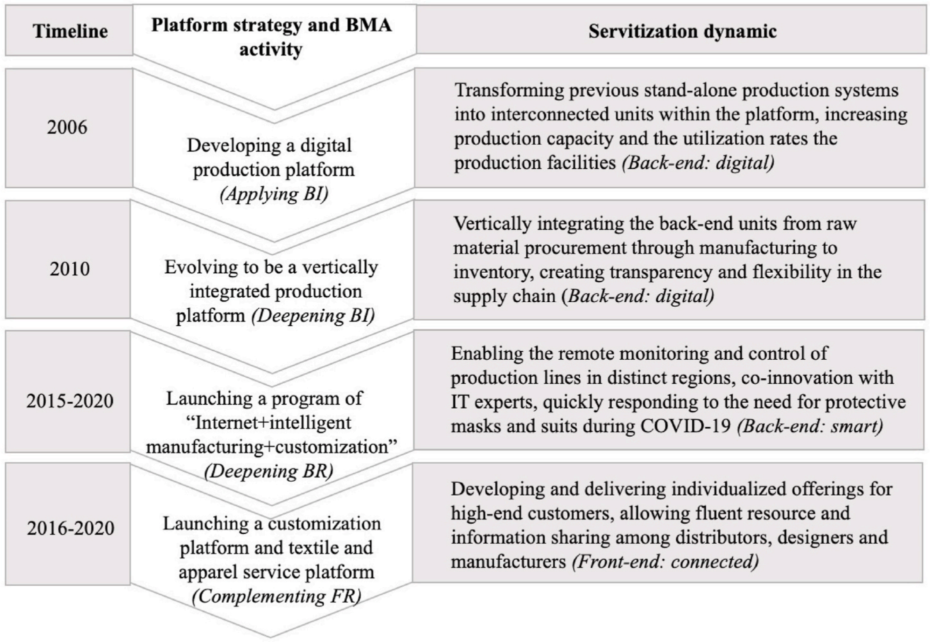

Fig. 4. Ruyi's platform-based servitization journey.

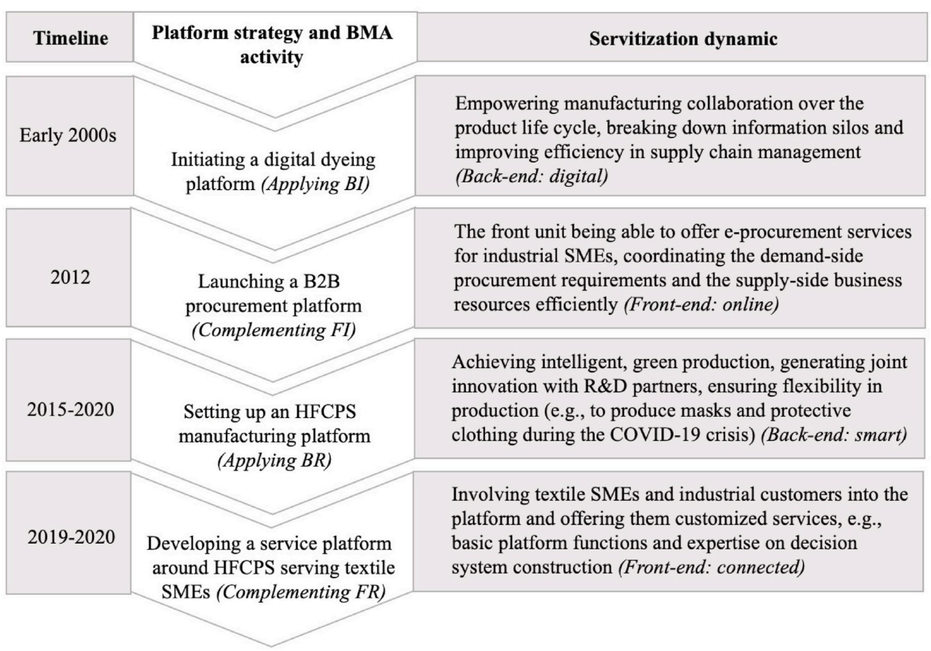

Fig. 5. Huafang's platform-based servitization journey.

4.2. Ruyi

The initial phase of Ruyi's platform journey started in 2006. Hit by increasing labor and raw materials costs, Ruyi sought to reestablish its competitive strength through digital transformation (see Appendix 5, RY4 under back-end analogue). The company first used the textile manufacturing platform of a software supplier to digitalize the production system. This platform approach allowed Ruyi to transform its previous stand-alone production systems into interconnected units within the platform. "We saw great opportunities in digital platforms. It's more than a facilitator of production efficiency, it is an overall back-end optimizer," according to the technological division representative (RY5).

In 2010, as the company extended its reach upstream to the sourcing of raw materials and downstream to apparel design and manufacturing, the platform was used to reinforce vertical integration. "We believed that our vertical presence along the industry value chain could bring us synergies and cost saving benefits. The digital platform gave us the flexibility of adjusting our operations, from raw material procurement through manufacturing to inventory," said the respondent (RY6). As such, Ruyi effectively managed the inventories according to the changes of raw material supply. On top, the platform-based integration of the organization's back-end enabled Ruyi to coordinate the supply chain, increasing transparency and flexibility.

As Ruyi progressed on its platform journey, more advanced technologies (e.g., IoT and BD) were used to enhance lean production to

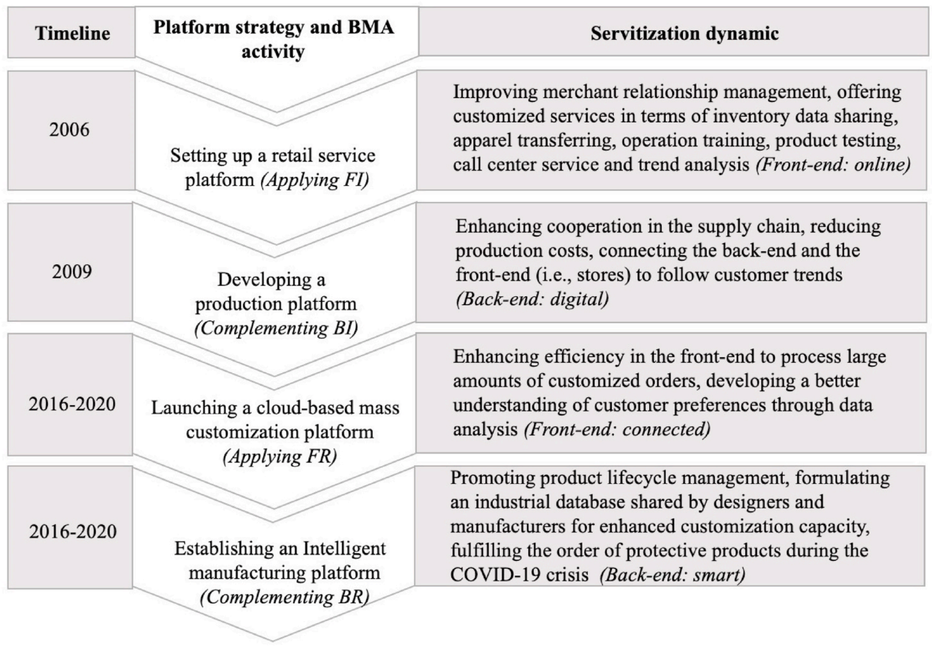

Fig. 6. Baoxiniao's platform-based servitization journey.

further reduce waste and enhance customer-orientation. In 2015, Ruyi introduced an industrial production upgrading project called "Internet plus intelligent manufacturing and customization", under which Ruyi introduced an intelligent manufacturing platform in 2017 to enable the active involvement of supply chain actors regardless of distance barriers (see Appendix 6, RY5). When further developing the platform, Ruyi placed a strong focus on investing in R&D with external IT experts. As a result of its innovation efforts, temporary production lines could be formed to address customer-specific needs. For instance, during the outbreak of the COVID-19 virus, Ruyi quickly transformed its production capacity and rearranged the workshop to fulfill the urgent demands for protective masks and suits (see Appendix 6, RY4).

In parallel, Ruyi slowly began transforming from a digital manufacturing technology developer into a service provider offering individualized products, services and experiences to industrial clients. Since 2016, Ruyi started developing a mass customization platform and cooperating with global luxury brands (see Appendix 4, RY4). Meanwhile, Ruyi gradually shifted to constructing a service platform which offered cloud manufacturing technologies and solutions to solve the bottlenecks faced by textile SMEs. In 2019, supported by the government, Ruyi set up a textile and apparel service platform to enhance the digital capacities for the SMEs and accelerate the coordination of the supply chain. The platform follows a resource sharing logic. For instance, an online distributor community was therefore established to link global customers and local production facility resources. When the COVID-19 crisis required Ruyi to shift its focus from the overseas market back to the local market, the company further strengthened its service platform to boost sales by linking new source of downstream collaboratoers, such as, online retailors and celebrities that sell products through live streaming. Today, Ruyi is optimistic about the network effects unleashed by the platform (see Appendix 8, RY4).

4.3. Huafang

In the 2000s, Huafang took its first steps toward developing a digital platform. The dyeing sector is considered one of the most time-consuming processes in the textile and apparel value chain (see Appendix 5, HF5). To address the issue, Huafang decided to establish a digital platform. Around 2010, Huafang's digital production platform, facilitated by Enterprise Resource Planning (ERP) software suppliers, was finally launched. The dyeing process was firstly digitalized. As a result, the data of each manufacturing process was exchanged and shared through the digital platform, which reduced the information silo issues and empowered manufacturing collaboration over the product life cycle. Also, the platform allowed Huafang to manage raw material suppliers and purchase orders more efficiently (see Appendix 5, HF4).

In 2012, a milestone of the "Digital Huafang" program was the introduction of a B2B procurement platform to serve local companies, bringing Huafang a new source of revenue (see Appendix 4, HF2). Huafang opened up its digital platform to industrial customers and expanded it to a B2B procurement platform offering e-procurement services to textile SMEs. The procurement platform coordinated the demand-side procurement requirements and the supply-side business resources, and significantly increased the transaction efficiency across the supply chain. By the end of 2015, the platform had registered 7000 supply chain users with over CNY 783 million (USD 111 million) transaction value. Ergo, Huafang received several provincial best awards in Shandong for its B2B e-commerce and platform services (see Appendix 7, HF4).

In 2015, triggered by the national government's MiC2025 call, Huafang launched an upgrading "Smart Huafang" program under which the company developed an integrated cyber physical platform (called HFCPS) (see Appendix 2, HF6). Great efforts were put in development of the HFCPS platform. For instance, an innovation hub for external partners, such as suppliers, universities and research institutes, was set up to continuously empower the joint innovation capability in data mining, computing and predictive analytics. The HFCPS platform allowed external technology experts to offer added value such as operation monitoring and machine performance diagnostics. Additionally, the platform enabled Huafang to quickly formulate temporary production lines for customized orders (see Appendix 6, HF1). During the COVID-19 crisis, Huafang's workshop was quickly transformed to produce face mask and protective suits. In the third quarter of 2020, the number of online transactions in Huafang's platform sharply increased. "Offline transactions were reduced to maintain social distancing. So, increasing users put more orders via our platform," said the Vice President (HF1).

On top, Huafang decided to extend its HFCPS platform to sell digital transformation knowledge to textile SMEs. Depending on the customer's level of digitization, Huafang offers a customized service package. “For companies with a low degree of digitization, we teach them how to use the platform’s basic functions. For companies with a higher digitization degree, we offer different framework solutions to construction a platform-based decision support system” explained the Vice President (HF1). Currently, Huafang continues to push forward its HFCPS solution in the local market with a focus on converting its knowledge of digital transformation into revenue enhancement.

4.4. Baoxiniao

In 2006, Baoxiniao started developing a service platform to digitally interlink its franchising stores in China. In order to address information silos issues in its previous operations (see Appendix 7, BX1 under front-end offline), Baoxiniao applied an identified ERP supplier’s solution system to construct an integrated retail management platform. In 2007, the platform was launched in more than 600 franchising stores, allowing for a set of service and option packages, such as, across-store cargo transferring and adjusting, store operation training, product testing, call center services and trend analysis services, thereby streamlining the operations of the stores and merchants. Today, the retail management platform also enables franchising stores to develop their own, customized marketing strategy. Within the platform, Baoxiniao initiated the “best merchant” competition to encourage stores to share their operational data, knowledge and experience. As such, the platform enhanced merchant engagement and trust, which in turn brought more merchant collaborators into the network.

Meanwhile, as Baoxiniao progressed on its platform journey, great efforts were invested in the upgrading of the organization’s back-end. In the post 2007–2009 financial crisis, Baoxiniao started leveraging a digital approach to facilitate its back-end operations to reduce production costs and offer more competitive products (see Appendix 4, BX3). The company applied a software supplier’s solution to build a production platform that enabled data exchange among production procedures and the supply chain. On top, the platform approach speeded up the company’s sales by sensing early trends and adapting its production (see Appendix 5, BX1).

In a next stage, Baoxiniao started integrating its digital resources to boost its most competitive customization business, seek higher sales performance and improve its margins. The company shifted its focus heavily toward mass customization (see Appendix 2, BX3 under applying FR logic). In late 2016, Baoxiniao decided to launch a cloud-based mass customization platform that supported clients to self-design their products. The online services (e.g., self-design) offered by the platform enhanced the efficiency of processing a large amount of customized orders (see Appendix 7 and 8, BX2). To develop more know-how about customers’ preferences, Baoxiniao applied digital solution packages (such as, the advanced personalization system to process customer orders and analyze their data) from a recognized ERP provider (see Appendix 8, BX1).

Meanwhile, Baoxiniao actively promoted upgrading its manufacturing infrastructure toward Industry 4.0 to enhance its responsiveness to customized demands. In 2016, an intelligent manufacturing platform approach was adopted. In practice, Baoxiniao introduced an advanced machine-to-machine manufacturing system and promoted product lifecycle management (PLM) software over its supply chain to obtain agility in production (see Appendix 4, BX2). Additionally, Baoxiniao established a database that incorporates billions of fabric, accessory and pattern data. The database was shared with designers and manufacturers to enhance Baoxiniao’s mass customization capacity (see Appendix 4, BX1). During the outbreak of COVID-19, the platform-enabled capacity empowered Baoxiniao to fulfill the mass customization order of protective products. Due to the recovery of the local demand, the online business contribution of some brands of Baoxiniao kept rising in the third quarter of 2020.

5. Discussion

Taking a cross-case perspective to the presented cases, we identify different trajectories and patterns in manufacturers’ platform-enabled servitization journeys. The four companies’ transitions are plotted on Fig. 7, which offers insight on servitization destinations and pathway dynamics. Specifically, we reveal three main kinds of platform-enabled servitization destinations: non-digital servitization (position 1), digital servitization (position 2), and smart servitization (position 3). In line with previous insights, this transition is not a smooth, unidirectional one (Kowalkowski et al., 2017b; Raddats et al., 2019). In practice, some companies may transit through an intermediate smart manufacturing position (position 4) on their way to achieve their final service destination. Also, they may take different pathways, namely a sequential or simultaneous BMA approach to either deepen or complement different platform logics, respectively. In the following sub-sections, we explain these servitization destinations (section 5.1), transition pathways as well as BMA dynamics powered by specific platform-leverage logics (section 5.2) and discuss the patterns that emerge from our empirical data (section 5.3).

5.1. Destinations of platform-based servitization

Our sampled manufacturers all start from position 1, where they have not yet leveraged the power of platforms. As such, non-digital services (e.g., product maintenance, customer support, advice) are delivered to the customer mainly through offline channels (e.g., personal communication, visits) and the company’s operations are still organized in a labor-intensive way. Next, the cases started evolving to position 2, where digital production platforms (e.g., program integration and optimization software) and/or online transaction platforms (e.g., retail management system and procurement websites) empower them to offer digitally-enabled services (e.g., technology consultancy, process integration, product or service customization). Finally, they moved to position 3, where they combine and leverage smart manufacturing platforms (e.g., IIoT) as well as connected transaction platforms (e.g., smart products and IoT-optimized service channels) to provide customers fully digital, smart services (e.g., Industry 4.0 solutions, mass customization). This combination of both Industry 4.0 and servitization, also regarded as IoT-powered servitization (Rymaszewska et al., 2017), is unlocked by deliberately exploiting platform synergies and platform partners’ engagement (Frank et al., 2019).

In non-digital servitization (position 1), in an effort to differentiate themselves from cost-driven competitors, manufacturers offer their know-how about physical products mainly through employees. Service provision improvement mainly relies on management and labor skills (Baines et al., 2009; Gebauer and Friedli, 2005) rather than technology. For example, Huaxing’s workshop used to rely heavily on employees to check and mend issues caused by yarn breaking in production (see Appendix 5, HX5). At Baoxiniao, the experience of tailors and the company’s expertise in product design are still considered to be critical resources for customized apparels (see Appendix 7, BX2). A final example is Huafang, where the dyeing process (e.g., machine scheduling) was mainly handled by employees (see Appendix 5, HF5). In such cases, product-extended services (e.g., customer support and advice) are offered mainly to fulfill and sustain product functionality in an efficient manner (Sousa and da Silveira, 2017). Although the studied cases started serving customers through more value-based offerings, a low-pricing strategy was considered the dominant means to create a competitive advantage and generate the highest returns at the time. This we learnt, for instance, from Ruyi, which competes with other companies serving customers mostly through low prices (see Appendix 5, RY4 under Back-end analogue). In this non-digital servitization stage, customers play a limited role in value creation. For example, in the case of Baoxiniao, the disconnect between different procedures caused difficulties in changing product portfolios to better address customer needs (see

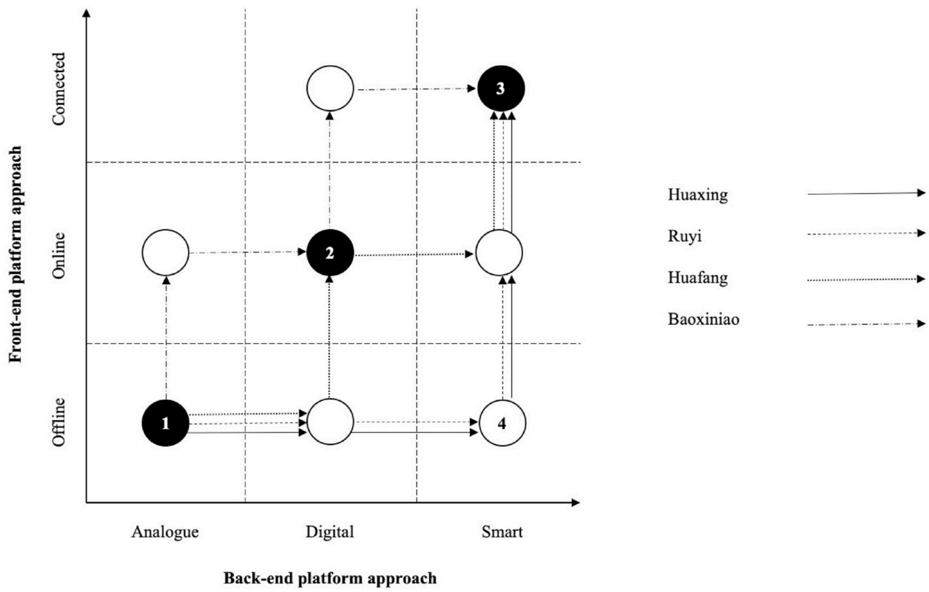

Fig. 7. Case companies' transition trajectories in platform-enabled servitization.

Appendix 7, BX1 under Front-end offline). Such inconsistency of internal (i.e., back-end) and external (i.e., front-end) organizational configurations is considered a type of servitization barrier (Alghisi and Saccani, 2015; Gebauer et al., 2020a), leading to the so-called "service paradox" (Gebauer et al., 2005) and the more recent "digitalization paradox" (Gebauer et al., 2020b), whereby manufacturers ultimately leave the digital servitization transition line.

In digital servitization (position 2), manufacturers overcome this barrier by utilizing technology to better align their internal and external organizational arrangements. A key factor here is the role of digital platforms to coordinate back-end manufacturing and front-end service delivery processes (Cenamor et al., 2017). As observed at Huafang and Baoxiniao, companies combine both BI and FI logics to leverage digital production and online transaction platforms, respectively, to reach this second servitization destination. In line with the literature, platform-enabled effects in terms of value co-creation with suppliers and customers become the foundation for digital-enabled service offerings (Kowalkowski et al., 2013; Lenka et al., 2017; Lerch and Gotsch, 2015). For example, Huafang created a production platform to improve its own manufacturing performance and also better integrate with suppliers, which allowed them to provide more customized e-procurement services (see Appendix 5, HF4). They also involved industrial customers into the network, creating even more learning effects and scale (see Appendix 7, HF4). In the case of Baoxiniao, the company used its retail management platform to integrate franchising stores and leverage networked production resources to provide accelerated support services for store-front customers (see Appendix 5, BX1; Appendix 7, BX1 and BX3 under Front-end online). As such, consistent with previous platform research (Lager, 2007; Thomas et al., 2014), our evidence shows that the use of digital platforms for value coordination in service offering creation and delivery reflects platform-leveraged thinking.

In smart servitization (position 3), manufacturers use IoT-based platforms to further integrate front- and back-end resources in the network, enabling future-oriented smart services. We consider this (at least currently) to be the highest level of Industry 4.0-based servitization (Frank et al., 2019). Our empirical data offers several illustrations of IoT-enabled, networked platforms that significantly enable manufacturers in creating tailor-made, integrated solution packages, thereby generating new customer value. For example, Huafang established an HFCPS manufacturing platform to support a flexible supply chain, which later became the technical foundation to provide a broad range of supplier-customer as well as industry-university joint innovations and Industry 4.0 solutions. Their platform also empowered the company to quickly resume production capacity to respond to the COVID-19 challenges (see Appendix 6 and 8, HF1). The case of Huafang may even be considered a best practice example of leveraging IoT-enabled flexible production capacity for smart solution provision. Another example is Baoxiniao, which created a cloud-based customization platform to lock-in and engage with customers while simultaneously enhancing its manufacturing basis, and which aggregated manufacturers and designers to supply enhanced customization services (see Appendix 6, BX2 and BX3). Their case is an illustration of "platforming and mass customization" (Alizon et al., 2009) outside the automotive industry. As such, IoT-based platforms allow manufacturers to enhance the individualization of products at the cost of mass production and compete in mass customization (Cenamor et al., 2017).

Though a linear transition from position 1 to 2 and finally 3 seems logical, manufacturers do not necessarily transition through position 2. They may also pass by position 4, where smart manufacturing platforms facilitate companies in a specific area of their servitization process while the platform-leveraged effect is still not yet fully released. Previous studies demonstrate that being a smart manufacturer is a way for companies to raise entry barriers and thus secure their position in the supply chain network (Ziaee Bigdeli et al., 2018). Yet in such a position, companies need to further invest in aligning the internal organization with the external environment (Alghisi and Saccani, 2015) to move forward on the PSI continuum (Bustinza et al., 2019). Huaxing, for example, first moved along the horizontal axis by sequentially leveraging BI and BR platform logics. The company first created an ICPS production platform that offers real-time monitoring, forecasting and control of spinning operations, which also stimulated the development of new products in a cost-saving manner (see Appendix 6, HX1). At this intermediate stage, its front-end channels were not yet completely integrated, which limited Huaxing's capacity to fully develop its "1 + 100" program of serving industrial customers through digital solutions. Another example is Ruyi's initial implementation of a vertically integrated, intelligent manufacturing platform, which generated a series of technological innovations (see Appendix 6, RY5). The platform offered Ruyi the capacity to produce a large variety of products and other simple customized offerings, such as protective masks and suits during the COVID-19 crisis (see Appendix 6, RY5). Meanwhile, its front-end interface remained to be heavily upgraded before it could integrate external designing, manufacturing and customer resources and handle mass customization orders for the high-end market.

5.2. Pathways and BMA dynamics of platform-based servitization

On top of four servitization destinations, our case companies illustrate two main pathways as BMA dynamics for platform-based servitization. First, companies can take a *sequential* BMA approach to move forward with front- and back-end digitization, following a temporal order. A sequential BMA approach refers to either moving forward with upstream network positioning to improve supply chain collaboration (Ziaee Bigdeli et al., 2018), then switch to downstream positioning to better lock-in customers through servitization (Bustinza et al., 2013; Vandermerwe and Rada, 1988; Vendrell-herrero et al., 2017), or vice versa. This sequential approach is suggested by previous research (e.g., Jovanovic et al., 2019), because the attempt of simultaneously developing both front- and back-end units is considered rather difficult and risky. This approach reflects a platform-deepening strategy as it allows manufacturers to continuously expand and maximize the positive impact of digital platforms on their production and transaction processes. Visnjic et al. (2018) also hinted at such a deepening strategy: as companies progress along the servitization path, the need to collaborate on a larger scale with partners and suppliers also increases, thereby expanding business opportunities. In so doing, a deepening strategy generates direct network effects. As illustrated by Wei et al. (2019), the direct network effects inherent in platforms can be stimulated when additional participants are involved into the network and, in the meantime, the inter-actor coordination is well-managed.

Among the studied cases, examples of undertaking such a sequential, deepening approach to platform-based servitization are Huaxing and Ruyi. These companies, located upstream the textile and apparel value chain, first focused on upgrading the organizational back-end by moving entirely along the horizonal axis, and then turned upwards along the vertical axis to reach the position of smart servitization (see Fig. 7). Specifically, Huaxing began with setting-up a back-end platform to enhance the roving process (the initial bottleneck in its manufacturing operations) and then integrated the whole spinning process (see Appendix 3, HX4). When this back-end platform approach reached a level of digital maturity, the company started to share its knowledge with industrial customers by offering digital solutions, a type of front-end service upgrading. On top, Huaxing's strengthened platform capacity powered the company to develop more market-appealing and customized offerings, such as protective wear for the COVID-19 crisis (see Appendix 3, HX6). Another illustration is the case of Ruyi, which first fully leveraged a back-end platform approach to integrate the spinning process and later applied it to its entire textile and apparel line, from raw materials to finished products (see Appendix 3, RY5 and RY6). Thereafter, the company's vertically integrated production capacity enabled the front-office to develop a mass customization business for the high-end market.

A second pathway is that companies adopt a simultaneous BMA approach by combining front- and back-end digitization in parallel. A simultaneous BMA approach refers to leveraging both back and front-end PLL in a complementary manner to support manufacturers' servitization transition. Such a simultaneous approach was also proposed by Oliva and Kallenberg (2003) and Meier et al. (2010), who advocated that manufacturers move gradually along the product-service continuum from being pure-product providers to advanced-service providers. A platform-complementing strategy is reflected in this approach, as companies combine both BI and FI platform-leverage logics first and BR and FR logics later. Though research has highlighted the difficulties of implementing such a simultaneous approach (e.g., Jovanovic et al., 2019), its appeal might be explained by the cross-side network effects explained by Gawer (2014) and Van Alstyne et al. (2016), who said that, as the number of platform participants on one side grows, it inspires potential participants on the other side to join the platform as well.

Our empirical data show two case companies implementing this simultaneous, complementing approach. Huafang and Baoxiniao, located downstream the value chain, almost simultaneously upgraded both back- and front-end operations to gradually reach the stage of digital servitization (position 2) and then further advanced to smart servitization by also implementing smart technologies on both fronts (see Fig. 7). Huafang was one of the first dyeing manufacturers in China to apply digital platforms in manufacturing and supply chain management. Shortly after the platform's implementation, the company leveraged its optimized production capacity to share the benefits with industrial partners, thereby creating new sources of revenue through offering e-procurement services (see Appendix 4, HF2). When the platform-leveraged effects were reached, the number of registered users kept rising, which triggered the need to further upgrade its current platform to serve a larger range of industrial partners. Another example is Baoxiniao, one of China's pioneering companies to operate a mass customization platform. Stimulated by the sharp sales increase of its customization business, the company started pursuing a cloud-based customization platform to further lock-in customers. Meanwhile, it reinforced its back-end production and design capacity to better fulfill customized requirements. An intelligent manufacturing platform was adopted that enabled their online store to efficiently align customer needs with providing capacity of suppliers and designers, enhancing both front-end and back-end collaboration (see Appendix 4, BX1 and BX2). When an increasing number of customers started putting more (customized) orders via their platform, Baoxiniao expanded its engagement to more manufacturers and designers to better respond to customer demand.

5.3. Patterns in platform-based servitization and BMA dynamics

Overall, by looking into how manufacturers develop and manage platforms to transit from a traditional product-centric approach to digital and finally smart servitization, we uncover several patterns. First, we find that smart servitization can be reached by leveraging increasingly digital and connected platforms in both the front- and back-end of the organization. As also highlighted recently by Paiola and Gebauer (2020), our cases show that the transition to digitally-enabled, service-oriented business models demands constant strategic moves, both incrementally and radically as well as horizontally and vertically (see Fig. 7). In line with previous literature, our study confirms that manufacturers can cross multiple destinations along their digital servitization journey—from non-digital servitization to digital servitization (or smart manufacturing) and smart servitization—while gradually building-up incremental and radical platform experience (Eloranta and Turunen, 2016; Gebauer et al., 2020a). This enables them to co-create value and learn from platform partners (Lenka et al., 2017) in order to further refine their service offerings (Cenamor et al., 2017).

Second, we find that manufacturers move gradually toward smart services by exploring and combining different pathways rather than embarking on a clear, pre-planned and disruptive servitization journey. Although no explicit end-destination was fixed, a strategy pattern (Miles et al., 1978; Mintzberg, 1978) of BMA dynamics emerged from the cases—a sequential BMA approach (through platform deepening) and a simultaneous approach (through platform complementing)—backed by a growing clarity on the different types of PLL (Thomas et al., 2014), namely a BI, BR, FI and FR logic. Initially, the studied cases' ambitions were relatively limited, but soon network effects drew them to further scale-up their platform leveraging power, leading them to introduce new platform extensions and additions. Next, they started combining two inter-linked servitization journeys, a back-end and a front-end track, and soon realized that both tracks reinforce one and another (Li, 2018; Tao and Qi, 2019). The case companies created platform-based B2B services to educate SMEs and convince them to join the platform, thereby sharing and optimizing resources, tapping data and gaining additional network effects (Eisenmann et al., 2011; Parker et al., 2017). These additional sources of revenue allowed them to continuously improve their platform technology. These platform approaches presented opportunities for our cases to implement flexible, order-driven and labor-saving manufacturing and delivery systems, which empowered them to address challenges during the COVID-19 crisis. Over time, they gradually learnt how to orchestrate and elaborate their linked platforms (Nambisan and Sawney, 2011; Perks et al., 2017). Building on the consulted theory and analysis of our empirical data, we suggest the following two propositions:

- *Proposition 1: Production-oriented companies located upstream the value chain are likely to take a sequential BMA approach in their servitization transformation journey and therein apply a deepening platform strategy to take advantage of its direct network effects.*
- Proposition 2: *Companies located downstream the value chain are likely to follow a simultaneous BMA approach to proceed in their servitization journey and apply a complementary platform strategy for its cross-side network effects.*

6. Conclusions

6.1. Theoretical contributions

This study empirically explores how manufacturers adopt platform-leveraged thinking to implement servitization in an Industry 4.0 context. Based on a cross-case analysis of four textile and apparel manufacturers from China, our findings reveal distinct platform-based servitization strategies and BMA dynamics to migrate from a conventional labor-intensive and product-centric business model to a smart, service-centric one. Different unique trajectories of the case companies reveal three specific servitization positions, four platform leverage logics and two BMA pathways. The research methods used enable us to derive valid conceptual insights from interpretive case studies that are also transferrable to practice. Altogether, we consider four contributions to the theory.

First, taking a hybrid Industry 4.0 and servitization perspective (Frank et al., 2019), we pay direct attention to how manufacturers leverage and adopt platform-based PSI systems for the purpose of servitization. This way, we address Teece and Linden's (2017) call for a more comprehensive understanding of how companies leverage and evolve platforms for service BMA. Specifically, based on a review of the literature on PSI, PLL and BMA, we created a conceptual framework to plot the purposefully sampled cases' unique business model transitions toward platform-based servitization. Our case insights explain how manufacturers leverage different platform logics leading to distinct service destinations and BMA transitions.

Second, we construct the basis for a theory that extends other current digital servitization models (e.g., Coreynen et al., 2017; Huikkola et al., 2020; Kohtamäki et al., 2020; Paiola and Gebauer, 2020) from a platform leverage lens. Based on the synthesis of prior research and analysis of our empirical data, three destinations of platform-based servitization in an Industry 4.0 context are identified: non-digital servitization, digital servitization and smart servitization. In line with previous studies (e.g., Meier et al., 2010; Oliva and Kallenberg, 2003), our cases show that manufacturers can move gradually along the product-service continuum, starting from a non-digital servitization position to a digital one and finally reaching smart servitization. As argued by Huikkola et al. (2020) that a company should change its logic by "introducing service elements into its product and manufacturing operations while introducing production elements into its service operations" (p.102), our empirical data also shows that manufacturers gradually transition into digital and smart servitization by simultaneously adjusting both the organization's front- and back-end configurations. Besides, a fourth destination emerges along the transformation, suggesting that manufacturers can migrate through an intermediate "smart manufacturing" position in order to first maximize back-end manufacturing and supply resources before moving into smart services later. As implied by previous research (e.g., Jovanovic et al., 2019), we find that manufacturers may experience difficulties when trying to digitally upgrade both front- and back-end elements simultaneously. In line with Kowalkowski et al. (2017b), our research shows that, rather than following a balanced approach to develop a product and service identity simultaneously, manufacturers can first evolve to becoming a smart manufacturer to reach an optimal production performance before adopting a more customer-centric approach.

Third, this study responds to the research call of Rabetino et al. (2017) to explore servitization pathways from a BMA lens. Our evidence allows us to identify two kinds of BMA dynamics for platform-enabled servitization. Based on the case insights, we find that companies either follow a sequential path of developing platform-based PSI systems or a simultaneous development path. In sequential BMA, companies begin in the organizational back-end and gradually infuse incremental (i.e., BI) with radical (i.e., BR) digital innovation before moving on to the front-end (i.e., FI and FR), whereas in simultaneous BMA, companies attempt to complement both front- and back-end platform-based PSI developments at the same time. Our data show that a sequential approach is more likely to be taken by production-oriented companies located upstream in the value chain, and a simultaneous approach by more market-oriented companies located downstream. Upstream companies are likely to follow a platform-deepening platform to take advantage of its direct network effects, whereas downstream companies tend to pursue a platform-complementing strategy for its cross-side network effects. As a result, by identifying these two pathways, we broaden servitization trajectory research (Jovanovic et al., 2019; Kowalkowski et al., 2015; Meier et al., 2010; Oliva and Kallenberg, 2003).

Last, using a longitudinal, interpretive case study method on four Chinese textile and apparel manufacturers, we highlight potential strategic roadmaps of manufacturers' transition toward platform-based service business models. This study answers the call for longitudinal case studies with illustrative examples on the dynamic development of platform-based systems (Frow et al., 2015; Möller and Halinen, 2017) as well as on the transformation trajectories in servitization and digitization (Sjödin et al., 2019). Also, by combining the process, content and context dimensions of analysis (De Wit and Meyer, 1994; Matthyssens and Vandenbempt, 2003; Pettigrew, 1992, 2012), our study outlines companies' progress in servitization (i.e., the process) in China's textile and apparel manufacturing industry (i.e., the context) and maps their activity changes regarding PLL and BMA to boost servitization (i.e., the content). This makes the process of leveraging and adapting platform-based systems for PSI more tangible and thus applicable to other B2B organizations that strive (but also struggle) to achieve platform-based servitization in their business contexts.

6.2. Managerial implications

Developing a platform-based PSI-system is a gradual process that consists of several steps. This study shows different service "destinations", platform "engines" and business model "pathways" that companies can take to move from stand-alone, traditional factories that produce standard products to smart factories using IoT-enabled, networked systems. For managers, this study can be inspiring as it shows several issues that companies face when embarking on any of the described servitization pathways. Our developed theoretical framework on platform-based PSI transitions and related propositions might act as a strategic choice model showing different options for manufacturers to start or continue their platform-based servitization journey. We suggest that companies take a strategic approach that suits their unique internal features and local market-specific conditions, which can lead to positive network effects inherent in platforms and major advances in their servitization process.

Key to developing such a platform-based PSI system is an alignment between the organizational front- and back-end through digital innovation as well as a strategic adjustment of companies' service business model in a timely manner. Managers should check if their companies (or business units) are proficient enough in terms of platform-based innovation attitudes, and whether they are able to simultaneously commit to digital transformation and incorporate services to create value. Once a platform-based servitization journey is initiated, as each successive position is reached, a greater level of servitization is required. Accordingly, it is essential for managers to modify their strategies and evolve their service business models in response to the changing environments (e.g., competition landscape, policy) before finally achieving synergies of platform-based servitization.

The transition toward platform-based PSI systems, besides lowering costs and increasing efficiency, opens up new business opportunities for companies by enabling new types of services, such as remote monitoring and control, predictive maintenance, integrated solution packages, and mass customization, which are considered key features of digital servitization (Rapaccini et al., 2020). Our empirical data shows that manufacturers offering such advanced services are less severally impacted by the COVID-19 crisis than companies relying on basic services and labor skills. Also, this research demonstrates that companies with platform-based PSI systems are able to reach into new customer segments, such as other sectors (e.g., by offering protective equipment) and even competitors (e.g., by selling digital servitization knowledge), thus increasing revenues. On top, our findings illustrate that companies should prepare themselves for unforeseen crises, such as the 2007–2009 financial crisis and ensuing economic recession and the COVID-19 epidemic. Managers who seek comparative advantages during such crises should adopt platform leverage thinking and increase their awareness on how to incorporate a platform approach to further boost PSI.

6.3. Limitations and suggestions for future research

First, building on current theoretical reasoning and applying extensive qualitative research methods, this article provides novel insights into what strategic approaches and servitization pathways manufacturers take to exploit platform-based PSI systems in an Industry 4.0 context, but given its interpretive methodology, it cannot claim generalizability. Future research can conduct further qualitative and quantitative empirical studies to extend and validate our findings. For instance, we developed two research propositions on different BMA approaches preferred by companies located upstream and downstream, requiring further investigation and validation. Also, scholars can broaden and deepen this research area by further identifying companies' strategic triggers, measuring companies' level of platform-based servitization and analyzing the impact on their performance, for instance, in terms of revenue enhancement and customer retention.

Second, this study uses a business model lens to observe the implementation of platform-based PSI systems. When managing a platform service business, companies also need dynamic capabilities (Brettel et al., 2014). For instance, Ritter and Pedersen (2020) already highlighted the importance of a digital capability, described as "an antecedent to a firm's digitalization, as this capability can impact all elements in business models" (p. 181), Sjödin et al. (2020) also suggested companies to develop the capability of agile co-creation for the purpose of digital servitization, and a final example is the recent study by Huikkola et al. (2020), who underlined the importance of being able to orchestrate both the supply and customer network. Future research, therefore, could identify the specific capabilities (e.g., digital analysis, network orchestration, value co-creation skills) necessary for manufacturers to manage platform-based PSI systems, and thereby improve our understanding of the strategic dynamics in platform-based servitization.

Third, our findings stem from analyzing four cases from China's textile and apparel manufacturing industry. Consequently, our cases are not representative for all manufacturing or business contexts. Frank et al. (2019) indicated that "servitization is influenced by the industry life-cycle, industry type and its environment" (p.349). Ergo, investigating cases from other industries could well yield different results regarding platform-based servitization trajectories, providing further valid contributions to the literature. The use of platforms to facilitate servitization can certainly be found in other traditional industries as well, such as the manufacturing of basic metal, furniture, leather, coke and refined petroleum products. Future studies could use our proposed theoretical framework to explore platform-based servitization in these and other industries.

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Appendix 1. Interview outline

1. Company profile

The introduction of the company's main products, production capacity and output, turnover and product competitiveness. The introduction of platform-driven smart servitization dynamics in production operation, technology development and marketing processes.

2. External environment of platform-driven smart servitization

The opportunities and challenges that the company encountered. The opportunities may be enabled by technology, policy and market changes. The challenges could originate from business and culture differences between China and other countries, and actors such as competitors, industrial leaders and radical innovators across-industry.

3. Purpose, process and emphasis of platform-driven smart servitization

The main purpose of platform strategy for smart servitization (e.g., to address labor shortage, to improve production efficiency, product quality, capital utilization and market response, and to fit the digital economy). The process and sequence of the development of platform-driven smart servitization. Including, platform utilization, the development of smart manufacturing and smart factory, the establishment and development of collaborative production platform, Internet-based transaction/service platform, IoT technology platform and mass customized platform. The main issues needed to be solved in platform development.

4. Barriers of platform-driven smart servitization

Encountered barriers are identified, they might include internal inertia and external obstacles, especially in the process of platform management and collaboration, smart production, smart designing and smart service. The gaps between the case company and international benchmarks/top companies of platform-driven smart servitization, e.g., in process of designing, manufacturing and marketing management.

5. Strategies of platform-driven smart servitization

The aim, content, technological sources and co-creators/stakeholders of the platform-driven smart servitization strategy. What specific operation processes were improved? The outcomes in terms of smart servitization and the economic and social returns; The specific activities the company conducted, e.g., cooperate/communicate/collaborate with external industrial network, address value conflicts, solve problems, and integrate. How did the company replicate, optimize, promote and export its experience in platform-driven smart servitization? What kind of policy does the company expect from the government to support the transformation (i.e., platform-driven smart servitization)? And in what specific process or aspect?

Appendices 2–8.

Appendix 2
Data structure of platform strategy and BMA activity

Aggregate dimensions, second-order themes, and first-order categories	Examples of supporting quotations from the case companies
Platform strategy and BMA activity	
1. Applying PLL	
A. Applying BI logic	"We opted for digital transformation. […] We found that there are many factors that could lead to yarn breaking, including raw materials, semi-finished products, equipment, and so on. After several observations and experiments, our engineers figured out that yarn breaking mostly happened when the yarn strength and tension reached the peak simultaneously. We reported this finding to our IT partners and jointly developed a data model and modified the equipment slightly with sensors, and control the operation via platform." (HX2) "We operated the whole spinning process on a platform base." (RY2) "Our digitization journey originated from 2000s. […] Around 2010, we launched a digital production platform. The key procedures, such as, dyeing process and accounting system were firstly digitalized." (HF3)
B. Applying FI logic	"We constructed an integrated retail management platform and applied the platform in more than 600 franchising stores in 2007." (BX3)
C. Applying BR logic	"An industry-wide platform that impacted the whole textile sector became the trend and it was the direction for us to further extend our previous procurement platform. Our purpose is to build a smart, green factory and a cloud-based platform interconnecting local dyeing manufacturers. Many of our competitors were working on it, so we needed to follow. As we invested great efforts in the development of the cyber-physical system, we named the platform as HFCPS." (HF6)
D. Applying FR logic	"The customization business had a great impact on our sales, which saw an annual revenue increase by 300 percent, whereas some of our non-customized businesses kept decreasing. Therefore, we shifted focus heavily toward mass customization. We decided to launch a cloud-based mass customization platform that supported clients to self-design their products in late 2016." (BX3)

Appendix 3
Data structure of platform strategy and BMA activity (Cont.)

Aggregate dimensions, second-order themes, and first-order categories	Examples of supporting quotations from the case companies
Platform strategy and BMA activity	
2. Deepening PLL	
A. Deepening BI logic	"We extended our platform reach upstream to the sourcing of raw materials and downstream to apparel design and manufacturing. We believed that our vertical presence along the industry value chain could bring us synergies and cost saving benefits." (RY6)
B. Deepening BR logic	"We summarized the whole transformation process, from identifying problems, discussing them with technology partners, to developing and implementing a platform as resolution. Building on such knowledge, we introduced technologically advanced production machines and thus developed an integrated cyber-physical system (ICPS) to formulate a smart spinning workshop." (HX4) "We introduced an industrial production upgrading project called 'Internet plus intelligent manufacturing and customization' in response to the national call of MiC2025 for more 'green manufacturing'. Under the project, we introduced an intelligent manufacturing platform." (RY5)
C. Deepening FR logic	"During the outbreak of COVID-19, we developed a series of medical products, such as protective masks and clothing. In a next step, we plan to develop more market-appealing products and explore new ways to better integrate online channels with back-end units to respond even more quickly to new market requirements." (HX6)

Appendix 4
Data structure of platform strategy and BMA activity (Cont.)

Aggregate dimensions, second-order themes, and first-order categories	Examples of supporting quotations from the case companies
Platform strategy and BMA activity	
3. Complementing PLL	
A. Complementing BI logic	"Following the 2007–2009 financial crisis, our physical stores suffered. To reduce costs and offer more competitive products in response to market requirements, we started to build a production platform that enabled data exchange among production procedures and the supply chain." (BX3)
B. Complementing FI logic	"This online approach turned out to significantly reduce costs for our company. So, we decided to help other manufacturers 'platformize' their procurement processes as well. We provided them our platform interface and guided them in adopting a platform approach, for instance, in releasing requirement information and managing procurement contracts." (HF2)
C. Complementing BR logic	"We adopted an intelligent manufacturing platform approach in 2016. Also, we introduced an advanced machine-to-machine manufacturing system and promoted product lifecycle management software over our supply chain. In particular, we invested greatly in the transformation of our workshop. For example, the suit manufacturing incorporates over 300 procedures, which we had to divide into three parts, separately implant digital threads and recombine them to the platform." (BX2) "Additionally, we established a database that incorporates billions of fabric, accessory and pattern data. We intended to share the database and its knowledge of tailoring with designers and manufacturers, which could further enhance our mass customization capability." (BX1)
D. Complementing FR logic	"We launched a '1 + 100' program to export ICPS platform services. Within the program, we set up a database center in the Cloud and several decentralized databases in user companies to enhance data security. The cloud databased stores basic information, which can be accessed by all platform users. Key manufacturing data, which accounts for 80 percent of all the data, is put in the decentralized databases." (HX3) "We firstly tried to self-build an online customization platform, and some of our OEM customers started putting orders in the platform. After that, we joined third-party platforms such as Secoo, the world's largest luxury e-commerce operator, to serve high-end customers. In the meantime, we noticed that most luxury brands purchase materials from China. We would like to take the opportunity to create a 'platformized' supply chain alliance through which we supported the participants with digital knowledge and technology to better integrate supply chain resources." (RY4) "We gained adequate knowledge regarding the complex digital transformation process. Many of our suppliers and even our competitors demanded for IoT-related manufacturing technology, asking us to share our digital transformation experience with them. So, we started sharing our technology and experience." (HF4)

Appendix 5
Data structure of servitization dynamics

Aggregate dimensions, second-order themes, and first-order categories	Examples of supporting quotations from the case companies
Servitization dynamics	
1. Back-end digitization	
A. Back-end analogue	"2007 was a tough year for textile manufacturers. We encountered severe challenges of demand decline and labor shortage. The traditional labor-intensive manufacturing was not the way to sustain competitiveness. […] The yarn production process incorporates carding, pre-combing, combing, drawing, roving, spinning, winding and double twist, which roving is the bottleneck. For example, in the high-speed roving process, due to the unevenness of the cotton material quality and the elastic force of the yarn during the roving process, it frequently causes yarn breaking. So, a traditional workshop would hire a large number of workers to check and mend the yarn breaking issues. This forced us to develop an essential platform to reduce such low-skilled, repetitive handwork." (HX5) "We operate in a labor-intensive industry. Also, raw material supply may affect our operations. We faced competition from a significant number of companies, including manufacturers offering similar products and services at lower prices than we do. It's the key to our business to manage labor and material costs and enhance productivity." (RY4) "The dyeing sector is considered one of the most time-consuming processes. In particular, the dyeing procedure incorporates a series of sequence-dependent operations and it takes one to 3 h to setup a dyeing machine for each consecutive order. In order to prevent chromatic aberration in the dyeing process, machine cleaning is required for dying different types of products. We saw a lot of potential opportunities in a digital platform useful in addressing the mentioned issues. For instance, compared with manual work, digitally enabled processes broke down information silos and improved the efficiency in coordinating multiple operations." (HF5)
B. Back-end digital	"The platform includes a series of entities, such as human, machines and materials, existing objectively in shop-floor. Data are integrated through the platform which allows collaborative production in the roving process and leads to leading to high efficiency, accuracy and transparency in a cost-saving manner." (HX2) "We operated the whole spinning process on a platform base, which increased our production capacity as well as the utilization rates of our production facilities." (RY2) "The digital platform gave us the flexibility of adjusting our operations, from raw material procurement through manufacturing to inventory." (RY4) "The digital platform allowed the data of each manufacturing process to be exchanged and shared online, which empowered manufacturing collaboration over the product life cycle. Additionally, the platform allowed us to manage raw material suppliers and purchase orders more efficiently. We are one the first dyeing manufacturers to apply platforms in China, which consolidated a sound basis for the development of digital supply chain." (HF4) "Through the platform, we integrated back-end data with front-store distributor information, such as sales, operating and inventory information, and coordinated the production resources to offer products that appeal to the taste of our customers." (BX1)

Appendix 6
Data structure of servitization dynamics (Cont.)

Aggregate dimensions, second-order themes, and first-order categories	Examples of supporting quotations from the case companies
Servitization dynamics	
1. Back-end digitization	
C. Back-end smart	"Industrial spinning depends on costly trial-and-error when introducing new products. However, a digital platform is promising to address this issue as a platform can create a digital twin of the physical resource units. Our ICPS platform allows the simulation of new product test, which enables us to save costs." (HX1) "Our ICPS platform allows flexible production and empowers us to adopt new operations. For instance, as the new mask facilities are brought to the physical workshop, our resource units could be quickly rescheduled and the collection of operation data could be adjusted and updated." (HX4) "Through the platform we can monitor and analyze the operation condition of the manufacturing lines in different regions such as Xinjiang, Ningxia and even Pakistan, operating in a production-optimized and energy-saving manner. We also placed a strong focus on investing in R&D. An innovation hub for cooperative R&D programs with a number of educational and industrial institutes worldwide was created. As a result of the efforts, we today have a diverse portfolio of intellectual property rights related to our intelligent manufacturing platform." (RY5) "The intelligent manufacturing platform allows us to serve existing customers better and target new customers. For instance, we quickly transformed our production capacity and rearranged the workshop to fulfill the urgent demands for protective masks and suits during the outbreak of the COVID-19 virus." (RY4) "Our HFCPS platform allowed technology suppliers, universities and research institutes to assist in operation monitoring and machine performance diagnostics. Also, the HFCPS platform allowed order-driven manufacturing. It ensured flexibility in production. In other words, our production system can quickly adapt to customized orders. For instance, our clothing workshop can make tooling suits, casual clothes and many other things. After the outbreak of the epidemic, our platform enabled us to immediately adapt to the order to produce masks and protective clothing and other products." (HF1) "The platform allowed for reconfiguration of individual production modules to meet customized needs without changing the coherence of the production architecture." (BX2) "Additionally, we established a database that incorporates billions of fabric, accessory and pattern data. We intended to share the database and our knowledge of tailoring with industrial partners, e.g., designers and manufacturers, which could further enhance our mass customization capability. […] During the outbreak of COVID-19, the platform empowered us to fulfill the mass customization order of protective products. Remarkably, the online business contribution of some brands of our company kept rising in the third quarter of 2020." (BX3)

Appendix 7
Data structure of servitization dynamics (Cont.)

Aggregate dimensions, second-order themes, and first-order categories	Examples of supporting quotations from the case companies
Servitization dynamics	
2. Front-end digitization	
A. Front-end offline	"We had utilized some management software to facilitate handwork in our operations since 2004. Still, we lacked a system to exchange data efficiently, which lead to information silos issues." (BX1) "The traditional customization model that relied on human labor, such as tailors and sales managers, limited our mass customization capacity." (BX2)
B. Front-end online	"We opened up our digital platform to industrial customers and expanded it to a B2B procurement platform offering e-procurement services. Through the platform, the demand-side requirements and the supply-side resources were digitally coordinated, which significantly enhanced the transaction efficiency. The number of registered platform users kept growing. We received several provincial best awards in Shandong province." (HF4) "The platform integrated our warehouse's inventory data and the end stores' operating and sales data, allowing store managers to look at specific information and use our services, such as transferring apparel across distinct regions. Our platform was helpful to coordinate our merchant partners and ensure consistency and efficiency." (BX3) "Our retail platform allowed for a set of service and option packages, such as, store operation training, product testing, call center services and trend analysis services. Also, the platform enabled franchising stores to develop their own, customized marketing strategy." (BX1)

Appendix 8
Data structure of servitization dynamics (Cont.)

Aggregate dimensions, second-order themes, and first-order categories	Examples of supporting quotations from the case companies
Servitization dynamics	
2. Front-end digitization	
C. Front-end connected	"To fulfill the government's order for protective masks, we quickly reconstructed our production resources. In the future, we intended to extend our reach to downstream retail customers and engage them in the development of market-appealing products." (HX4) "The platform follows a logic of sharing resources among customers, designers and manufacturers. For instance, an online distributor community was established as a link between global customers and local production facility resources. The platform has attracted several local manufacturers and provided over 20,000 work opportunities. We believe that the platform will empower the vertical integration of upstream raw materials manufacturers, midstream textile and apparel manufacturers and downstream branding merchants and retailer companies in our value chain, enabling collaborative manufacturing." (RY4) "We brought industrial customers to the HFCPS platform and offered them customized service packages. For companies with a low degree of digitization, we teach them how to use the platform's basic functions. For companies with a higher digitization degree, we offer different framework solutions to construction a platform-based decision support system." (HF1)

(*continued on next page*)

Appendix 8 (*continued*)

Aggregate dimensions, second-order themes, and first-order categories	Examples of supporting quotations from the case companies
	"Platforms that share a set of product design options, e.g., from raw material to accessories, and have self-design modules that engage customers in product design, were needed to ensure the efficiency of processing a large amount of customized orders." (BX2) "Additionally, for better understanding of customers' preferences, we applied digital solution packages, such as, the advanced personalization system to process customer orders and analyze their data." (BX1)

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