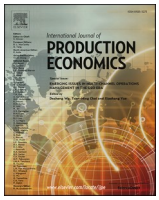
Int. J. Production Economics 258 (2023) 108808

Contents lists available at ScienceDirect

International Journal of Production Economics

journal homepage: www.elsevier.com/locate/ijpe



Supply chain antecedents of servitization: A study in ETO machinery companies

Antonio Masi *, Margherita Pero, Nizar Abdelkafi

Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Via R. Lambruschini, 4B 20156, Milano, Italy

ARTICLE INFO

Keywords:
Engineer-to-order
Customer order decoupling point
Servitization
Product-service systems

ABSTRACT

Nowadays, manufacturers are increasingly shifting towards Product Service Systems (PSS) by accommodating servitization. Whereas a fair body of research investigates the effect of servitization on the product supply chain, studies on the impact of the supply chain on the company's service offerings are scarce and reveal controversial results. In this paper, we aim to clarify the latter relationship by studying the impact of three supply chain features on servitization within three Engineer-To-Order (ETO) machinery Small- and Medium-sized Enterprises (SMEs). First, our results reveal that companies located downstream in the product supply chain exhibit higher servitization levels. Second, the level of customization, represented by the position of the Customer Order Decoupling Point (CODP) in the supply chain, and the company's servitization level seem to be unrelated. Whereas it is true that higher product customization, per se, enables companies to offer more services around the product, the operational challenges encountered because of higher customization levels can lead companies to deliberately reduce their menus of services to the customer. Third, higher levels of vertical integration support the provision of basic services because companies have more control on supplies required for services such as maintenance and repair. Companies with low levels of vertical integration cannot provide the speed and responsiveness required for basic services, but can still offer advances services, provided that they engage in strong collaboration with their suppliers. Thus, with this work, we highlight the extent to which product supply chains can support or inhibit the servitization endeavours of ETO companies.

1. Introduction

Today, global competition, higher risk of imitations, shrinking innovation lifecycles, and more demanding customers constitute significant threats for manufacturers. Because of this, the mere production and sale of goods may no longer be an adequate business logic (Kastalli et al., 2013). Many manufacturers have started transforming their value creation by shifting from selling physical products to Product-Service Systems (PSS). A PSS is as an integrated offering of products and services that delivers value in use to customers (Baines et al., 2009). The process by which companies shift to PSS is called servitization, which leads to a growing relative importance of services over products, thus resulting in a higher servitization level (Brax et al., 2021).

Product manufacturers that implement servitization are confronted with several managerial challenges, since services require adapted or even completely new organisational solutions, structures and processes (Alghisi and Saccani, 2015). Servitization requires the integration of capabilities from different organizations, going beyond the focal firm to include the network of customers and suppliers (Windahl and Lakemond, 2006). Hence, servitization can have implications for the supply chain. Conversely, especially for product-centric companies, services are often added on top of an already well-established product business (Sousa and da Silveira, 2019). Thus, the product supply chain features, which have been defined to run the product business, can have an impact on the company's servitization endeavours. From this, it follows that servitization capabilities and supply chain features are interrelated in both directions: supply chain features can effect servitization capabilities and vice versa.

As shown by a systematic review conducted for the purpose of this research (section 2), extant literature has provided a lot of attention to the implications of servitization for the supply chain, for example in terms of buyer-supplier relationships (e.g., Vendrell-Herrero et al., 2017) or supply chain design (Alkalha et al., 2022). However, the effects of product supply chain features on servitization is the least investigated relationship. More importantly, literature seems inconclusive regarding the effects of certain supply chain features. While there is agreement that

* Corresponding author.
E-mail addresses: antonio.masi@polimi.it (A. Masi), margherita.pero@polimi.it (M. Pero), nizar.abdelkafi@polimi.it (N. Abdelkafi).

https://doi.org/10.1016/j.ijpe.2023.108808
Received 30 April 2022; Received in revised form 3 February 2023; Accepted 12 February 2023
Available online 18 February 2023

collaboration and integration support servitization, the results on the effects of the company's position along the supply chain (e.g., Finne and Holmström, 2013) and those of vertical integration are controversial. Hence, our research objective is *to investigate the effects of product—or physical—supply chain features on servitization.*

To investigate this research question, we select Engineer-To-Order (ETO) environments as the context for the empirical analysis, since ETO companies are essentially product-centric, but increasingly accommodating servitization. In fact, ETO supply chains typically deliver complex, technologically innovative, capital intensive and long-lasting products, and these characteristics are considered as antecedents of service provision (Sousa and da Silveira, 2019). Due to high levels of product customization, the physical product supply chain is fundamental to ETO companies. For example, the machinery industry, which is the focus of our study, is a typical ETO sector that engineers, makes and delivers customized equipment to other businesses (Cannas et al., 2019). This industry has also exhibited, over the recent years, an increasing level of servitization, although this process is still far from being mature, especially in Small to Medium-sized Enterprises (SMEs) (Copani, 2014; Adrodegari et al., 2018). As such, servitization activities seem to build upon – and thus affected by – established physical supply chains.

Whereas ETO is an ideal environment to study the impact of the physical supply chain on servitization, ETO may lead to some confusion as engineering activities may be considered themselves as services. According to the "IHIP" framework, engineering activities exhibit the features of a service because they are intangible, heterogenous, inseparable, and perishable (Wikner et al., 2017). Hence, ETO firms are offering PSS by design. However, in this research, we do not adopt this view. Engineering activities determine the physical shape/design and functionality of the product. As such, they are an inherent part of the making of a physical product. In our understanding, therefore, the term "services" should be dedicated to intangible outputs, which are separable from the product, e.g., after sales service or product training (in line with Baines et al., 2009), as opposed to engineering activities, which are embedded in the product itself.

By relating the objective of our research, which is mentioned above, with ETO as context of investigation, we can formulate the following research question:

RQ How do the features of the supply chains of physical products in ETO companies affect servitization?

To answer this research question, we conduct case study research in the Italian machinery industry. From a practical perspective, our research can support ETO companies in estimating the suitability of their servitization levels, while uncovering opportunities for increasing or reducing servitization levels. Moreover, studies explicitly relating the ETO fulfilment strategy to servitization are still scarce (Cannas and Gosling, 2021; Masi et al., 2021a). Hence, by leveraging ETO-environments as a context, our research also contributes to the ETO literature.

The remainder of our paper is structured as follows. Section 2 presents the literature background for our research, whereas section 3 identifies the main supply chain variables that affect servitization, operationalizes these variables, and investigates the relationships between them, leading to a set of three propositions. Section 4 describes the research methodology, which is based on case study research. Section 5 presents the within-case and cross-case analysis. Section 6 discusses the results against the extant literature. Finally, the last section summarizes the main insights, addresses its limitations, and proposes directions for future research.

2. Literature background

There is a fair body of research dealing with the relationship between servitization and supply chain features, albeit not as rich as other research streams such as those about intra-organizational or environmental enablers of servitization (Shah et al., 2020).

In line with our research question, our objective is to investigate how extant literature has discussed the relationship between servitization and supply chain. Hence, we search and review journal articles in the Scopus database based on a systematic approach, in line with Tranfield et al. (2003). We choose Scopus because it is an extensive and multi-disciplinary database (Kamal et al., 2020), thus matching the features of servitization, a field of research with scientific contributions from different disciplines. We use as search query a combination of "servitization" (or "servitization") and "supply chain" in the title, abstract or keywords, to get results that fit our research objectives. We limit our search to peer-reviewed journal articles in order to ensure the quality of the references to be analysed (Kamal et al., 2020). We do not specify any publication period, as we aim to get most complete insights into our topic.

This search leads to 86 articles. After having read their titles, abstracts, introductions, and conclusions, we could remove all articles that do not deal with the impact of servitization on the supply chain or vice versa. In this way, 48 articles could be excluded. The reasons for excluding them from our sample are manifold. For example, some articles using "supply chain" as a synonym for "industry" in the abstract. Other articles focused on the implications of digital technologies for servitization, without discussing how this would affect supply chains. In addition, some articles are rather focused on pure services without discussing servitization. After excluding the articles that do not fit our research, we obtain a sample of 38 articles, which we have read entirely, and classified in two groups (Fig. 1). This classification is the result of a careful scrutinization of research objectives, questions and frameworks in all 38 articles. The first group (28 articles) contains research articles that address the impact of servitization on supply chain features. The second one (10 articles) deals with the impact of supply chain features on servitization.

From this, it follows that research addresses more frequently what impacts could servitization have on the supply chain and less frequently the impact of the supply chain on the company's servitization endeavours, although the latter relationship seems more relevant, as most companies develop their product supply chains before they switch to a servitized model.

In the following, we review the articles on the impact of supply chain features on servitization, Table 1 provides a summary of the relationships that arise from the literature.

A first feature that emerges from the literature as potentially affecting servitization is vertical integration. The level of vertical integration represents the extent to which a company performs product-related value adding activities by itself as compared to all activities that are required to make the product. Hence, a highly vertically integrated company is directly engaged in different aspects of production such as raw material processing, manufacturing, transportation, and retailing (Baines et al., 2011). For vertical integration, there is no agreement on the impact on servitization. Baines et al. (2011) found, by means of multiple case studies, that a higher level of vertical integration positively impact servitization. High vertical integration of subsystem design and production activities favours the delivery of advanced services because it allows companies to be faster and more responsive,

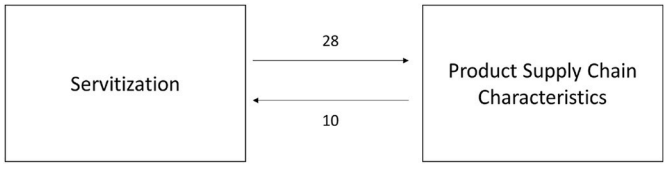


Fig. 1. Reviewed articles on the impact of servitization on product supply chain characteristics, and vice versa.

Table 1
Impact of supply chain characteristics on servitization level according to reviewed articles.

Features References	Vertical Integration (- Low/+ High)	Supply Chain Position (- Downstream/+ Upstream)	Supply chain Integration and Collaboration (- Low/+ High)	Supply Chain Configuration (- Centralized/+ Decentralized)
Baines et al. (2011)	+			
Baines et al. (2012)				+
Finne and Holmström (2013)		–	+	
Szász and Demeter (2015)	–	–		
Chakkol et al. (2018)			+	
Shah et al. (2020)			+	
Purvis et al. (2020)		+		+
Freije et al. (2021)			+	
Li et al. (2021)			+	
De La Calle et al. (2021)			+	

while minimizing costs. However, Szász and Demeter (2015)'s survey, which involves 445 machinery companies from 13 European countries, highlights that outsourcing is the prevailing trend. Lower vertical integration is conducive to servitization because it allows for a higher focus on a narrower set of supply chain activities, leading to higher specialization and better performance.

The second supply chain feature with impact on servitization is the firm's supply chain position. The position in the product supply chain denotes where the manufacturing firm is placed with respect to upstream suppliers and downstream customers. There is again no agreement in the literature on the impact of supply chain position on servitization. According to Finne and Holmström (2013), downstream firms are in a favourable situation for achieving higher servitization because they can build upon a stronger relationship with end-users, who provide the information necessary for the service. The authors show how a company that has been pushed upstream in the supply chain through intermediaries that integrated the supply chain could regain access to end-users by collaborating with these intermediaries to share the responsibilities on the services offered. For example, an upstream manufacturer can control the provision of advanced maintenance, while leaving basic maintenance to downstream companies, e.g., the intermediaries with lower product-related competencies. Similarly, Szász and Demeter (2015) conclude that servitization opportunities are higher, the more downstream in the supply chain the firm is positioned, though servitization is still possible for upstream companies. However, Purvis et al. (2020) discuss the case of a company that was able to provide more servitization because it could shift to a more upstream position in the supply chain. The case is about a Logistics Service Provider (LSP) that has started doing manufacturing activities by customizing product configurations to end users. Originally, the LSP only performed shipment activities of final products to end users. By embracing manufacturing activities its position shifted more upstream in the supply chain. Because it has access to end users data, the LSP is able to create new services such as forecasting solutions that can be offered to other stages in the supply chain.

Other supply chain features emerge from the literature review, but there is consensus among authors on their impact on servitization. First, literature agrees on supply chain integration and collaboration as necessary requirements for the achievement of higher servitization levels (Finne and Holmström, 2013; Chakkol et al., 2018). Shah et al. (2020) and Li et al. (2021) conclude that basic services require more supplier integration, while advanced services require more customer integration. Moreover, Freja and de la Calle et al. (2021) emphasize the need for intra- and extra-company integration to achieve higher servitization levels, while de la Calle et al. (2021) mention that for a successful digital servitization, supply chain integration is required. Specifically, internal integration is necessary for both basic and advanced services, whereas external integration is crucial for advanced services only (de la Calle et al., 2021). Second, literature agrees that a decentralized supply chain configuration can support servitization. Baines et al. (2011) and (2012) point to the positive impact of moving facilities closer to customer's operations on service availability and reliability, despite higher costs. In addition, Purvis et al. (2020) explain how distributed manufacturing can help LSPs offer new services and improve the existing ones.

3. Research framework

3.1. Identifying the framework variables

Based on our literature review, three supply chain characteristics need more clarification with respect to their impact on servitization: (i) level of vertical integration, (ii) supply chain position, and (ii) position of the Customer Order Decoupling Point (CODP). Vertical integration and supply chain position have been controversially discussed in the literature whereas CODP captures the level of customization within a supply chain. As such it is also an important design variable in supply chains (Wikner, 2014) with potential influence on the level of servitization (Sousa and da Silveira, 2019). Fig. 2 illustrates our research framework.

3.2. Operationalizing the framework variables

3.2.1. Servitization level

Over the past two decades, several PSS taxonomies have been proposed. This study builds upon Tukker's (2004) and Sousa and da Silveira's (2019) frameworks.

Tukker (2004) identifies eight subtypes of PSS classified as product-oriented, use-oriented, or result-oriented PSS. Product-oriented PSS are centred around the product and include product-related services (e.g., maintenance) as well as advice and consultancy. In use-oriented PSS, product ownership stays with the provider that lets the customer use it through leasing, renting, or pooling. In result-oriented PSS, the client and the provider agree on a result like in outsourcing, pay per service unit, and functional result PSS.

Sousa and da Silveira (2019) distinguish between basic (BAS) and advanced services (ADS). BAS aim to install and maintain basic product functionality. They broadly correspond to Tukker's product-oriented services and include product installation, provision of spare parts, maintenance, and repair. ADS, instead, are characterized by a co-creation of value that goes beyond basic product functionality. They broadly correspond to Tukker's use- and result-oriented PSS and include training, upgrades, consulting, and rental.

Based on these two categories, we define servitization level as the number of different BAS and ADS offered by a company to its customer for a certain product family. The framework allows us to code accurately the services observed in the case companies.

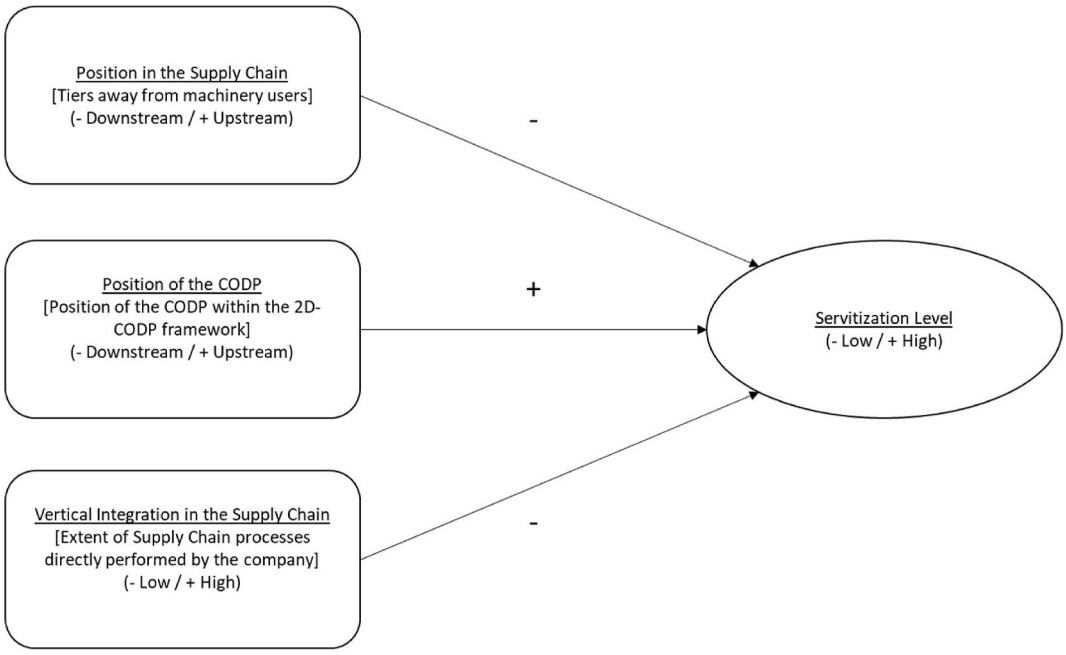


Fig. 2. Research framework.

3.2.2. Position in the product supply chain

The position in the product supply chain denotes where the manufacturing firm is placed with respect to upstream and downstream actors of the supply chain. We define it as the number of echelons that separate the machinery producer from the machinery user. For example, Tetra Pak is a company that designs and produces food processing and food packaging equipment, supported by a wide range of services (https://www.tetrapak.com/). It serves industries such as food and beverage or dairy, whose companies use Tetra Pak's machinery to serve final consumers. Hence, it is one tier distant from machinery users. Conversely, Alfa Laval (https://www.alfalaval.com/) designs and produces heat transfer, separation and fluid handling products and services. Alpha Laval's customers use its products as subsystems of larger equipment. Hence, it is two tiers distant from machinery users. We adopt this convention because ETO machinery companies operate in a B2B markets and, therefore, the relevant users for them are the machinery users, not the final consumers that use the products made with these machines.

3.2.3. Vertical integration in the product supply chain

The degree of vertical integration denotes the percentage of value that a manufacturing firm generates itself (internally) in relationship to the total value of the product. A decreasing level of vertical integration has been observed in manufacturing firms, which is essentially due to decreasing transaction costs (Williamson, 1981) because of information and communication technologies (Picot et al., 1996) as well as lower transportation costs, making it financially advantageous for companies to outsource components and systems to external suppliers.

3.2.4. Customer order decoupling point position

CODP is the point where a product is assigned to a specific customer order, thus separating the activities made to forecast and to order (Hoekstra and Romme, 1992). The CODP position is strictly related to product customization, since customization depends on where customer involvement in the supply chain occurs (Sousa and da Silveira, 2019). For measurement purposes, we rely on the 2D-CODP framework, which measures CODP along engineering and production processes (Wikner and Rudberg, 2005; Cannas et al., 2019). ETO companies themselves can exhibit different levels of customization and consequently different CODP positions. For example, one ETO company may leverage modularity by defining a mix of standardized and customizable modules, whereas another ETO company may build a fully customizable product with an integral architecture.

3.3. Relating the framework variables and propositions

3.3.1. Position in the product supply chain and servitization level

The user of a product made up of various components requires services related to product installation and/or maintenance. Given the diversity of parts that are used on ETO machinery and the complexity of the machinery itself, it appears that the more downstream a company is located in the supply chain, the more services it potentially offers to the customers. Conversely, the more upstream the company is, the more distant it is from the machinery users. Therefore, downstream companies that produce machinery for companies that directly serve final consumers, are expected to sustain a higher level of servitization than those located in the upstream supply chain:

Proposition 1. *The more upstream an ETO company's supply chain is located, the farther it will be from the machinery users, and the lower the servitization level will be.*

3.3.2. Position of the CODP and servitization level

To the best of our knowledge, the relationship between the position of the CODP and servitization has been scarcely studied in past literature. Sousa and da Silveira (2019), based on the results of their cross-sectorial survey, found that product customization strongly favours the provision of both basic (BAS) and advanced services (ADS). The authors posit that product customization may favour BAS because of the high technical interdependency between product-oriented services and customized products. In addition, customization can be conducive to ADS due to the high level of interaction that occurs between customers and producers when making customized products. Therefore, we posit:

Proposition 2. *The more upstream the CODP is located within the supply chain, the higher the product customization, and the higher the servitization level will be.*

3.3.3. Vertical integration in the product supply chain and servitization level

We expect that vertical integration at the product level influences the firm's willingness to accommodate value-adding services. In other words, an ETO company will rather transfer its supply chain practices at the product level to service. Thus, a firm with a high vertical integration would rather internalize service activities instead of outsourcing them to independent suppliers. Because these manufacturing firms will not accommodate new services unless they do them themselves, they would tend to exhibit a lower level of servitization. By contrast, firms that are used to rely on their suppliers' network to make physical products because of their low vertical integration, will exhibit network orchestration capabilities (e.g., Windahl and Lakemond, 2006) that will enable them to integrate new value-adding services much faster. Hence, the following proposition:

Proposition 3. *The higher the vertical integration at product level, i.e., the bigger the range of activities under direct control of an ETO company is, the lower the servitization level will be.*

4. Methodology

4.1. Case study design

To examine the relationships between the product supply chain feature and servitization, we apply a case study research approach, which is particularly suitable for dealing with why-research questions, when no control over behavioural elements is required, and when it is necessary to study a contemporary phenomenon such as servitization (Yin, 2018).

Our case study design is mainly explanatory because we want to understand why ETO companies exhibit different levels of servitization, by testing three propositions. However, it also has an exploratory purpose due to the open-ended nature of the problem under investigation. Hence, we expect to support or reject the formulated propositions based on the case study approach.

To achieve the explanatory and exploratory objectives and to increase the external validity of the findings (Yin, 2018), we conduct multiple case studies. However, to have a higher control of possible variations within the population, we limit our case study investigation to one sector only (Voss et al., 2016): the machinery industry, which has been the object of different studies dealing with ETO in the past decade (Cannas and Gosling, 2021). The unit of analysis is the supply chain related to a PSS delivered by an ETO machinery company.

4.2. Case selection

The case study selection was based on three criteria. The first selection criterion is that all case companies should be as homogenous as possible in terms of sector, size, and location. In effect, all companies should belong to the same sector, which is machinery industry; they should have similar size: SMEs; and they should all be operating in Italy. The second criterion is that all companies should offer PSS. The third one is that the case companies offer PSS based on an ETO fulfilment strategy. The case selection is based on literal replication (e.g., cases with similar level of servitization) and theoretical replication approach (cases using different practices, e.g., in terms of supply chain design and product customization) (Yin, 2018).

The case selection process was conducted in two steps. First, we identified a set of Italian machinery SMEs by using the AIDA database (Bureau Van Dijk, 2022), while limiting the results to the machinery sector (AIDA categories 284 and 289) and the number of employees to 250 people or less, according to the European definition of SME (2003/361/EC). Hence, in our sample, companies are all SMEs producing machinery and operating in Italy. This way, the first criterion is fulfilled. Then, we randomly sampled a smaller set of companies and analysed their websites to check whether they offer PSS (second criterion) and do ETO (third criterion). We searched the companies' websites for specific information on their services, and for quotes to verify whether the company was a provider of ETO solutions. Consequently, we short-listed 24 Italian ETO machinery SMEs, from which three companies accepted participation in this study.

4.3. Data gathering and analysis

To conduct the case studies, we relied on three main sources of information: (i) interviews with the companies' managers, (ii) information from their websites, (iii) and economic data from the AIDA database. Although interviews were our main source of data, the other data material was helpful for cross-checking and expanding the information collected. For instance, websites were crucial to identify the different types of services offered by the companies as well as the main products and their key characteristics, while the AIDA database provided us with some data regarding headcount, revenues, and profits, which were essential to highlight key differences among cases.

We conducted three rounds of about 1-h interviews with each company. Whereas the first round of interviews was conducted personally, the second and the third ones took place remotely, via Microsoft Teams, due to the COVID-19 pandemic restrictions.

Table 2 shows an excerpt of the case study protocol used to collect data. The first interview round took place in 2019 and was focused on the companies' products, their product supply chains, and the specifics of their ETO fulfilment strategies, especially product customization. The second round was carried out in 2021 and focused on the services as well as the related software solutions provided by each company. The third round was conducted in 2022. Its objective was to investigate in more depth the relationships between company's position in the supply chain, vertical integration, product customization, and servitization level. We interviewed key informants with positions in general management, innovation management, supply chain management, production management, and sales management.

To collect information, we use a semi-structured interview guide, which consists of open questions to provide interviewees the possibility to recount anecdotes that are relevant for the study, but that were not necessarily expected by the researchers during the preparation phase of the study. Each interview was recorded and then transcribed. All the interviews were conducted in Italian since it was the preferred language of the interviewees. Subsequently, all relevant excerpts are translated word-by-word to English.

5. Results

5.1. Company overview

Table 3 provides an overview of the companies in terms of context, size, and economic performance. Some data such as the companies' names are hidden for confidentiality reasons. Instead of displaying true profits, we provide an approximated number of the companies' turnover in 2019 followed by its net profit margin (computed as the ratio between profits and revenues in 2019).

Company A is a 50-year-old producer of dosing systems, headquartered in Italy with subsidiaries in Asia – where it has grown most during the last years – and in America, where it has recently started to expand. It is the largest company in our sample in terms turnover – about 18 million €, five per cent of which coming from services – but it is also the one with the lowest profitability level (7%). Company B is 80 years old and the oldest in our sample. It produces industrial mechanical power transmissions. About 10 years ago, the company was sold to a larger multinational group, for which it now operates as a subsidiary. Company C produces modular automatic assembly lines sold in the domestic and foreign markets and is the youngest (40 years old). Together with company A, it has the highest number of employees of the

Table 2
Case study protocol (data collected).

Source	Data Collected	Company A	Company B	Company C
Interview Round 1	General information: company's approximate turnover, headcount, and product portfolio. Description of the main product families offered and of their characteristics in terms of customization. Description of the product engineering process and positioning of the CODP within it. Description of the production process, and of its level of vertical integration.	General Director	Italian Area Sales Manager	Innovation Manager
Interview Round 2	Description of the service menu offered to the market and its impact on the company's turnover. Description of the different service customization levels offered: standard services, personalized services, modular offerings, and customer co-creation. Description of the software provided by the company to its customers, and its level of vertical integration.			
Interview Round 3	Description of the company's position in the whole supply chain of the products delivered. Reasons for the product vertical integration levels and its impact on servitization level. Reasons for the service vertical integration levels and its impact on servitization level. Reasons for the product customization level and its impact on servitization level.	Production Planning Manager	Italian Area Sales Manager + Supply Chain Manager	
AIDA	Company's industry (AIDA classification), website, number of employees. Selection of economic data (revenues, costs, profits) for year 2019.			
Company Websites	Mission, vision, and/or strategic objectives. Products offered and their main characteristics. Services offered and their main characteristics. Technologies employed in the products and/or the services.			

Table 3
Case companies overview.

Company	A	B	C
Age [years]	~50	~80	~40
Sector	Dosing systems dyes for fabrics, rubber and plastic, food and cosmetics	Mechanical power transmission, especially industrial gearmotors	Assembly lines to produce furniture, automotive, and electrical and mechanical hardware
Location	Headquartered in Italy, with subsidiaries in Asia and America	Headquartered in Sweden, with subsidiaries in Europe (including Italy), Asia, Australia, and America	Headquartered in Italy, with subsidiaries in Europe and America
Target markets	All around the world, with a recent growth in China	All around the world	1/3 Italy, 1/3 Europe, 1/3 rest of the world
Employees (2019)	~120	~120	~70
Revenues (2019)	~18 million €	16 million €	~13 million €
Net profit margin (2019)	~7%	~10%	~11%
Share of revenues from services	~5%	~1%	~10%

sample (about 120), but with a lower turnover, to which services have a small direct contribution. Among the companies in our sample, it has the highest profitability level (11%) and exhibits the highest share of revenues generated through services (around 10%).

5.2. Within-case analysis

5.2.1. Analysis of the positions in the product supply chains

Fig. 3 shows company A's supply chain. Suppliers deliver raw materials (mostly steel and aluminium), simple components (e.g., valves, actuators), and hardware (e.g., tubes, consumables). In addition, A buys measurement tools (e.g., scales) and electric engines (e.g., 3-phase motors). A serves five main groups of customers: (i) fashion companies, (ii) textile companies, which are usually fashion companies' suppliers, (iii) food companies, (iv) rubber companies, and (v) cosmetic companies. Their customers use A's machinery to serve final consumers. Hence, A is one tier distant from machinery users.

Fig. 4 shows company B's supply chain. B purchases raw materials (mostly steel) or simple subcomponents (e.g., standard gears), which are used to make B's industrial gearmotors. If required by its clients, B also buys sensors. B's clients are machinery producers (60%) or distributors of machinery sub-components (40%). Hence, B's products become part of larger machinery. Consequently, B can be considered as two to three tiers away from machinery users.

Fig. 5 shows company C's supply chain. C mostly purchases finished products with high degrees of complexity like robots. It also buys software such as its remote monitoring system. C assembles the outsourced elements and sells its systems in different markets such as furniture, vehicles, electro-mechanical hardware, or jewellery. These companies use C's assembly lines to serve final consumers. Hence, C is one to two tiers away from machinery users.

5.2.2. Analysis of vertical integration levels

A's level of vertical integration is located between 40 and 50%. A outsources the production of simple components and hardware, as well as minor modifications to its machines, such as surface treatments and installation of electrical panels. Some components may also be produced internally. In fact, A's interviewee mentions: "in the case of the valves used to distribute liquids in our machines, we produce them internally, and we produce internally also the actuators that control those valves. This allows us, when there is a problem of anything else on which we may want to intervene, to be faster". So, vertical integration of production activities seems to allow company A to be more reactive when it comes to delivering a service. In addition to this, high vertical integration might benefit company A's product quality, as the company can make a lot of tests, while relying on customers as collaborators.

Company B carries out several activities internally: product engineering; fabrication of sub-components such as customized gearboxes

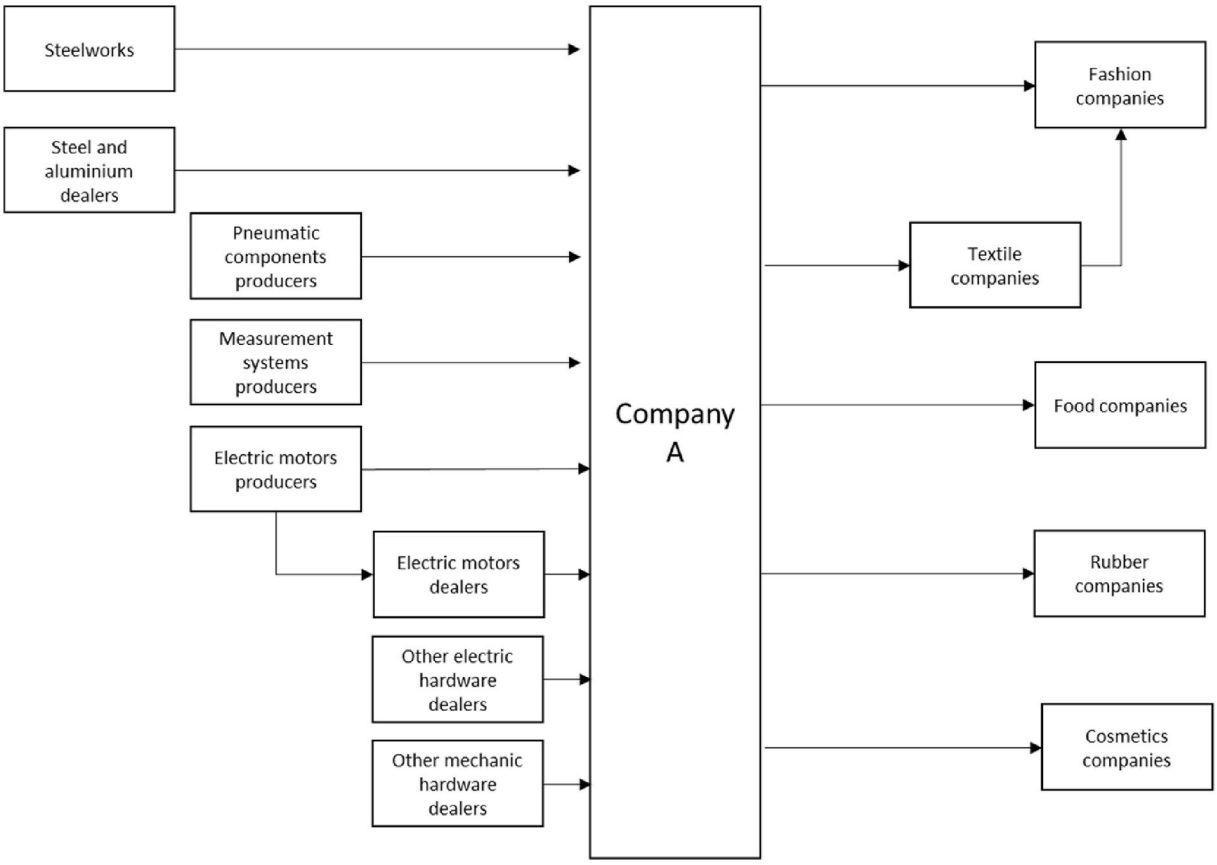


Fig. 3. Company A's supply chain.

produced by its internal foundry, or customized gears produced by its mechanical workshops; and assembly performed by B's subsidiaries. For some of these activities such as the fabrication of standard gearboxes, they may rely on external providers as alternative channels. The service part is mostly outsourced to some B's partners, who deliver, for example, the spare parts (repair kits) when customers ask for them. According to B's interviewees, the vertical integration level is of about 80%.

Company C outsources the production of the modules, while keeping internal the assembly process. C's level of vertical integration is about 30%, and the reason for this is made clear by C's innovation manager: "we need to focus on our core business. Our core business is not producing the pieces to be put in the machines. If you want, our core business is not even assembling the machines, although we are obviously still doing it internally. Our core business is engineering machines, and then installing them and providing assistance."

5.2.3. Analysis of CODP position

Fig. 6 shows the positions of the CODPs according to the framework by Cannas et al. (2019). Each CODP has been justified with quotes from the interviews. For example, company C designs assembly lines customized to their clients' needs and budget. Consequently, the CODP of C's engineering process is at the "design" phase. Regarding production, C lets its-subcontractors produce the mechanical, electrical, and robotic parts of their assembly lines, and later performs minor modifications on them, if required. Therefore, the CODP of C's production process can be placed at the "finalize" phase. In A and C, we study one product family for each. Hence, we have one PSS and consequently one unit of analysis. For B, we have two units of analysis, corresponding to two product families and therefore two supply chains: standard (B_{ST}) and special products (B_{SP}). Note that A, C, and B (special products) exhibit similar levels of product customization, whereas standard product family of B has a much lower customization degree.

5.2.4. Analysis of servitization levels

To estimate the servitization level of the case studies, we use the classification that distinguishes Basic Services (BAS) and Advanced Services (ADS) (Sousa and da Silveira, 2019). The servitization level is assessed by looking at the services that A, B and C's clients receive. Hence, it regards the next tier in the supply chain. Table 4 provides a summary of this analysis.

Company A's services consist of maintenance, installation, spare parts, software upgrades, and helpdesk. These services are bundled within a technical assistance contract. This contract is free during the first year of warranty, and then becomes subject to a short-term or long-term subscription fee, depending on the client. Most of A's services are enabled by a software package that collects and analyses machinery data, used by A's technicians, or shared with clients. This software package is upgraded for free if the relationship with the client has a long enough duration.

B's main services are spare parts provision and maintenance. It provides repair kits mainly for the largest gearmotors, for which reparation is cheaper than substitution. Repair kits are usually provided by B's distributors, with whom B has developed trust relationship. Moreover, for what concerns special products, B also offers a simple maintenance service. This can be either performed by one of B's European subsidiaries or, if the customer is in Italy, by one of B's trusted partners.

Currently, C provides the widest range of services: maintenance, installation, spare parts, upgrades, help-desk, and training. In addition to the on-demand provision of spare parts, C also provides its clients with a list of the components that are most subject to wear-and-tear together with their technical drawings, so that they can either produce them themselves, or purchase them from company C. In the future, company C is even thinking of starting the production of spare parts by using 3D printers. Moreover, C also offers its clients the possibility to revamp or upgrade already existing assembly equipment in their plants,

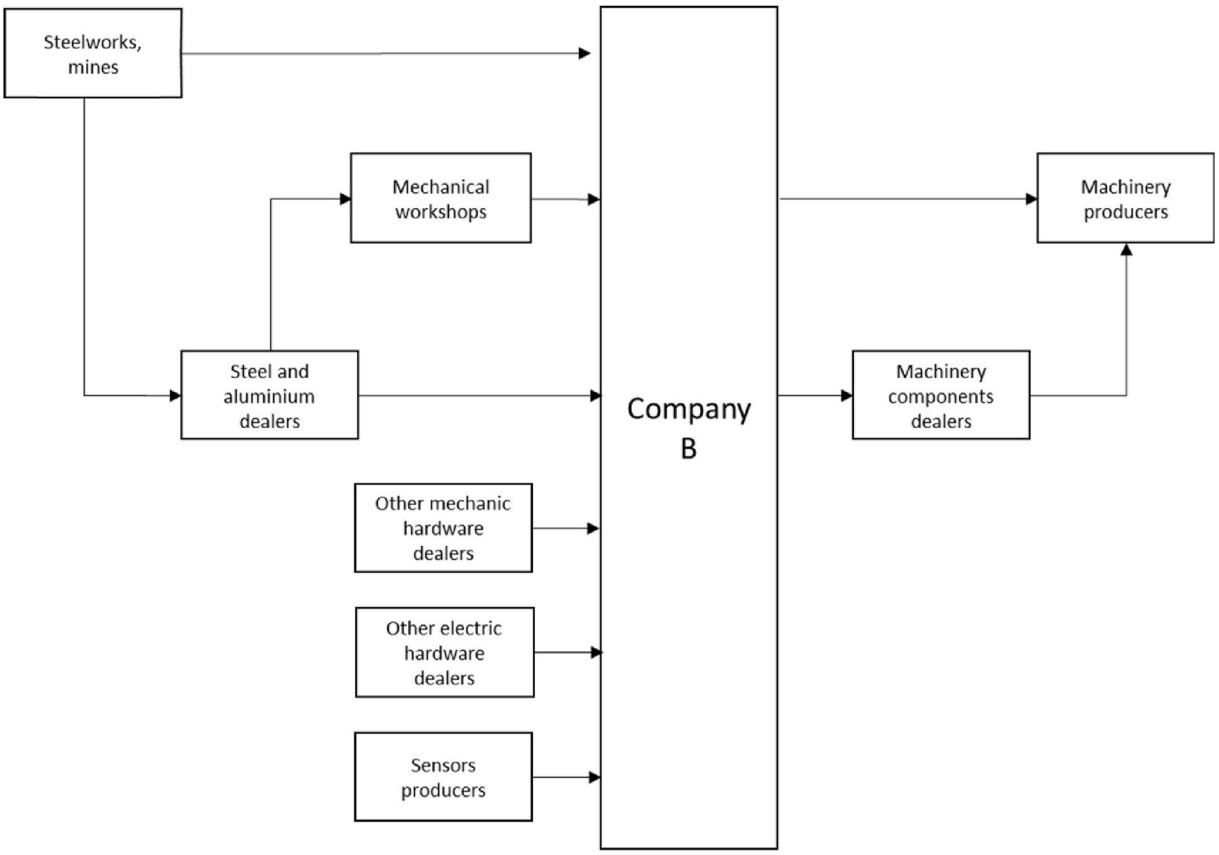


Fig. 4. Company B's supply chain.

which is possible thanks to their high modularity.

Interestingly, C is also the company which made more steps towards "digital servitization". For example, it is investing in Augmented Reality (AR). First, AR can be used to provide supervised assistance. By equipping the client's operators with AR glasses and tablets, they can receive support from the company's technical staff. Second, AR enables unsupervised assistance. For instance, the client's operators can scan the QR codes placed on the different parts of the assembly lines to visualize video-tutorials that can support them, e.g., in substituting certain components. Similarly, AR allows company C to train the client's operators remotely, either through live courses or through video tutorials.

5.3. Cross-case analysis

Table 5 summarizes the results of the case studies and highlights the differences and similarities related to the supply chain positions, their product customization levels, vertical integration levels, and servitization levels.

According to the case studies, the more downstream in the supply chain a company is, the higher its servitization level. A and C exhibit higher servitization levels than B and are closer to machinery users. For B, servitization brings risks related to "*operating in a field which is not ours*". In addition, "*everything needs to be integrated with an end-user, which, in 99% of the cases, has already activated an assistance service*", a service that is provided by a third-party. When companies are located upstream in the supply chain, their production output (e.g., components, subassemblies, or modules) is part of a larger product system that is made by a subsequent supply chain stage (e.g., manufacturer). At such stage, manufacturers usually have the capabilities to internally develop and offer most of the services required by their own customers. Therefore, upstream companies have fewer opportunities to servitize their offers. B explains, "*we may give to the customers the components and the idea of what the service would be … but then, customers develop the service autonomously*". Hence, the position in the supply chain impacts the resources and competencies to be developed by the company. In the case of A, when asked if they were considering a downstream shift, they respond, "*it would be a totally different type of company and of personnel. It would not be this company*". It should be noted, however, that in spite of their upstream positions, companies can still extend their service offerings, for example by making products that support servitization. For example, B equips its gearmotors with all the sensors necessary if the customer, later, wants to collect data to offer a predictive maintenance service to end users. Sometimes, this can even open opportunities for innovation as explained by B: *"when customers have this need [for new sensors], in 90% of the cases we propose a range of possibilities. Then, customers, who maybe had not foreseen a certain option, think about it, consult their engineering office, and tell us if they need certain sensors with specific features"*.

While product customization levels in A, B_{SP} and C are mostly the same, these cases present different servitization levels. This unexpected pattern is the result of two superposing effects pulling in opposite directions. First, a higher product customization can make servitization more strategically promising, as customers may ask for more services related to the customized product. Customers find it more convenient to approach the manufacturer that made the customized product for get the required services. As such, the product manufacturer is the preferred service supplier. Company B notes: "the more a product is customized, the more we have a monopoly on the service we offer" and "the monopoly is based, above all, on the trust you earned by delivering a product that works well and that has been functioning for several years". However, the second effect that can act in an opposite direction—thus against servitization—is that implementation of a higher servitization level for customized products can be challenging from an operations perspective. B mentions that "the more a product is standardized, the

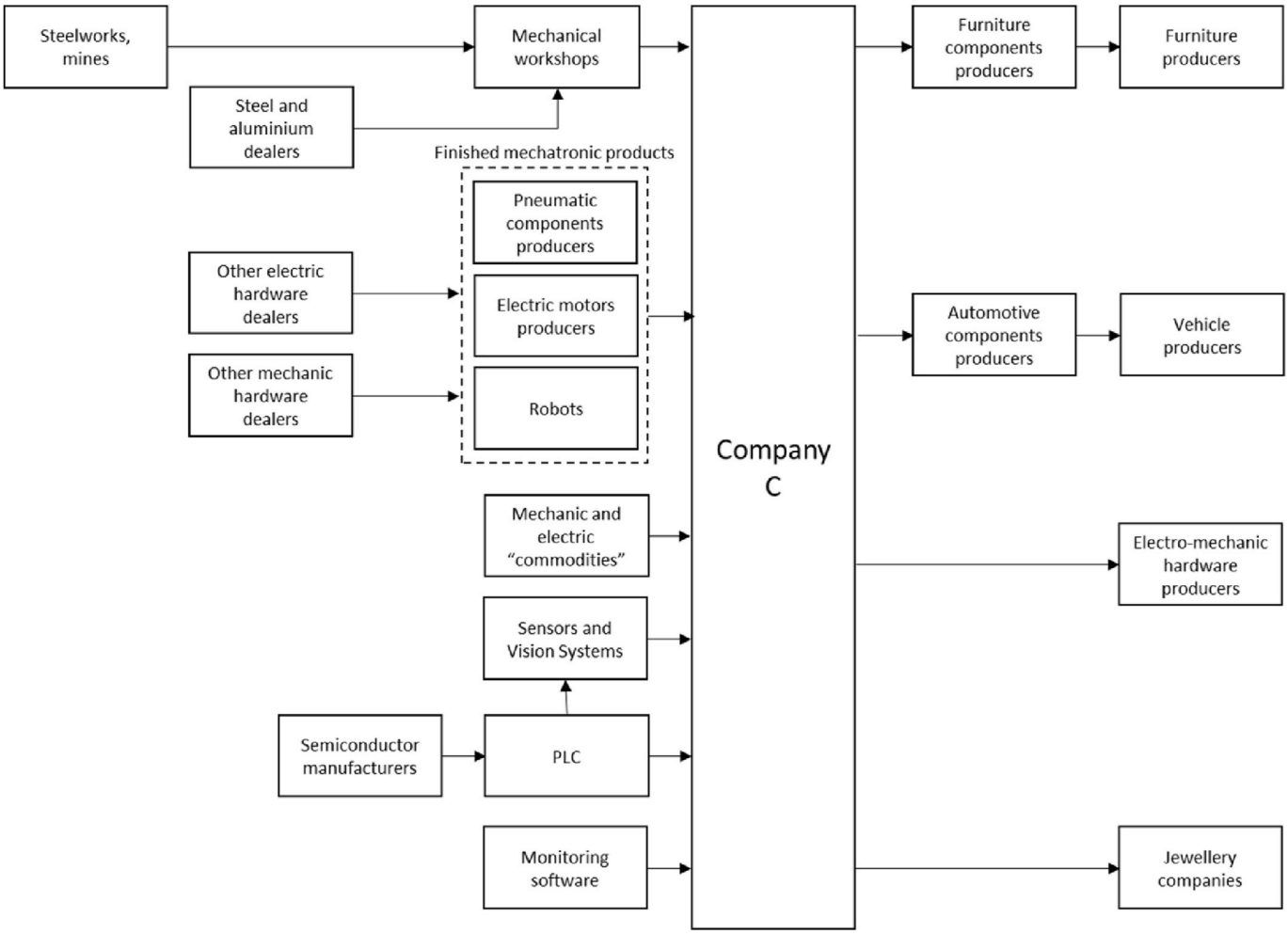


Fig. 5. Company C's supply chain.

fewer issues we have in terms of delivery speed because the more you make a product customized, the less you will be able to rely on the market, if you need spare parts", and"a client of us (…) must pay a very high insurance fee incase of missed production. So, today they are forced to have some spare parts in stock. Of course, the spare parts of a very large, powerful, and special gearmotor are very expensive". Hence, higher product customization can lead to higher servitization level, provided that the company's operations can cope well with these challenges. A possible strategy to deal with such challenges is modularity as explained by company C, which can afford to provide a "revamping" service for old products, "only if the plants are modular (…) and somehow standardized, that is, if there are standard interfaces so that you can use a plug-and-play logic. You can remove a module, and put a newer one".

Regarding vertical integration, it can be observed that C with the lowest vertical integration (30%) has the highest servitization level whereas A has medium levels of vertical integration (50%) and servitization. B, which has a vertical integration level equal to about 80%, exhibits the lowest level of servitization. This result lets us assume that vertical integration and servitization move in opposite directions. However, a more in-depth consideration of our case studies reveals additional insights.

First, we observe that in-sourcing product-related activities supports the provision of basic, product-oriented services. Insourcing allows companies to have higher control on service activities directly related to the product such as repair and spare part supply, while enabling them to increase delivery speed and reducing costs when servicing their customers. Because of this, companies prefer maintaining the manufacturing of the components required for service delivery in-house, thus increasing their vertical integration level. Company A states: *"our valves are made internally, and we make internally also the actuator that commands these valves. This allows us, when there is a problem, to be fast. (…) It has not been always like this, but then we understood that (…), since the time to deliver these things and the costs are not negligible, we should stay on that direction"*.

Second, the high level of servitization of C is due to the delivery of ADS such as training or revamping. For example, C is currently updating the training service to its customers through the usage of virtual reality. As opposed to basic services, more control on upstream component manufacturing will have less to no impact on the development and delivery of a virtual reality-based service. Hence, ETO firms are not affected by the low level of vertical integration of their supply chain and can provide advanced services, e.g., by involving downstream service suppliers. To do so, A and C, which have lower levels of vertical integration, maintain strong collaboration with strategic service suppliers is necessary. Company C mentions that "*the workshop, which basically works for us, since (…) we account for about 90% of their turnover, was about to get bankrupt, back in the '80s. We bet on this workshop and we made it grow*". However, the development of these collaborations may not be easy, as mentioned by A: *"at a certain moment, to devote ourselves to different things, we tried for certain components to re-engage some external suppliers, but then we did not agree when we talked about certain numbers, and we needed to have more partnership"*.

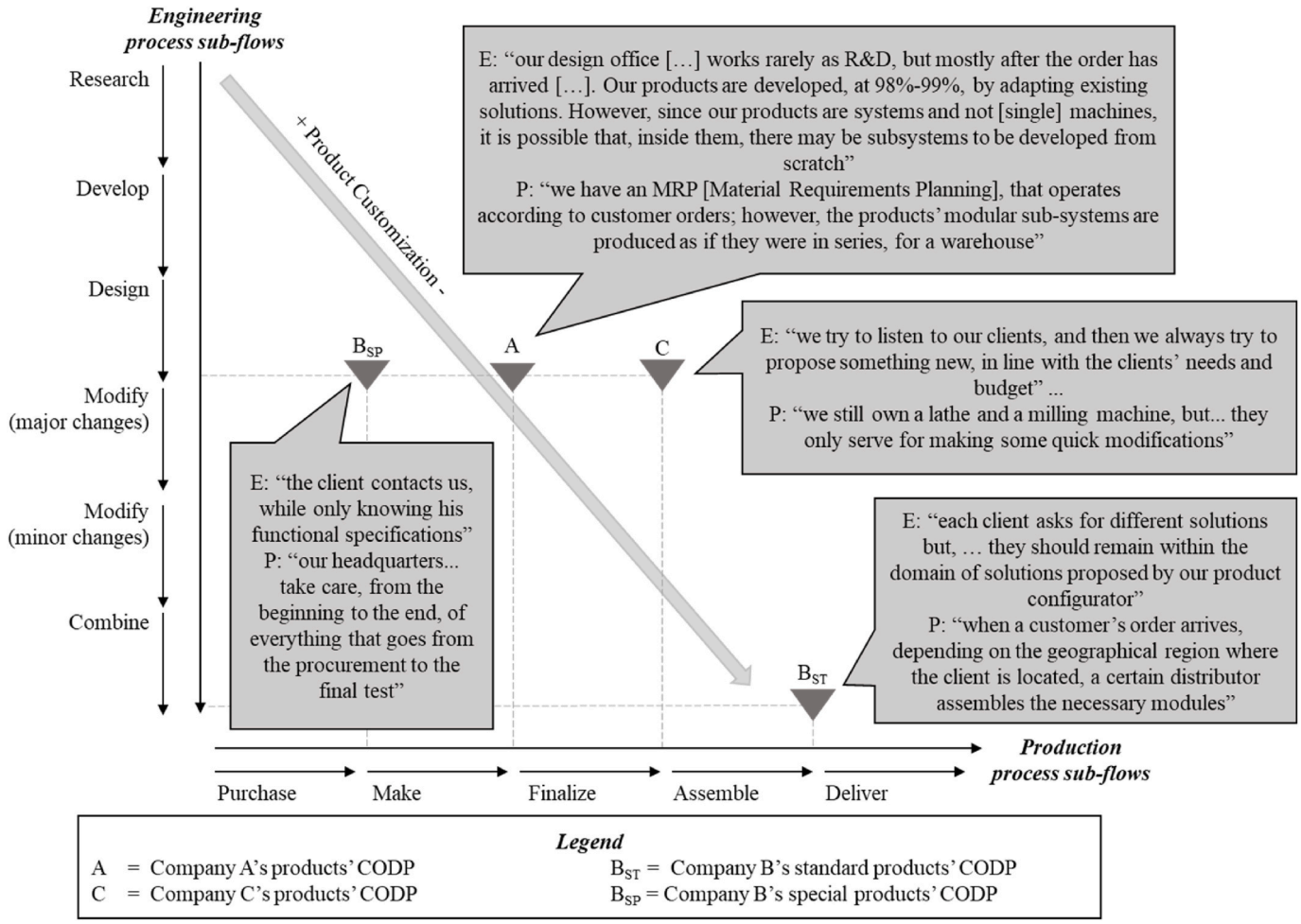


Fig. 6. Positions of the 2D-CODPs for the case studies.

Table 4
Analysis of servitization levels.

		A	B_{ST}	B_{SP}	C
Basic services (BAS)	Maintenance	Both predictive and reactive, performed both by A's technicians or by the clients' ones, supervised by A remotely		Reactive, performed by B's technicians or by its partners	Reactive, performed both by C's technicians or by the clients' ones, supervised by C remotely
	Installation	Performed by A's technicians			Performed by C's technicians or by the clients' ones, supported by C remotely
	Spare parts	On-demand provision of spare parts and consumables	On-demand provision of repair kits	On-demand provision of repair kits	On-demand provision of spare parts, and suggestion of the components most prone to wear and tear. Future implementation of 3D printing
Advanced services (ADS)	Rental/lease				
	Upgrades	Software upgrades			Product upgrades and revamping, by substituting assembly equipment with newer modules
	Help-desk	Analysis of data from machinery to support maintenance activities			Analysis of data from machinery to support maintenance activities
	Training				Remote training during all the machinery lifecycle thanks to digital technologies
	Consultancy				

6. Discussion

In the following, we discuss the findings from the case studies in relationship with the formulated propositions, while highlighting the extent to which the obtained results are in line with extant literature.

Proposition 1. – *Relationship between supply chain position and servitization*

The case studies confirm proposition 1 that the more downstream companies are located in the supply chain, the higher their servitization level.

These findings match the survey results in Szász and Demeter (2015), who found a higher prevalence of customer-oriented services in firms with downstream positions in the supply chain. Interestingly, Szász and Demeter (2015) emphasize the fact that upstream companies with no or

Table 5
Summary of the assessment of the variables for the case studies.

	Case A	Case B_{ST}	Case B_{SP}	Case C
Position in the Supply Chain	1-3 tiers far from end-users	3+ tiers far from end-users		1-3 tiers far from end-users
Vertical Integration in the Supply Chain	40–50%	80%		30%
Product Customization (2D-CODP)	E: Modify P: Finalize	E: Combine P: Assemble	E: Modify P: Finalize	E: Modify P: Assemble
	Standard-customized Machines	Modular Machines	Standard-customized Machines	Standard-customized Machines
Servitization Level	BAS(3) + ADS(2)	BAS (1)	BAS (2)	BAS (3) + ADS (3)

low service levels are not necessarily unprofitable. In our sample, case B maintains a good level of profitability (10%) despite a low servitization level. As such, servitization may not make sense in all circumstances, and companies must examine whether servitization is a valuable option to them or not.

However, our finding is not in line with Finne and Holmström (2013). The authors discuss the case of a company whose product has become less and less appealing to the market because of the increasing technological maturity of competitors. To differentiate itself from competition, the company, with an upstream position in the supply chain, leveraged its product competences to offer services to downstream companies. In contrast, company B, with the most upstream supply chain location, did not develop its own services, but adapted its high-quality products in a way that other actors in the supply chain can servitize later on. This approach exhibits a better fit to B's product-related resources and competences. The differences between our results and those by Finne and Holmström (2013) could be explained by our choice for the ETO context, which is strongly product-oriented.

Purvis et al. (2020) also discuss the case of a logistics service provider that could increase its servitization level by integrating activities upstream in the supply chain. However, their case is different from those in our sample, as a logistic service provider is, per se, a service company, not a product company that shifts to servitization.

A final remark should be made concerning the concept of "shifting downstream" in the supply chain. According to previous literature, the downstream shift is appropriate when three conditions are satisfied (Wise and Baumgartner, 1999): (i) the installed base of products or equipment is larger than the number units sold per year; (ii) the customers' usage costs over the product lifecycle are higher than the initial purchasing price; and (iii) the downstream activities are more profitable than product margins. Interestingly, the first two conditions are satisfied by most ETO companies (Adrodegari et al., 2013), so that the third condition should be evaluated case by case. It should be noted, however, that it may not be always possible for companies to move downstream and establish direct links to the final users. For example, Finne and Holmström (2013) point to system integrators and intermediaries that place themselves between manufacturers and end users, leading to manufacturers losing their direct links to final customers and moving involuntarily upstream the supply chain. Because of this, their abilities to provide servitized offerings can decrease considerably. Thus, although the position in the supply chain seems, at first glance, a variable that depends on endogenous factors under the control of the company's management, it can also be affected by exogenous factors outside its direct control.

Proposition 2. : *relationship between the position of the CODP and servitization*

Sousa and da Silveira (2019) posit that product customization may favour basic services because of the high technical interdependency between such services and customized products, and that it may favour advanced services due to the high interaction that occurs between customer and supplier when delivering customized products. Our cases confirm that the technical interdependency between product customization and servitization can create a customer lock-in because customers would only trust the manufacturer of the customized product to provide the related services. Differently from Sousa and da Silveira (2019), however, we cannot conclude that a higher product customization level leads necessarily to higher servitization. As companies increase their customization levels, the provision of services to customers may become challenging from an operational perspective, leading companies to decide deliberately to not increase their servitization level.

Sousa and da Silveira (2019) proposed the existence of a moderating variable that could impact the relationship between product customization and servitization, but their survey results did not confirm this. Based on the insights from our case studies, a possible moderating variable could be operational efficiency. In effect, higher customization can even make the provision of additional services difficult to realize. Our focus on ETO context could be the reason why we detected this variable, as ETO companies offer a high level of product customization, making the moderating effect particularly strong. In this sense, our results are more in line with those by Kohtamäki et al. (2020), who highlight the need for achieving both "effectiveness in the customization of solutions" and "efficiency in product manufacturing" as the main "paradox" of servitization. As suggested by Kohtamäki et al. (2020), product modularity could be a viable strategy that can support companies in increasing customization and servitization at the same time, similarly to what we observed in company C. Whereas modularity can restrict the level of variety offered by ETO companies, a study conducted by Masi et al. (2021b) provides evidence that ETO companies are increasingly leveraging modular product architectures to mitigate operational challenges.

Proposition 3. : *relationship between vertical integration and servitization*

Concerning the level of vertical integration, we assumed that high vertical integration at the product level leads to lower servitization because companies, per se, would lack the orchestration capabilities that would enable them to accommodate third-party services fast. Our case studies support this proposition, as the results show that vertical integration and servitization are moving in opposite directions. In particular, we notice that companies focusing on advanced services do need less level of control on the product supply chain than those offering basic services. Companies with a lower vertical integration at product level seem to better manage the trade-off between effectiveness in customization and efficiency in service delivery (Kohtamäki et al., 2020) by concentrating a large part of their activities on service delivery, while outsourcing a larger portion of their product-related activities to external suppliers.

These results do not match exactly with Baines et al. (2011), who suggest that a company needs to in-source production-related activities to gain the speed and responsiveness that are necessary for the delivery of advanced services. Our case studies acknowledge the speed and responsiveness benefits of vertically integrated companies. However, this positive impact is apparent only for those services that are directly related to the product (basic services). For advanced services, less vertically integrated supply chains, like C, are able to achieve speed and responsiveness, through integration and collaboration with suppliers that deliver the services. This in also line with the findings of de la Calle et al. (2021), who show that external integration is crucial for advanced services provision. Whereas A collaborates with customers to develop a virtual prototyping service, C collaborates with an ecosystem of new ventures to develop virtual reality-based services. Since A and C strongly differ in terms of vertical integration of product-related activities but are both digitalizing their offer (although C to a higher extent), it is unclear

whether there is an impact of vertical integration on digitalization, as well. In particular, it would be interesting to identify the level of vertical integration after which companies, ceteris paribus, would experience difficulties in accommodating technologies that are conducive to servitization. Addressing this aspect could be interesting because, while companies may base decisions regarding what to insource and outsource on different grounds such as transaction costs, it may also be beneficial that they additionally consider their future servitization objectives.

7. Conclusions

This paper investigates the impact of the product supply chain features on servitization by focusing on ETO machinery companies. ETO companies represent an ideal context for our investigation because they are highly product-centric (Adrodegari et al., 2013, 2018) and their services are added on top of an established product business (Sousa and da Silveira, 2019). Hence, the features of the supply chain of machinery equipment may act as constraints or facilitators for servitization.

After reviewing the literature, we identify three supply chain features, whose impact on a company's servitization level needs further clarification. Accordingly, we elaborate three propositions, which we test with a multiple case study research. First, we find that the closer to the machinery users an ETO company is, the higher its servitization level. This is mirrored in the more service-related capabilities that downstream firms develop as compared to the more upstream companies in our sample. However, we notice how upstream ETO firms can still maintain a good profitability by remaining product-centric, and by acting as suppliers of products "suitable for servitization", e.g., by endowing products with sensors that collect relevant data. Moreover, we observe that the CODP position and servitization level seem to be unrelated in ETO companies. This is because, although high product customization favours servitization from a strategic standpoint, as it leads to a higher demand for services, operations can become challenging due to the paradoxical nature of providing a customized product-service system efficiently and effectively at the same time. Furthermore, we find that the lower the vertical integration level of an ETO machinery company, the higher its servitization level. This is because companies that outsource product-related activities can better focus on the provision of advanced services, while also achieving good speed and responsiveness in the provision of basic services if they are well integrated with their suppliers.

Consequently, from a theoretical standpoint, our paper contributes to the literature on the operational implications associated with servitization. More precisely, as shown by our literature review, studies on the impact of supply chain features on servitization levels are fewer than those on the opposite relationship, and provide partially contrasting results, which we tried to clarify with this work. Moreover, by focusing on ETO contexts, we make a first step towards the call by Cannas and Gosling (2021), who ask for the identification of appropriate supply chain configurations that support servitization trends in ETO contexts. Realizing that the 2D-CODP can be used as an indicator to differentiate between different supply chain configurations, our research suggests that there may be more than one supply chain configuration that can support a given servitization level (same 2D-CODP but different servitization levels). We suggest operational efficiency as possible moderating factor of this relationship. The role of this variable could be further investigated in the future.

From a practical standpoint, this research provides suggestions to product-centric companies that aim to embark on a servitization journey, as our results can provide them orientation toward achieving the most suitable servitization level, based on their current physical product supply chain features. In fact, this research highlights which, and how decisions taken in the realm of product supply chain may be conducive to or constrain servitization. In particular, the success of a servitization strategy appears to be favoured in companies that can offer high product customization while maintaining high operational efficiency. Moreover, it suggests that companies positioned closer to the final market can reach higher servitization, while companies upstream in the supply chain can play a fundamental role to enable such servitization. Finally, the choice of vertical integration in product-related activities can become a constraint for offering ADS.

Our research is not without limitations. Although we interviewed different roles across the case companies, not all of them agreed to let us interview different roles within the same organization. We acknowledge that this may reduce the robustness of our results. However, we sought to leverage data source triangulation as much as possible by relying on data coming from online sources. Furthermore, we are aware of the fact that a larger set of case studies might have led to richer and more robust results. It is important to note, however, that our aim was not to look for statistical evidence in favour or against our propositions, but we were rather trying to support or reject propositions derived from literature.

Our paper also opens up several directions for future research. Our discussion of the position in the supply chain and of the vertical integration level shows the necessity of precising whether an assessment is made in the "product supply chain" or the "service supply chain" (Johnson and Mena, 2008; Finne and Holmström, 2013). A more complex framework may make this distinction possible and make us understand whether and how these concepts are intertwined. Moreover, in the framework, we included the CODP, although it could have been interesting to use "decoupling zones" instead of "decoupling points" because this would allow one to consider whether production flows are determined instantly or after some time, e.g., because of negotiations, or information uncertainty (Wikner, 2014). Moreover, since we provide a "snapshot" of ETO machinery companies (Supply chain features and servitization levels are fixed), it could also be interesting to complement this perspective with a "processual" one (Dmitrijeva et al., 2022), which could better clarify the transition towards servitization. Hence, we outline the following future research question: *how can traditionally product-centric companies become service-centric?* Moreover, from our discussion on the product customization level, it emerges how "paradoxical" it is to maintain a high level of customization, while increasing the servitization level (Kohtamäki et al., 2020). Hence, the other question: *how can product manufacturers achieve the transition to service centricity, without compromising their product excellence, especially in terms of customization?* In addition, from our analysis, it becomes obvious that it is still unclear what is the optimal level of vertical integration, when companies offer digital services. This leads to our final direction for future research: *starting from which level of product vertical integration would companies,* ceteris paribus*, experience difficulties in accommodating technologies that are conducive to servitization?*

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

References

Adrodegari, F., Alghisi, A., Bacchetti, A., 2013. Analysis of servitisation in engineering-to-order manufacturing companies: an empirical research. In: Proceedings of the Summer School Francesco Turco.

Adrodegari, F., Bacchetti, A., Saccani, N., Arnaiz, A., Meiren, T., 2018. The transition towards service-oriented business models: a European survey on capital goods manufacturers. Int. J. Eng. Bus. Manag. 10, 1–10.

Alghisi, A., Saccani, N., 2015. Internal and external alignment in the servitization journey–overcoming the challenges. Prod. Plann. Control 26 (14–15), 1219–1232.

Alkalha, Z., Al-Zu'bi, Z.B.M., Jum'a, L., 2022. Investigating the impact of servitization architecture and development on supply chain design. Supply Chain Forum Int. J. 23 (1), 68–80.

Baines, T.S., Lightfoot, H.W., Benedettini, O., Kay, J.M., 2009. The servitisation of manufacturing: a review of literature and reflection on future challenges. J. Manuf. Technol. Manag. 20 (5), 547–567.
Baines, T., Lightfoot, H., Smart, P., 2011. Servitization within manufacturing: exploring the provision of advanced services and their impact on vertical integration. J. Manuf. Technol. Manag. 22 (7), 947–954.
Baines, T., Lightfoot, H., Smart, P., 2012. Servitization within manufacturing operations: an exploration of the impact to facilities practices. J. Eng. Manufacture 226 (2), 377–380.
Brax, S.A., Calabrese, A., Ghiron, N.L., Tiburzi, L., Grönroos, C., 2021. Explaining the servitization paradox: a configurational theory and a performance measurement framework. Int. J. Oper. Prod. Manag. 41 (5), 517–546.
Cannas, V.G., Gosling, J., Pero, M., Rossi, T., 2019. Engineering and production decoupling configurations: an empirical study in the machinery industry. Int. J. Prod. Econ. 216, 173–189.
Bureau Van Dijk, 2022. Analisi informatizzata aziende italiane (AIDA). Last time retrieved online on 16/01/2022, at: https://www.bvdinfo.com/it-it/le-nostre-soluzioni/dati/nazionali/aida.
Cannas, V.G., Gosling, J., 2021. A decade of engineering-to-order (2010–2020): progress and emerging themes. Int. J. Prod. Econ. 241, 108274.
Chakkol, M., Karatzas, A., Johnson, M., Godsell, J., 2018. Building bridges: boundary spanners in servitized supply chains. Int. J. Oper. Prod. Manag. 38 (2), 579–604.
Copani, G., 2014. Machine tool industry: beyond tradition? In: Lay, G. (Ed.), Servitization in Industry. Springer, Cham, pp. 109–130.
de la Calle, A., Freije, I., Oyarbide, A., 2021. Digital product–service innovation and sustainability: a multiple-case study in the capital goods industry. Sustainability 13 (11), 6342.
Dmitrijeva, J., Schroeder, A., Bigdeli, A.Z., Baines, T., 2022. Paradoxes in servitization: a processual perspective. Ind. Market. Manag. 101, 141–152.
Finne, M., Holmström, J., 2013. A manufacturer moving upstream: triadic collaboration for service delivery. Supply Chain Manag.: Int. J. 18 (1), 21–33.
Freije, I., de la Calle, A., Ugarte, J.V., 2021. Role of supply chain integration in the product innovation capability of servitized manufacturing companies. Technovation 118, 102216.
Hoekstra, S., Romme, J., 1992. Integral Logistic Structures: Developing Customer-Oriented Goods Flow. McGraw-Hill Book Company Limited.
Johnson, M., Mena, C., 2008. Supply chain management for servitised products: a multi-industry case study. Int. J. Prod. Econ. 114 (1), 27–39.
Kamal, M.M., Sivarajah, U., Bigdeli, A.Z., Missi, F., Koliousis, Y., 2020. Servitization implementation in the manufacturing organisations: classification of strategies, definitions, benefits and challenges. Int. J. Inf. Manag. 55, 102206.
Kastalli, I.V., Van Looy, B., Neely, A., 2013. Steering manufacturing firms towards service business model innovation. Calif. Manag. Rev. 56 (1), 100–123.
Kohtamäki, M., Einola, S., Rabetino, R., 2020. Exploring servitization through the paradox lens: coping practices in servitization. Int. J. Prod. Econ. 226, 107619.
Li, H., Yang, Y., Singh, P., Sun, H., Tian, Y., 2021. Servitization and performance: the moderating effect of supply chain integration. Prod. Plann. Control 1–18.
Masi, A., Pero, M., Abdelkafi, N., 2021a. A literature-based exploration of servitization in engineer-to-order companies. In: Dolgui, A., Bernard, A., Lemoine, D., von Cieminski, G., Romero, D. (Eds.), Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems. APMS 2021. IFIP Advances in Information and Communication Technology. Springer, Cham, p. 633.
Masi, A., Pero, M., Abdelkafi, N., 2021b. Modularity and operational efficiency in engineer to order companies: a study in the machine tool industry. In: Proceedings of the Summer School Francesco Turco.
Picot, A., Ripperger, T., Wolff, B., 1996. The fading boundaries of the firm: the role of information and communication technology. J. Inst. Theor. Econ. JITE 152 (1), 65–79.
Purvis, L., Lahy, A., Mason, R., Wilson, M., 2020. Distributed manufacturing as an opportunity for service growth in logistics firms. Supply Chain Manag.: Int. J. 26 (3), 307–322.
Shah, S.A.A., Jajja, M.S.S., Chatha, K.A., Farooq, S., 2020. Servitization and supply chain integration: an empirical analysis. Int. J. Prod. Econ. 229, 107765.
Sousa, R., da Silveira, G.J., 2019. The relationship between servitization and product customization strategies. Int. J. Oper. Prod. Manag. 39 (3), 454–474.
Szász, L., Demeter, K., 2015. Business models along supply chain position and servitisation: an empirical investigation of European manufacturers. Acta Oecon. 65 (3), 367–391.
Tranfield, D., Denyer, D., Smart, P., 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br. J. Manag. 14 (3), 207–222.
Tukker, A., 2004. Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Bus. Strat. Environ. 13 (4), 246–260.
Vendrell-Herrero, F., Bustinza, O.F., Parry, G., Georgantzis, N., 2017. Servitization, digitization and supply chain interdependency. Ind. Market. Manag. 60, 69–81.
Voss, C., Johnson, M., Godsell, J., 2016. Case research. In: Karlsson, C. (Ed.), Research Methods for Operations Management, second ed. Routledge, New York, NY, pp. 165–197.
Wikner, J., 2014. On decoupling points and decoupling zones. Product. Manufacturing Res. 2 (1), 167–215.
Wikner, J., Rudberg, M., 2005. Integrating production and engineering perspectives on the customer order decoupling point. Int. J. Oper. Prod. Manag. 25 (7), 623–641.
Wikner, J., Yang, B., Yang, Y., Williams, S.J., 2017. Decoupling thinking in service operations: a case in healthcare delivery system design. Prod. Plann. Control 28 (5), 387–397.
Williamson, O.E., 1981. The economics of organization: the transaction cost approach. Am. J. Sociol. 87 (3), 548–577.
Windahl, C., Lakemond, N., 2006. Developing integrated solutions: the importance of relationships within the network. Ind. Market. Manag. 35 (7), 806–818.
Wise, R., Baumgartner, P., 1999. Go downstream: the new profit imperative in manufacturing. Harv. Bus. Rev. 77.
Yin, R., 2018. Case Study Research and Applications, sixth ed. SAGE Publications, Inc.