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Revisiting the servitization-sustainability link: A case study in the professional printing supply chain

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ABSTRACT

This paper investigates the link between servitization and sustainability. Extant literature assumes a positive effect of servitization on sustainability, while limited contributions report that, under certain conditions, servitization can also have negative effects. Through a case study on the professional printer supply chain, we show that the positive relationship between servitization and sustainability does not always hold true, and we clarify the nature of the links between servitization and sustainability. By drawing on causal loop diagrams based on system dynamics modeling, we differentiate between "built-in sustainability in servitization" and "sustainability potential in servitization". With the former, we refer to the inherent sustainability effect that results from the mere application of servitization. For example, servitization leads, ceteris paribus, to the reduction of the number of required printers to achieve the printing jobs required by customers. The latter shows, however, that there is a latent sustainability potential that can be released, only if refurbishing and component recycling activities take place to extend the product lifetime. The case study also highlights that a systemic view is essential for assuring the overall positive impact of servitization on the environment. If manufacturing firms or institutions cannot track the way printers are disposed, e.g., outside of the borders of a country, the full potential of sustainability embedded in servitization cannot be achieved.

1. Introduction

Servitization, an organization's shift from selling products to Product Service Systems (PSS), has been studied by scholars for many years (e.g., Barravecchia et al. 2021, Gomes et al. 2021). Servitization changes the company's value proposition, its value creation process, as well as how value is captured from customers (e.g., Parida et al. 2014). Servitization calls for deep changes in the supply chain, affecting the upstream and downstream business, while possibly redistributing power among supply chain partners (Mosch et al. 2021).

Servitization can impact the triple bottom line: economic, environmental, and social sustainability (Elkington and Rowlands, 1999). From an economic perspective, servitization enables firms to differentiate their offerings (Gebauer et al., 2011; Vandermerwe and Rada, 1988) from those produced by companies based in low-cost regions (Confente et al. 2015) and generates a stable flow of income over the product lifecycle, thus making companies' revenues more robust against economic downturns. In addition, it is widely accepted that PSS business models (Reim et al., 2015) positively impact the environment and society (Blüher et al., 2020; Yang and Evans, 2019). Servitization enables re-manufacturing, extends product lifecycles, and reduces emissions (Yang and Evans, 2019; Reim et al., 2015). Studies on car sharing (Kolleck, 2021; Stasko et al. 2013) found – without claiming causality – that every new car introduced into a car sharing system replaces about 9–15 privately owned cars. From a social viewpoint, servitization enables low-income customers that cannot buy certain products to get access to them. In particular, pay-as-you-go models enable customers to avoid the high upfront investment, which can constitute a hurdle against product accessibility. If customers cannot buy cars, they can share them with others and still benefit from car usage.

Servitization can come in different flavors with various impacts on sustainability. For example, pay-as-you-go, renting and leasing are recognized models for servitization, yet exhibit some differences in spite of similarities. For instance, General Electric (GE) uses pay-as-you-go in the airplane engine industry. When the aircraft is flying, airlines are paying GE for engine use (pay per hour model based on the level of consumption). Renting is about using the product for a certain time against fees (e.g., renting a car or an apartment). The renting fees do not depend on consumption or usage level of the piece of equipment. Leasing contracts are similar to renting. They are generally set for longer

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periods of time, but do not depend on the usage level as pay-as-you-go, and customers can decide to own the equipment at the end of the leasing contract by paying the equipment's residual value (Edbring et al. 2016). Tukker (2004) has recognized that "pay-per-unit-use" or "product renting and sharing" approach to servitization are drivers of sustainability, whereas product lease could have overall detrimental effects on the environment. Kuo (2011) shows that maintenance management and product design drive sustainability performance of servitization. Thus, a typical PSS-based supply chain is referred to as sustainable if it satisfies three conditions:

1) Reliance on a "pay per use", rental or sharing business models to increase the level of utilization of products and consequently reduce the number of produced goods to cover the requirements of the market.
2) Offering maintenance services to extend product lifecycles. These maintenance services are also necessary to ensure continuous product functionality as well as good service quality.
3) Leverage of product design (e.g., modularity) to support refurbishing, remanufacturing, and recycling.

In this research, we conduct a case study within the professional printer supply chain in Italy, a typical PSS supply chain. The first requirement is fulfilled because professional printers, which were once marketed with a razor-and-blade business model, a model that offers a relatively cheap base product (razor) and sells required disposals at higher margin (blades) (e.g., Gassmann et al. 2014), now rely on a "pay-per-use" model. Customers do not own the printers but pay a fee depending on the utilization level (number of printed copies). According to law in the European Union (EU), since the ownership of printers stays with producers, they must collect them after usage. In line with the second requirement, professional printers are likely to be reused many times before disposal due to maintenance services that guarantee continuous product functionality, like the case of Xerox shows (Xerox website, 2022). The third requirement is satisfied because printers can be refurbished or remanufactured. In addition, at the end of their lifecycle, they become e-waste or Waste of Electrical and Electronic Equipment (WEEE), which has profound implications in terms of environmental sustainability. This is due to the very specific nature of this waste, which contains hazardous as well as valuable materials. Moreover, among the whole range of urban solid waste, e-waste is comparatively rising at the fastest pace, and this trend is expected to continue in the future due to the quality and quantity of hi-tech product consumption (Forti et al. 2020).

The printer supply chain is an interesting case because of the European regulations, which aim at achieving circularity and fostering environmental orientation. In Europe, e-waste management is regulated by the WEEE Directive (2002/96/EC; recast 2012/19/EC). In 2007, such framework introduced the Extended Producer Responsibility (EPR) principle. In other words, producers are requested to take financial responsibility of the end of life of the electronic appliances they put on the market. This gave rise to EPR schemes, which turned into the backbone of the e-waste management supply chain in many European countries. The WEEE Directive has also introduced e-waste collection targets based on a step-by-step approach. Today, European countries are requested to collect 65% of the Put on the Market. Despite differences in the levels of accomplishment of such targets within Europe, the reverse supply chain of domestic e-waste has witnessed the major evolution, while the professional one is mostly out of the EPR schemes and barely captured by national statistics. In this context, the Italian case is not an exception because the collection performance of EPR schemes is still at about 40%, which is 463.953 tons, out of which 24% consists of professional flows. Consequently, our case study additionally sheds light on the current environmental practices in the professional reverse supply chain of the printing industry.

Despite advanced servitization in the printing industry, environmental sustainability targets are lagging far behind expectations. This does not match with state-of-the-art literature, which mostly assumes a positive effect of servitization on sustainability. Only limited contributions report that, under certain conditions, servitization can even lead to negative effects (Reim et al., 2015). Thus, this study reconsiders the servitization-sustainability link and questions a widely accepted proposition that servitization improves sustainability. Hence, our research question: "why does servitization not necessarily lead to the achievement of environmental sustainability objectives, as opposed to what is found in most existing literature?"

Blüher et al. (2020) mention that the current debate lacks a systemic approach. Therefore, our analysis draws on systemic considerations and takes a holistic supply chain perspective. Servitization may appear sustainable within the confines of a particular system, but when the system boundaries change, this can lead to a fully new and different picture.

As our case study provides a counterexample to the proposition that servitization per se improves sustainability, it shows that the positive effect of servitization on sustainability does not hold always true. Additionally, we go beyond the simple rejection of this proposition to clarify the nature of the links between servitization and sustainability. By adopting a systemic view and drawing on causal loop diagrams from system dynamics modeling, we differentiate between the sustainability that is inherently built in servitization (called built-in-sustainability) and sustainability potential in servitization. Whereas built-in-sustainability can directly derive from the implementation of a servitization business model, sustainability potential cannot be achieved until it is activated by means of adequate processes. Even the built-in sustainability may not be achieved until certain conditions are fulfilled.

The remainder of the paper is organized as follows. The next section provides some background on servitization and sustainability. Section three is focused on research methodology, which is based on in-depth case study on the professional printer supply chain in Italy. Section 4 provides a detailed overview of the case study results. In section five, we discuss the servitization-sustainability link. Section six concludes and provides directions for future research.

2. Background: Servitization and sustainability

Servitization denotes the shift from selling products to offering value propositions based on Product Service Systems (PSS), thus resulting in PSS-business models (Reim et al., 2015). PSS offerings can be placed on a continuum, in which "the reliance on the product as the core component of the PSS decreases" (Tukker, 2004, p. 249). There are three main PSS categories (Gaiardelli et al., 2014; Tukker, 2004):

1) Product-oriented services: Products are enhanced by related services such as maintenance or insurance contracts.
2) Use-oriented services: Accessibility is at the core of value creation through leasing, renting, or sharing instead of selling products.
3) Result-oriented services: The delivery of pre-determined results is the key part of the provider's value proposition (e.g., pay-per-unit). Providers decide freely how to deliver these results.

Because our study aims to investigate the servitization-sustainability link, a definition of sustainability is, here, in order. There is a plethora of sustainability definitions that have been proposed in the literature (Salas-Zapata and Ortiz-Muñoz, 2019). Nevertheless, our understanding for sustainability is in line with the most agreed upon definition, the one provided by Elkington and Rowlands (1999, p. 229), who refer to a business as sustainable "…when it lives up to the "triple bottom line" of economic prosperity, environmental quality and social justice." Economic sustainability is straightforward to estimate and depends on the firm's financial profitability. Environmental sustainability can be measured by the extent to which a business uses efficiently materials and energy and leverages renewable as well as clean resources. Social

sustainability can be measured, for example, through the company's contributions to improve relationships with local communities and stakeholders, work safety, and work environments (Abdul-Rashid et al. 2017). Hence, the environmental and social elements of sustainability are less straightforward to evaluate by means of indictors than economic performance.

Economic performance has been at the focus of business activity more than environmental and social sustainability (e.g., Walker et al., 2020), but it has been shown that companies must increasingly embrace sustainability practices, as environmental and social sustainability are long-term drivers of economic prosperity. Eccles et al. (2014) found that, in the long run, high sustainability firms exhibit better financial performance than low sustainability firms. The main difficulty lies in the fulfillment of all three objectives at the same time (e.g., Walker et al., 2020), as tradeoffs characterize the relationships between the elements of the triple bottom line (e.g., Gao and Bansal, 2013). For example, a clash of interest can arise between environmental orientation and economic performance of private firms (Schulz, 2022). In addition, paradoxical tensions can exist between economic and social objectives (Iivonen, 2018). Therefore, managing these tradeoffs is essential step toward sustainability. In this regard, servitization seems an adequate approach to deal with these tradeoffs and to reconcile all three elements of the triple bottom line (e.g., Lindahl et al., 2014).

Take, for example, pay-per-use a widely used servitization model. It provides economic benefits to the firm because it addresses a segment of customers that could not have been reached if customers had to buy the product. From an environmental viewpoint, because customer needs can be satisfied with shared equipment, a better usage of equipment can be achieved, leading to less capacity waste. In laundry washing, Bocken et al. (2018) found that pay-per-use-models support sustainable consumption and environmental sustainability, as customers reduce the number of washes and decrease the washing temperature. From a social perspective, whereas this aspect deserves more research in the context of the pay-per-use model (Ockwell et al. 2019), some contributions point to positive impacts of this model on social justice. For example, Barrie and Cruickshank (2017) illustrate the wide technological applicability of solar home systems in Central East Africa if combined with pay-per-use models, resulting in improved accessibility to electricity. In addition, from the employee's perspective, servitization in general calls for a higher level of empowerment, which increases workforce responsibility, thereby contributing to improved working conditions (Dubruc et al., 2014). Thus, advanced servitization models such as pay-per-use can support companies in managing the tradeoffs between the sustainability elements of the triple bottom line.

Also, less sophisticated product-oriented servitization models can have positive impacts on the environmental element. Such services are related to maintenance, repair, and reconditioning, which can extend the product lifetime and therefore reduce the global ecological impact of product use (Brouillat 2009; Doni et al. 2019; Kühl et al., 2019; Reim et al., 2015; Yang and Evans, 2019). This positive link has also been supported by a recent review by Blüher et al. (2020), who found about 10 times more statements in the literature pointing to a positive link than statements referring to a negative relationship between servitization and sustainability (Blüher et al. 2020). Whereas the large number of statements can be interpreted as evidence for the environmental benefits of servitization, it may also be seen as a lack of research addressing potential limitations of servitization in achieving sustainability targets.

A survey conducted among manufacturing firms in China could not confirm an independent positive relationship between servitization and environmental sustainability. The authors (Hao et al. 2021) conclude that servitization per se does not necessarily bring about a positive environmental performance. However, the form of the negative relationship between servitization and sustainability should be specified. For example, sometimes authors conclude the existence of a negative impact when not all positive benefits can be achieved (e.g., Yang and Evans, 2019), or when the level of positive effects is reduced (e.g., Tukker, 2004). Negative effects can arise when non-ownership of the product leads users to exhibit careless behaviors that shorten product lifetime (Tukker, 2004). For instance, the driving behavior of car sharing users may not be as car-friendly as the behavior of car-owners. Furthermore, servitization can boost consumption because it increases the accessibility to goods, leading non-users, who are not able to pay the upfront investments, to convert to product users. For example, users of public transportation, which is more environmentally friendly than passenger cars, can convert to car sharing service users. As a matter of fact, Kühl et al. (2019) notice that the environmental concerns of PSS providers are questionable, as servitization is mostly driven by strategic and commercial interests. Therefore, selling PSS instead of products does not necessarily lead to higher circularity. Kurpiela and Teuteberg (2022) point out that economic dimension still predominates over the environmental aspect. In addition, the adoption of new approaches oriented towards a sustainable design of PSS, like the Environmental Break-Even Point (Barletta et al. 2018), is still rare. Consequently, the thesis that servitization is conducive to sustainability, as confirmed by a large body of research, should be confronted with the antithesis that servitization does not necessarily improve sustainability, although the body of literature in this regard is still limited.

The link between servitization and sustainability can depend on many factors. Yang and Evans (2019) link the possibility of benefiting from a positive effect to the type of PSS implemented. The intensity of these positive effects is rather limited when the PSS business model is product-oriented, higher when it is use-oriented, and highest when it is result-oriented. Tukker (2004) point to different impacts of servitization on sustainability, depending on whether the product is leased, shared or rented, concluding that product leasing might result in a higher environmental damage than the traditional selling of products, whereas sharing and renting have a better environmental effect.

Blüher et al. (2020) argue that system boundaries can influence the effects of servitization on sustainability performance. The dominance of literature assuming a positive servitization-sustainability relationship might be linked to the system that is chosen as reference. For instance, global supply chains that have a reach beyond one country or region have different system boundaries than local supply chains. The specificity of different countries regarding laws, regulations and infrastructure can have an impact on sustainability effectiveness (Kühl et al., 2019).

Concluding, most of the literature is popularizing the positive effect of servitization on environmental performance, leading to a general belief that the switch to more service-oriented business models is associated with better sustainability. However, this may not be true as the servitization-sustainability link can be more complex than assumed. Using an in-depth case study methodology, our objective is to provide evidence that servitization does not support sustainability in all instances, and that the servitization-sustainability link deserves a more careful analysis.

3. Research methodology

To investigate the servitization-sustainability link, we conduct an in-depth case study (Yin, 2017). The case study methodology enables us to get insights into current practices and to develop a solid theoretical basis (Meredith, 1998). Since we analyse the servitization-sustainability link from systemic perspective, we consider multiple actors and all phases of the product lifecycle. Because of this, the supply chain is chosen as unit of analysis. The in-depth case study was performed according to a structured approach to help prevent/reduce the limitations of qualitative research methodologies.

3.1. Case study selection

Our case study is the supply chain of professional printers in Italy. The selection of this supply chain as context of our research is adequate

for three reasons. First, the professional printer industry constitutes a positive example for the application of servitization strategies (Visintin, 2012). Second, the EU law requires producers to collect printers after usage, making the legislative environment a driver for sustainability efforts. Third, a good coverage of all supply chain stages can be achieved by approaching several actors in the industry in order to collect a rich pool of data.

3.2. Interviewees selection

The actors in the professional printer supply chain were identified by drawing on literature, web search and preliminary discussions with a group of nine of the major printers' producers, which supported our work along the case study research. These producers were selected since they showed interest in the topic. They account for around 65% of the Italian Put On the Market in tons. This led to a first list of potentially relevant companies. By analyzing the websites of the companies in this preliminary list, we got a good overview of the companies' operations, activities, positions in the supply chains, and sustainability orientation. With the aid of the industry representatives' group, the final list of companies to be involved in the study is determined. When applicable and possible, we involve in the study the companies, in which these representatives are employed. In general, companies have been included due to their size (as a proxy for their weight in the industry) and/or because of their importance in the Italian market, e.g., when other actors refer to their relevance to the printer supply chain.

Overall, 14 interviews were conducted with all types of actors involved in the professional printers' supply chain. Table 1 provides the list of actors interviewed, key informants, and their specific roles in their organizations. It should be noted that some actors (e.g., reconditioning brokers) were not considered at the start of the study, but we discovered them and their relevance to the supply chain as we progressed with the interviews.

3.3. Data collection and analysis

To guide the research, a case study protocol is defined. The main sources of information are the semi-structured interviews conducted according to a questionnaire with four parts: (i) role of the interviewed company in the professional printers' supply chain, in other words, their own activities, suppliers, and customers; (ii) management of the printers' flows in the supply chain including reverse logistics ; (iii) types of contracts used with end customers (e.g., leasing or selling contracts), and (iv) managed portion of the printers' lifecycle with a focus on the decisions concerning reconditioning and disposal.

Interviews were conducted over Microsoft Teams, and the average duration is about one hour. After the interviews, follow-up phone calls or email exchanges helped the collection of missing information. Additional data and supporting documents such as company presentations or internal reports have been collected whenever possible to triangulate different data sources. All conducted interviews were transcribed. Then, the coding was performed by the researchers independently, while considering the transcriptions and supporting documents. In-depth discussion among the researchers aimed at reaching agreement on the interpretation of the data. Additionally, the intermediate results of the study were shared and discussed with the above-mentioned group of representatives of producing companies.

4. Results

This section deals with the results of the case study analysis and consists of four sub-sections . First, we introduce the overall structure and specifics of the printer downstream supply chain. Second, we discuss the findings and insights from the case study. Third, we model the mechanisms that reflect the servitization-sustainability link inside the printer downstream supply chain by means of a stock and flow diagram from system dynamics. The fourth section introduces, based on the case study findings, two forms of impact that servitization can have on sustainability to create a better understanding of the servitization-sustainability link.

Table 1
List of interview partners.

Role in the supply chain	Number of organizations interviewed	Role of the key informants	Other supporting documents
Manufacturers	2	(1) Printing commercial channel sales manager. (2) Technical director	Website
Dealers	1	(1) Both company's owners	Website, Balance sheet
Distributors	2	(1) Investor relations manager & head of group vendor management (2) Chairman	Website, balance sheet data, internal reports on distribution channels and sales
Reconditioning brokers	2	(1) CEO, department director and logistics manager in Italy (2) CEO	Website, links to videos and online resources on projects performed by the companies
Financial companies	1	(1) Vice-president, marketing, and communication representative	Website
Final customers	1	(1) Responsible manager for rental, purchase, and tendering of multifunction printers; expert in sustainable procurement as well as in green public procurement	Website, Calls for tenders
NGOs	1	(1) Chairman	Website
Scrapping companies	3	(1) Executive Director (2) Logistics and Production Control Manager (3) Commercial Director	Website
Customs agency	1	(1) Statistics and open data office	Reference laws

4.1. Analysis of the printer downstream supply chain

The professional printer downstream supply chain mainly consists of three parts: first-hand, second-hand, and end-of-life management supply chains. After the end of the first lifecycle, printers commonly get a second life. They usually go through a reconditioning process and are subsequently re-sold in the secondhand market in Italy (home country), outside Italy (export), or donated to NGOs. Printers that stay in Italy at the end of their lifecycle are collected, dismantled, and finally disposed of by specialized actors.

4.1.1. First-hand supply chain

The first-hand supply chain makes and delivers new products. It involves five types of actors: manufacturers, distributors, dealers, financial companies, and final customers. The manufacturer puts professional printers on the market through direct sales or rental. Rental may also include pay-per-copy contracts, thus charging a price that is proportionate to product use. To reach professional clients (i.e., companies, institutions, or public administrations), manufacturers can follow two

channels: *direct* and *indirect*. Over the direct channel printers are sold directly to the final customer. The indirect channel involves intermediate actors such as large distributors or small dealers.

Customers that get their printers directly from manufacturers or indirectly from dealers can receive loans from financial companies to fund the rental or purchase of printers. The typical dealer in the industry is small, has limited resources, and manages only one or a few brands. Because of this, dealers do not keep printers on stock. They first collect the orders and then source the printers from the manufacturers or distributors.

In contrast to dealers, distributors are larger companies and can afford to deal with a variety of different products and brands. They may sell to small dealers or directly rent or sell to customers. Distributors do not participate in the reverse flow of printers; they do not collect professional printers at the end of their lifecycle and do not take care of reconditioning. Therefore, distributors are not part of the second-hand market. To reduce their costs, distributors keep their stocks of printers at a relatively low level, generally between 4 and 6 weeks of inventory.

Once the printers reach the end of first lifecycle (3–4 years on average), manufacturers, resellers, reconditioning brokers, or non-profit organizations (NGOs) can take them back from customers. In almost all cases, customers replace their old printers with new or reconditioned ones. The collected printers through the circular loop enter the secondhand market. Note, however, that customers may also decide to not return the printers, thus creating internal stocks of used printers. The creation of stocks is common in public administrations that buy professional printers with a sales contract.

If financial companies are involved, they could remain owners of the assets after the expiry of the contract. In almost all cases, however, the financial company does not manage the printers' end of life. It can sell them to dealers, who can arrange new rental contracts; to reconditioning brokers, who refurbish the product; or just put the printers in the second-hand market.

4.1.2. Second-hand supply chain

Customers that own professional printers and want to dispose of them or replace them at the end of their first lifecycle can address four different actors: manufacturers, dealers, reconditioning brokers, or NGOs.

Manufacturers can refurbish the printers to be sold in the second-hand market both in Italy and abroad. Alternatively, if completely exhausted, these printers can be sent to actors specialized in printer end-of-life management.

Dealers usually collect, recondition, and resell used printers in the second-hand Italian market. However, like manufacturers, when reconditioning is not feasible or economically disadvantageous, a printer is handed over to companies that manage the product's end-of-life.

Reconditioning brokers are part of an international system dealing with the recovery of various types of WEEE, also WEEE generated by professional printers. These brokers are the only actors that can recover large fleets of machines. Some manufacturers even rely on them to take back used printers from large clients. Consequently, the overall volumes of printers handled by the brokers are significant. Once reconditioned, these printers can be sold in the Italian or foreign second-hand markets. Those printers that are not reusable are dismantled and disposed of. For reconditioning purposes, manufacturers, dealers, or reconditioning brokers can cannibalize some printers to use their functioning parts, still in good condition, in second-hand machines.

At the end of the product lifecycle, customers can give the professional printers to non-profit organizations that recover e-equipment or make donations to other NGOs or people in Italy and abroad.

Printer reconditioning and second-hand market extends the lifetime of printers. However, what happens to the second-hand printers? Since export seems a frequent exit for the second-hand printers, it is not clear what process printers go through after their second life, as explained by a financial company:

> *"Saying that [this type of product, Ed.] is sold abroad means, mainly, that it is sold in Africa, and from that moment on, there are no more records of it. This is why Italian disposers do not receive a significant number of printers to dismantle"* (Financial company).

This is also confirmed by reconditioning brokers that point to the fact that manufacturers are encouraging the sale of secondhand printers abroad to reduce competition with new printers in the Italian market. In the same context, a distributor mentions:

> *"It's mainly the manufacturers that don't want the product to come back to the Italian market because they obviously want to sell the new product. […] At the end of the "pay-per-print" contract, the printer is reconditioned and sold abroad – we are talking about Arab countries and not Europe"* (Distributor).

Previous studies support this observation and suggest that in the electrical and electronic equipment (EEE) sector a high amount of equipment is exported, either as waste or as a product that can be reused. A study conducted in France on professional equipment showed that about half of used professional EEE is exported (Aurez et al., 2018). Another study by Forti et al. (2020) estimates that about 7% to 20% of the WEEE generated is exported.

4.1.3. End-of-life supply chain

Printers for disposal in Italy are handled by two categories of actors: (i) extended producer responsibility systems (i.e., consortia like ERION), or (ii) companies specialized in scrapping. Because printers do not contain precious metals to be recycled, the residual value of exhausted professional printers is low. This suggests the existence of a very limited unauthorized market served by non-certified actors. The low desirability of professional printers at the end of their lifecycle is reflected in the following statement:

> *"…we prefer those [machines, Ed.] with more copper and precious metal content. So yes, we do handle printers, but as few as possible, because they are poor in these materials"* (End-of-life treatment company).

Product design can support disposal and component recovery activities. In the professional printing industry, it seems that there is still progress to be made regarding design for disposal and recyclability. With respect to disposal activities, a company involved in end-of-life treatment mentions that:

> *"Even after the cartridge is removed, there is still the recovery tray to extract. This activity is not easy to perform"* (End-of-life management company).

For components recycling, the same company says:

> *"The recovery of these printers is not profitable; most of the components have no market anymore. The components are so complex to disassemble that it is no longer economical to do such work and, therefore, they have no place in the recovery market"* (End-of-life management company)

For retailers, who are also active in the collection and reconditioning of second-hand products, the cost of consumables and rapid obsolescence of software can make it unprofitable to recondition machines:

> *"A lot of equipment would still be valid, but consumables cost a lot of money, and therefore it is uneconomical to repair them […] not to mention that software is constantly being updated and needs updated machines, which can connect to all platforms and mobiles"* (Dealership).
> *"There are many products that would have a market if there were not the software"* (Reconditioning broker).

For the dealers, end-of-life management of the printers incurs significant costs since disposal is "*difficult and very expensive*". These issues have also been reported by many actors such as the financial company and the company specialized in end-of-life treatment:

"The problem is mainly related to logistics and storage. It is a problem also found by talking to dealers. When they pick up the machines, these machines occupy too much space, and this has a cost. This issue is also related to the design of the printer" (End-of-life management company).

"My colleagues prefer to deal with PCs, which are simpler, while the printer is voluminous, and has a transportation cost" (Reconditioning broker).

The incentive of dealership to resell the printers in the Italian market is relatively low, because

"The cost of reparations is too high compared to the commercial value at which they could be re-introduced to the market" (Dealer).

Therefore, they are sold abroad or disposed of. In this regard, a noteworthy case comes from Public Administration, which has its own peculiarities that can make the collection of end-of-life products more complex:

"One problem with the management of this type of waste in administrations is that when the asset stops being used, it must be removed from the list of assets of the institution. This activity causes an administrative difficulty that administrations do not want to deal with" (Client).

Heavy regulations and policies do not seem to facilitate the reuse of printers and to support secondhand market. The bureaucratic aspects of the process are apparently challenging, and the supply chain actors can encounter many difficulties in this regard. In particular, the dealers are looking for

"Less bureaucracy and less costs for disposal" (Dealer).

"Making it easier […] for those working in the sector to become a focal point for disposal" (Dealer).

4.2. Case study discussion

The case study provides evidence that despite advanced servitization, the professional printer supply chain still faces many sustainability challenges. The identified sustainability issues demonstrate that a positive link between servitization and sustainability cannot be assumed. What eventually makes other studies overestimate positive sustainability effects of servitization is the myopic consideration of single actors and/or the unique focus on the first-hand supply chain. In effect, the first-hand printer supply chain makes one believe erroneously that the industry is sustainable, since at the end of their first life, printers can get a second life after going back to the supply chain in order to be refurbished. Evidently, this loop is advantageous from an environmental viewpoint, and servitization, especially when ownership stays with manufacturer, supports the reverse flow of used printers. However, the sustainability problems start becoming clear when we look beyond a single actor and first-hand supply chain and give attention to how second-hand and end-of-life supply chains function.

Our case study identifies five major types of problems that can hinder a servitized supply chain from achieving sustainability targets. The first problem is systemic in nature. Many second-hand printers are not reinserted in the Italian market, leading actors in the industry to completely lose track on these printers, how they are disposed of, and whether they are recycled or not. What looks sustainable within the boundaries of a one region is not necessarily sustainable when the geographical system boundaries are expanded. The second problem is about the still high commercial orientation of printer producing companies, which want to sell high-margin new printers, instead of supporting second-hand products in finding their way back to the market. This problem is already known in literature (Kurpiela and Teuteberg 2022). The third problem is inherent to the product and its design. The incentive for recycling printers is low because they are bulky products, require high storage capacities, and exhibit a low density of precious materials. In addition, disassembly seems difficult, and updated software constitutes a barrier against the re-use of older models, as new software rather supports connectivity of the newer printer models. Because of this, reparations and refurbishing activities can incur high costs, making it uneconomical to engage in closed supply chain loops. The fourth challenge is about customers of professional printers, which can be reluctant to delete assets from their inventories. Finally, the fifth problem relates to regulations, which may either exclude or make it difficult for some supply chain actors to be part of the reverse supply chain (e.g., dealers).

Consequently, the mere implementation of servitization does not necessarily guarantee the achievement of sustainability objectives. The achievement of sustainability is not unconditional. Hence, a differentiated consideration of servitized supply chains is required. A professional printer supply chain that manages well the problems identified above will be better capable of achieving sustainability.

4.3. Stock and flow diagram of the printer downstream supply chain

To achieve sustainability, a printer supply chain should keep track of six relevant types of stocks. Keeping only track of the first-hand printers will not be conducive to sustainability. In the following, we identify six types of stocks by analyzing the interview statements (Table 2). In addition, these stocks are related to each other as represented by the causal loops (Fig. 1).

Table 2
Selected interview statements corresponding to the identified stocks.

Stocks	Selected interview statements
First-hand printers in use (Italy)	• "*A printer can last up to 8–10 years; an average rent is 4 years, so it can do 2 cycles.*" (Distributor) • "*On average, leasing contracts have a duration of about 3–4 years.*" (Retailer)
Printers in reconditioning (Italy)	• "*The machines that we collect are generally ready to be resold, since they can last for 3–4 more years. Sometimes they are almost new!*" (Reconditioning Broker) • "*Dealers do not give printers back because they might keep them to collect spare parts […]. Dealers do not give printers back because they think of reconditioning them and selling them by themselves.*" (Manufacturer)
Second-hand printers in use (Italy)	• "*There is a large market for second-hand printers. There are traders all around Europe that sell used printers and put them even in the Italian market.*" (Distributor) • "*We also import used machines from abroad, since they might be interesting products. […] We prefer Northern European markets, where products have lower lifecycles, and therefore we can collect less worn-out machines.*" (Reconditioning broker)
Printers in disposal/ recycling (Italy)	• "*When the final user buys a new machine, he almost always gives the old one to the dealer, who has to manage it. I think in the 90% of the cases the dealer finds himself having a used machine after selling a new one, and then he needs to either dispose of the used one or reselling it.*" (Distributor) • "*There are dealers that collect the old products when they bring the new ones and in order to recondition other printers, they keep some spare parts that they need, while disposing of the rest.*" (Scrapping company)
Printers in reconditioning (Abroad)	• "*There is also a foreign market, especially in North Africa. Oftentimes, the companies that manage large fleets of machines buy them and resell them in these territories. It happens that we are contacted by Egyptians or Tunisian traders – in the last months this has not happened frequently due to the Covid pandemic – who bought end-of-lease or end-of-rent products.*" (Distributor)
Second-hand printers (Abroad)	• "*Our markets are Italian and foreign such as in Germany, where–probably—they re-sell again our products, abroad.*" (Reconditioning Broker) • "*The dealers then resell those machines to brokers that go and sell them in the Middle East, in Africa, or in South America, after reconditioning them.*" (Manufacturer)

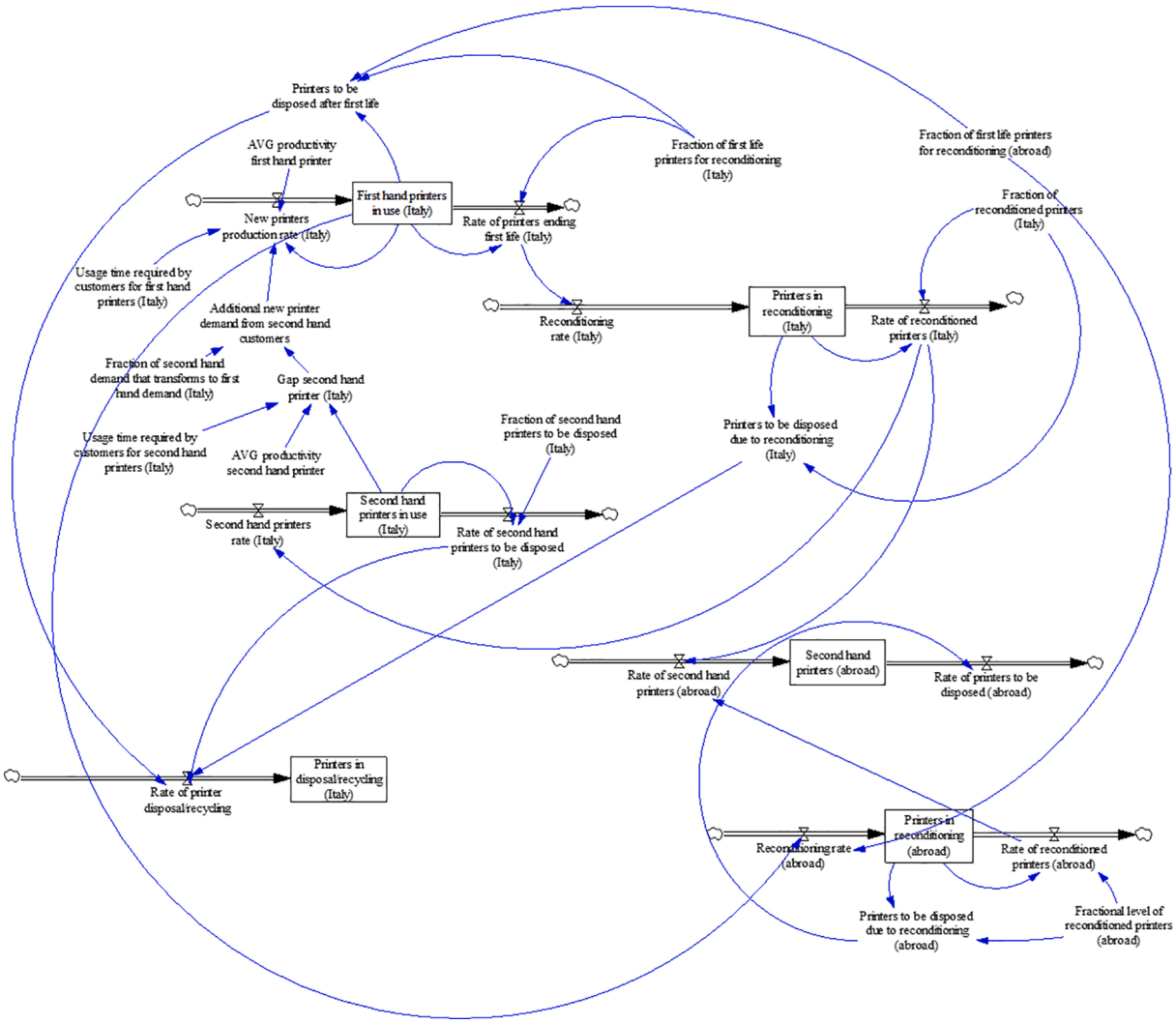

Fig. 1. Stock and flow diagram for the printer downstream supply chain.

(1) First-hand (New) printers in use (Italy): This stock consists of new printers that are functional in Italy. They are used by companies, public administrations, etc.

(2) Printers in reconditioning (Italy): This stock corresponds to printers that reached the end of their first lifecycle, e.g., after the expiration of a contract with a manufacturer, dealer, or distributor. These printers are being refurbished to be used afterwards in the second-hand market. However, not all firsthand printers have a second life in Italy. In other words, the number of printers at their end of first life is not equal to the number of printers entering the Italian secondhand market. This is due to many reasons. First, only a fraction of firsthand printers is reconditioned in Italy, while another fraction is refurbished abroad. Second, some printers must be disposed (or recycled) after their first life. Third, some printers in reconditioning must be cannibalized to re-establish the functionality of printers that will enter the secondhand market. These cannibalized printers will be disposed/recycled.

(3) Printers in reconditioning (abroad): These printers are exported for use outside the Italian market. There is no track of these printers once they reach foreign territories.

(4) Secondhand printers (Italy): Because of the reasons explained above—also driven by the manufacturers' incentive to push new products to the market—only a fraction of printers reaches the secondhand market in Italy. These printers can reduce the demand for new printers. Because of the co-existence of first and secondhand printers, customers may only ask for new printers, secondhand printers, or change their mind to buy or rent new products, once secondhand printers are not available. It is also noteworthy that new and secondhand printers **can** exhibit different productivities, which is measured by the available utilization time (maximum capacity) and the speed at which copies can be made. Nevertheless, the reason behind the choice of printer manufacturers is purely economic and takes into account the characteristics of the market and the refurbishment processes. The market for refurbished printers is global. Refurbishment processes can be easily located outside Italy, and the different markets exploit the printers at different levels of productivity. For the domestic market, it is unlikely that professional customers declare explicitly they want new printers. Often these customers do not even know if the printers are new or secondhand. Most important for the customer is that these printers meet the functional requirements.

(5) Secondhand printers (abroad): This denotes the stock of secondhand printers that are currently in use in foreign countries. This stock is composed of printers that have been either reconditioned in Italy or abroad. While it is possible to track the number of printers that are reconditioned in Italy and sold to foreign markets, it is not possible to know exactly how many secondhand

printers are functional outside Italy. This is because the efficiency of the reconditioning process abroad is not known.

(6) Printers in disposal/recycling (Italy): This stock consists of the printers to be disposed or recycled. The incoming flow is composed of printers that are disposed of after their first life, second life, or after they have been cannibalized to serve for the refurbishing of secondhand printers.

The stock and flow diagram uncovers the complexities of the printer downstream supply chain. It is noteworthy that the identified stocks are not under the control of one single actor. Instead, many actors, driven by different interests, can impact stocks and flows, thereby collectively influencing the supply chain environmental sustainability. Ideally, from an environmental perspective, the supply chain should strive for reducing the stock of new first-hand printers as much as possible and increasing the stock of second-hand printers in use by supporting refurbishing and recycling activities. In addition, the local actors in the supply chain should aim at regaining control over two types of stocks: (i) second-hand printers (abroad), and (ii) printers in reconditioning (abroad). In practice, however, the control of stocks placed abroad can be difficult or even impossible to achieve. Since it is not possible to guarantee proper and environmentally correct disposal of printers abroad, to induce a substantial improvement in environmental sustainability, some or all stocks abroad can be eliminated, though at the cost of reducing accessibility of printers to secondhand markets, mostly located in developing countries. The resulting model may be more sustainable from an environmental perspective. However, it is questionable whether the model will be economically sustainable because of the current product designs, which are less conducive to recycling and disposal activities. We believe, therefore, that to make the professional supply chain printer sustainable, a more fundamental change should occur in the industry than the mere switch from a product-oriented to a servitization-based business model.

4.4. Servitization and sustainability analysis of the printer downstream supply chain

Based on our case study analysis, Servitization can have two implications for the sustainability of the printer supply chain. The first implication derives directly from the main idea underlying PSS systems. A PSS system combines the printer—as a physical product—with a range of services such as (remote) maintenance—e.g., by leveraging IoT technologies—to increase the availability and accessibility of printers to customers. Thus, servitization per se improves the productivity of printers. In addition, because of optimally planned maintenance services, printer lifetime is expected to increase. An increased productivity and extended printer lifetime both can decrease the stock of required new printers, leading to positive effects on sustainability. We call this effect **built-in sustainability** of servitization. This sustainability is inherent to servitization.

The second implication of servitization for sustainability is rather indirect. Because a contract between manufacturer and client is result- or outcome-oriented, printers can be replaced by the manufacturers to fulfill the accessibility objective. This way, printers at the end of their lifetime—when there is a significant decline in their productivity— can be collected and refurbished to enable a second life for the printers, whereas secondhand printers may be sold or marketed as a PSS. We call this effect **sustainability potential in servitization**. It only represents a potential because it is still up to the manufacturers or other actors to decide whether to refurbish the machines or not. As discussed above, dismantling and remanufacturing used printers can be associated with high costs, in addition to the impact on the sales and renting of new printers. Hence, the positive effects can only unfold if they are adequately activated by the manufacturers and other actors. If manufacturers discourage the usage of secondhand printers and push new printers to the customers, this sustainability potential due to reconditioning and reuse cannot be leveraged.

In addition, the stock and flow diagram shows that positive sustainability effects can be achieved only if servitization is leveraged within the boundaries of a well-specified (geographical) system. In effect, the industry has a good track of the printers when they are used, refurbished, disposed of, and recycled in the home country. Once the printers are exported for use, reconditioning, or disposal outside the home country, companies and public administration can no longer track the products. This way, the effects on sustainability are uncertain, especially if the destination countries do not have adequate policies that enforce sustainability measures.

5. Implications for practice and research

5.1. Implications for the printing industry

Our results highlight that the actual situation presents lights and shadows. Within Italian borders, the supply chain of professional printers is characterized by good environmental sustainability performance. There is a high percentage of reuse and refurbishing of professional printers, and a high percentage of used printers are treated by legally authorized actors at the end of their lifecycle. If we consider the whole world, results show that the untracked export of used professional printers to foreign markets absorbs a large part of refurbished or still to-be-refurbished printers. Selling the machines in foreign markets makes it possible to extend the lifetime of printers, even if it shifts the problem of disposal to geographical areas beyond the control of the Italian legislator. It was not possible to collect evidence relating to the application of the procedure provided for by Legislative Decree 49 of 14 March 2014 for the case of reuse abroad.

Selling abroad allows more people and institutions to access printing machines at an affordable price (social component), but given the lack of tracking tools, there is no guarantee that the exported products will be reconditioned, and subsequently treated and properly disposed of at the end of their lifecycle. Therefore, what can be seen as a “socially” responsible practice also represents a serious threat to environmental sustainability of the sector from a global perspective.

Thus, this result calls for looking at the implications of servitization for sustainability with a system thinking approach. Our results are in line with Blüher et al. (2020) since we observe that the sustainability performance of a servitized supply chain depends on the system boundaries that are taken into consideration. To fully evaluate the implications for sustainability, the system boundaries may be set beyond the borders of a single country or region (e.g., Europe) to include a global view that can consider the whole planet. Focusing on only a portion of the world would lead to over-estimate the benefits of a practice, whereas a larger system view can break a seemingly positive link between servitization and sustainability.

5.2. Implications for servitization research

Literature contends there is a positive relationship between servitization and sustainability (Yang and Evans, 2019; Reim et al., 2015). This research highlights how and eventually under which conditions servitization can support sustainability. Therefore, by using as reference the insights derived from the printing industry, we can build causal loop diagrams that uncover the variables and the relationships determining the link between servitization and sustainability. Although the printing industry is our reference, our results can be extended to servitization contexts beyond this particular industry. We start with the (1) base case model, which is then enriched and extended step-by-step to explore three other models: (2) Servitization: Built-in sustainability, (3) Servitization: Built-in and Potential sustainability and (4) Servitization: Extended sustainability. The servitization models (2)-(4) build on top of each other. In (2) servitization aims at increasing the product lifecycle time; in (3) refurbishing of finished product is added to model (2); and in

(4) component and material recycling are represented.

5.2.1. Base case

The base case (Fig. 2) corresponds to the scenario without servitization. In the base case, two loops are at work: reinforcing and balancing. In the reinforcing loop, the more products go out-of-use, after having reached end of lifetime, the larger the gap between operational printer time required by customers and realized operational time by products, the more additional (new) products are needed to be manufactured. If the available printers can perform all the printing activities required by customers without significant delay, then there is no need for additional printers. In the balancing loop, the more products are used, the higher the potential availability time of products, and the lower the gap between customers' requirements and actual productive time by machines, leading to fewer new products to be put into operation. The balancing effect is larger if product lifetime and product productivity increase. The environmental damage results from the use/operation of new products and when products go out of use and must be disposed of. Note that environmental damage generally arises with some delay and not immediately.

5.2.2. Servitization: built-in sustainability

A company that supports its offerings with services can ensure an improved productivity of its products (product availability) and extended product lifetime, which can result in longer product-based contracts provided to customers. In effect, servitization with its different forms, be it offering maintenance contracts, ensuring accessibility, or providing result-oriented services such as pay-per-use, has a positive effect on the availability level of products, which is the potential productive time where the products can be effectively in-use, and thus not idle. For instance, a printer that is sold with maintenance contracts, is inspected, and maintained more efficiently, leading to a product that can live longer. Or, if the printer manufacturer sells accessibility, it is in its own interest to maintain the printer regularly and ensure a high level of availability, so that it is possible to capture highest value. Because of this, the product lifetime increases, and this enables manufacturers or other actors to engage in longer contracts before replacing the product through another one.

Servitization, as illustrated by the causal loop diagram, strengthens the balancing loop that decreases the number of products required to cope with customers' requirements. From a theoretical perspective, servitization does not introduce any new causal loop, but strengthens the balancing loop, which decreases the number of required printers. Because of this ceteris paribus decrease in the number of printers, the negative environmental effects are also reduced. This constitutes an inherent positive effect of servitization on sustainability performance (Fig. 3).

5.2.3. Servitization: built-in and potential sustainability

The causal loop diagram (Fig. 4) additionally considers the potential sustainability in servitization. This potential sustainability can only be achieved if the company collects and refurbishes products at the end of their first lifecycles. Sustainability performance of the PSS system depends on the refurbishing level, in other words the extent to which companies can generate functional second life products for the second-hand market. Servitization can have a positive effect on the contract time for new products and can also lengthen the lifecycle time of second-hand products. The causal loop diagram is drawn under the assumption

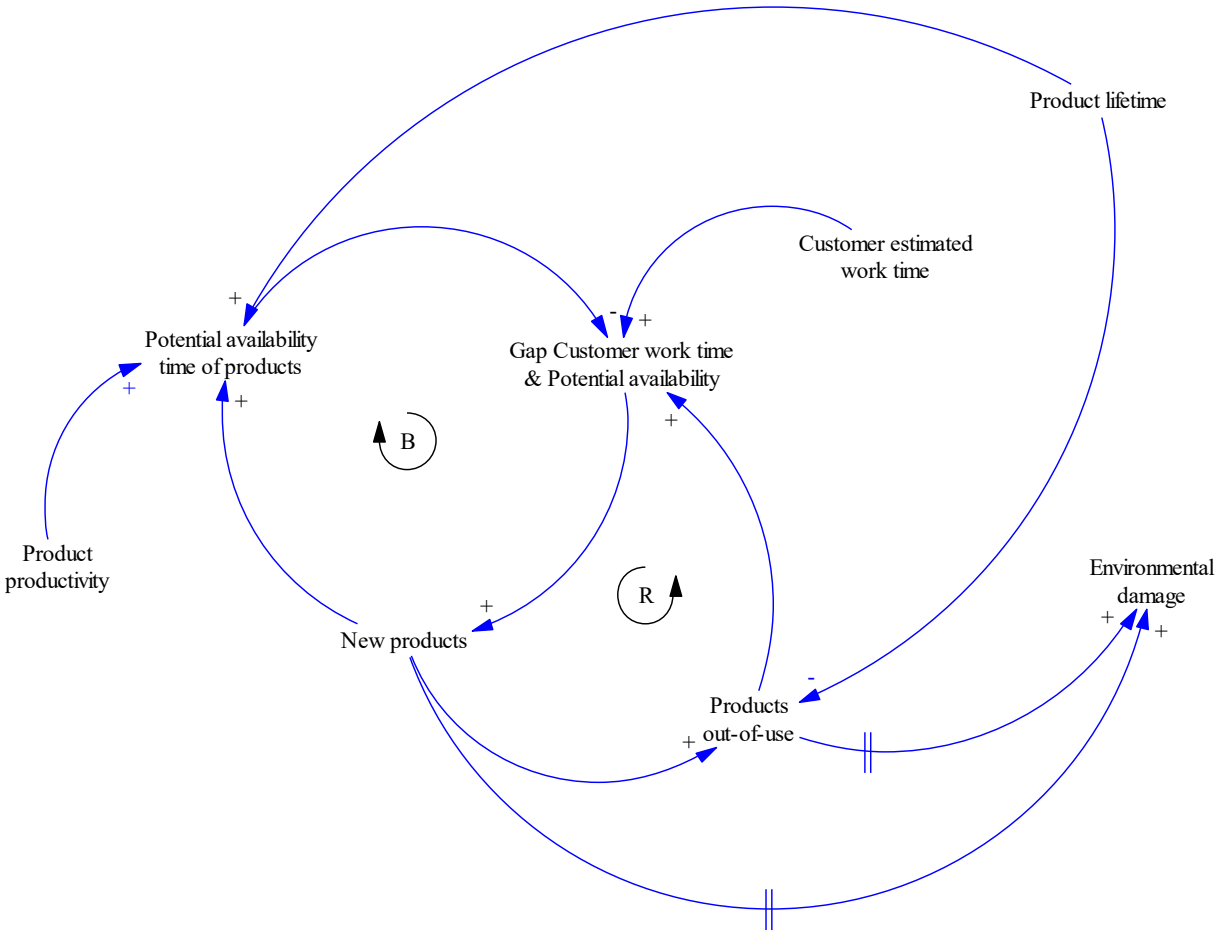

Fig. 2. Model (1) – Base case causal loop diagram.

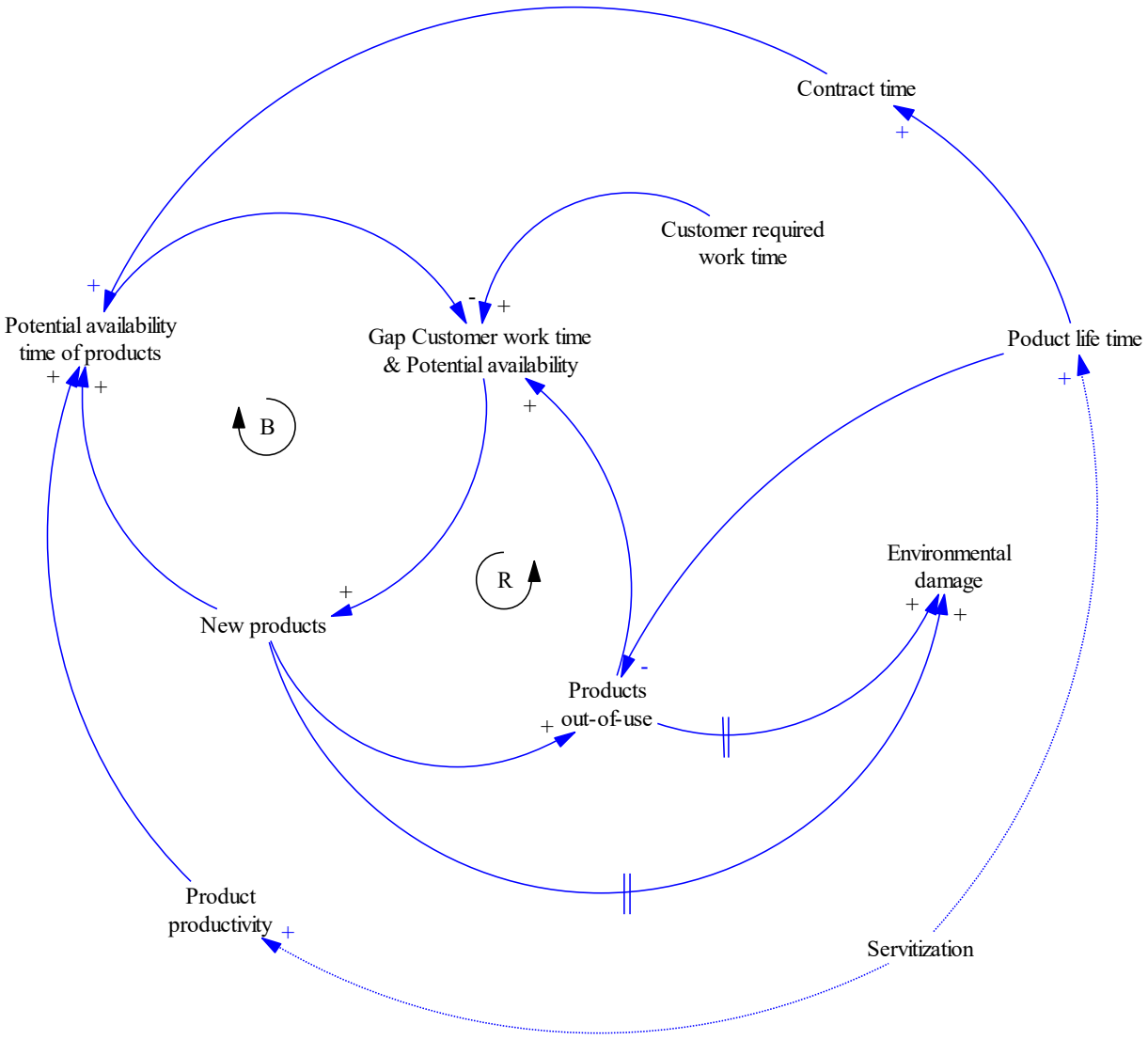

Fig. 3. Model (2) – Causal loop diagram for built-in sustainability in servitization.

that there is no third-hand, fourth-hand markets, etc. While theoretically possible, companies may be reluctant to do so, because the costs may outweigh the economic benefits. By internalizing the costs of the environment, however, a further refurbishing of secondhand products may make sense.

5.2.4. *Servitization: Extended sustainability*

The causal loop diagram in Fig. 5 extends the sustainability view on servitization. In this case, called extended sustainability, we include the possibility of product recycling to obtain an even better sustainability performance, as the recycled components and materials can be used in the same or other supply chains (circular economy). In addition, we consider potential update of customer's beliefs and awareness with respect to environmental sustainability (e.g., Abdelkafi and Täuscher, 2016). If the environmental pressures on customers increase (because of policies that are released because of an increased environmental damage), customers will strive for finding ways to improve their productivity in using products, thus decreasing the gap between customers' requirements and potential availability time of products. This decreases the number of products in use, thus reducing the environmental damage. As such, customer awareness is an important driver for sustainability.

5.2.5. *Models discussion*

The elaborated models expand previous literature such as Tukker (2004) and provide an explanation as to how and why servitization can have a positive impact on environmental sustainability. Derived from our case study insights, the causal loop diagrams show that the positive effects of servitization on environmental sustainability primarily depends on the extension of product lifetime, and hence on the increased level of product availability. This is even the case in model (2), which represents the inherent potential in servitization. In other words, if servitization does not result in an extended availability of the single product, the sustainability benefits will not be achieved. This condition does not hold true, for instance in the case of leasing, in which careless behaviour of customers during product usage (Tukker, 2004) eventually results in a reduction of the product lifetime.

Our results also highlight that the full positive impact of servitization on sustainability is not achieved if companies (i) do not refurbish products that are subsequently inserted into second-hand markets and (ii) do not recover valuable materials from used components through recycling. The causal loop diagrams contain the variables "Refurbishing level of products after first life" to denote the average percentage of products refurbished (Models (3) and (4)), and "recycling level" to refer to the value that is recovered from used components (Model (4)). Both refurbishing and recycling levels decrease environmental damage

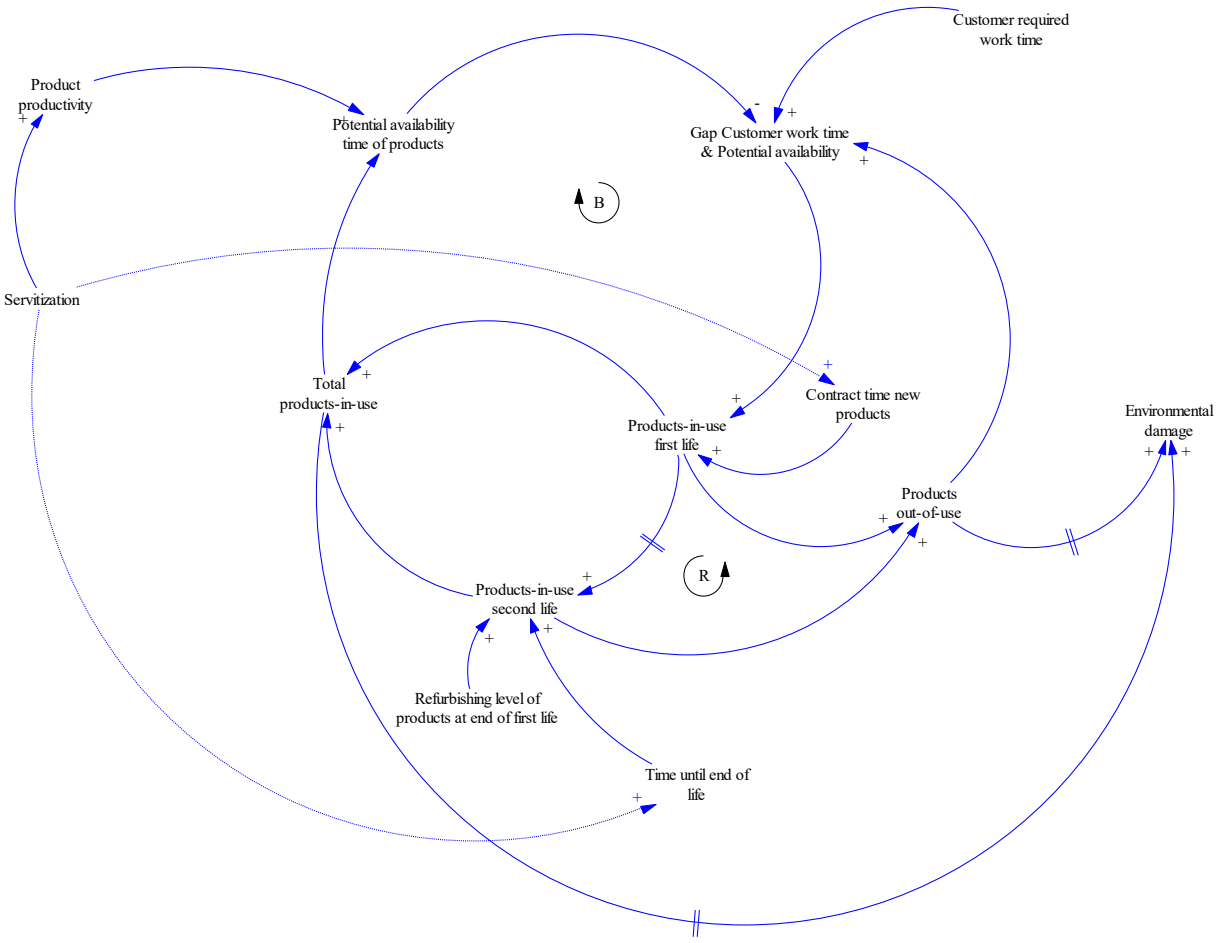

Fig. 4. Model (3) – Causal loop diagram for Built-in and potential sustainability in servitization.

through longer product availability driven by product lifetime extension. However, whereas this aspect is essential to achieve sustainability potential in servitization, companies may not leverage it because of commercial reasons, e.g., when they aim to sell new printers with high profitability margins.

As our causal loop diagrams are inspired by the professional printer case study in the B2B field, the models may have to be slightly adapted or extended when applied to B2C. In B2C, Bocken et al. (2018) found that servitization of laundry washing through a pay-per-use model can drive customers toward a more sustainable consumption by reducing the number of washes and washing temperatures. Thus, customers tend to optimize their product usage with servitization, and this aspect is captured in model (4) through the variable "customer's productivity in product use". As opposed to business customers, however, individual consumers in a B2C relationship may engage in productivity improvement not because they do feel environmental pressures as represented in model (4). Instead, the pricing level of a service unit can lead customers to change their consumption behaviour by opting for a more environmentally oriented pattern.

In addition, note that social sustainability has not been explicitly integrated in the models, as environmental sustainability is our major focus. However, the presence of a second-hand market gives the opportunity to people with a lower income to afford products. It is true that models (3) and (4) explicitly include second-hand products, which can be used for social purposes, but this does not necessarily mean that servitization *per se* does guarantee a full exploitation of latent social potential, as illustrated by the built-in sustainability diagram in model (2).

6. Conclusions and directions for future research

This research investigates the relationships between servitization and sustainability, by discussing the case of the professional printers' supply chain.

Most of the literature assumes a positive relationship between servitization and sustainability. Limited contributions point to the fact that it might not always be the case. This paper enriches the discussion on these relationships in different ways.

Firstly, we discuss the positive relationships between sustainability and servitization, and when these positive relationships are activated. In fact, we show that servitization per se has a "built-in" sustainability, in that the application of this model decreases, ceteris paribus, the number of produced products, provided that servitization increases product lifetime and contract time. Moreover, we point out that more benefits in terms of sustainability can be obtained only if companies and supply chains activate processes aimed at refurbishing and recycling materials, thus creating a second-hand market for products and components. In the latter case, also positive social implications can derive, in that functional products can be sold at a lower price to users with very limited resources. In the case of the professional printers, the export of the printers can allow more people around the world to get access to these products.

Secondly, we discuss why a systemic approach is required when dealing with the link between servitization and sustainability. Given that the environmental damage depends on the proper management of the end of life of the printers, we claim that the possibility for servitization to have an overall positive impact on sustainability depends on the control of the proper management of all the phases of the product lifecycle, including disposal. Specifically, with respect to the analyzed

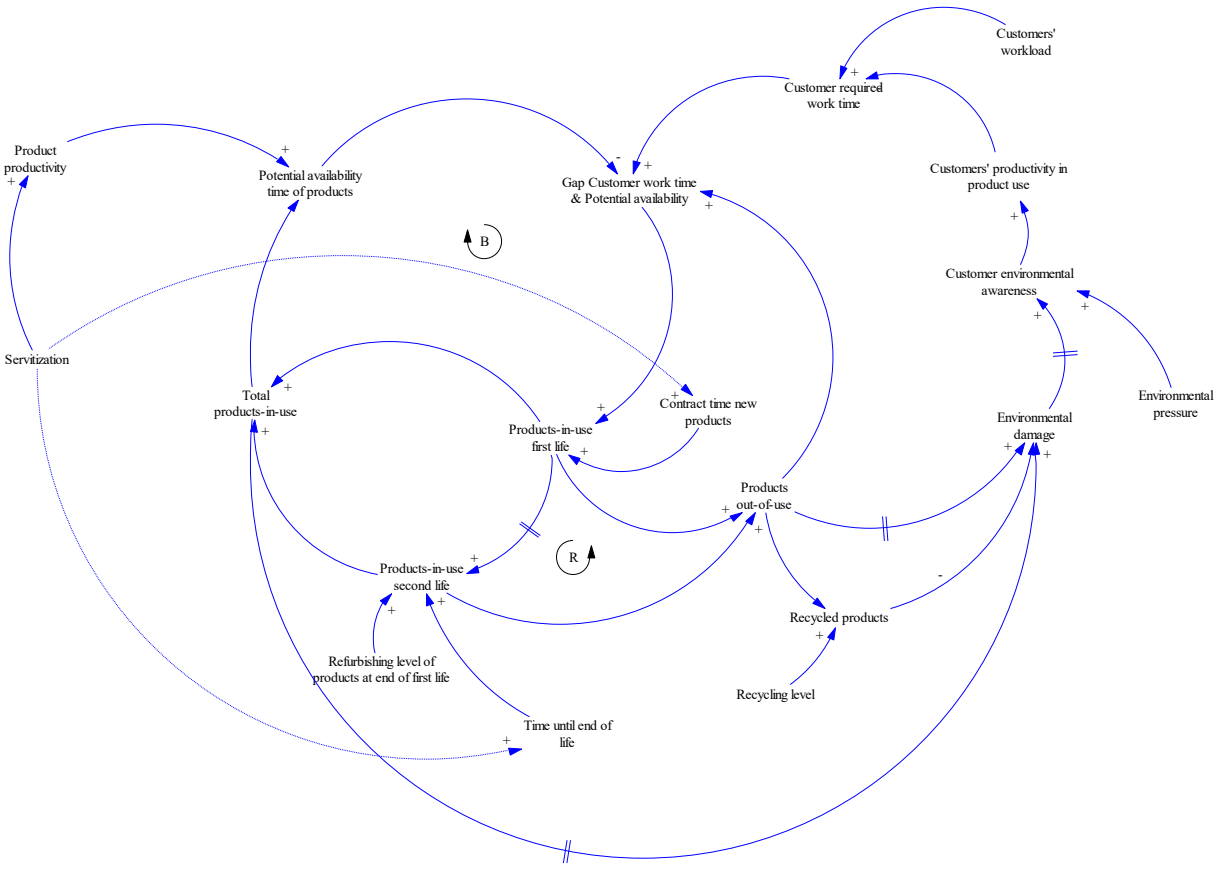

Fig. 5. Model (4) – Causal loop diagram for extended sustainability in the servitization context.

case, a precise evaluation of the implication of servitization on sustainability cannot be estimated, unless the place of disposal of the printers is known and tracked by the exporting countries or the producers themselves.

Therefore, this paper contributes to the debate on the implications of servitization on sustainability by demonstrating that, in line with the claim by Blüher et al. (2020), to properly assess whether servitization is positively or negatively impacting sustainable performance a systemic view should be taken, while considering all phases of product lifecycle, especially the geographical location where these phases take place. This result contributes to the literature on circular economy, in that it supports that to fully exploit the circular economy paradigm in increasing the sustainability performance of supply chains, traceability systems are key (Kouhizadeh et al. 2020).

This research has implications for managers and policy makers. Given the customers' rising awareness about the importance of sustainability, this paper indicates that managers can increasingly leverage servitization to improve sustainability performance of their supply chains. Moreover, investments in activating proper refurbishing and recycling processes are needed to activate the full potential of servitization in improving sustainability. For policy makers, this paper highlights the importance of developing policies, systems, and infrastructures to trace products and to assure their proper disposal.

This research presents, however, some limitations that open the way for further research. The study presents the causal loop diagrams in different sustainability scenarios, while a simulation model can be developed to investigate the effects of servitization-related choices on the final sustainability performance. Moreover, similar studies can be conducted in other sectors to enable a cross-sectoral comparison and learning. Finally, future models can expand our work by taking into account the impact of servitization choices on economic and social sustainability of companies.

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.

References

Abdelkafi, N., Täuscher, K., 2016. Business models for sustainability from a system dynamics perspective. Organization & Environment 29 (1), 74–96.
Abdul-Rashid, S.H., Sakundarini, N., Ghazilla, R.A.R., Thurasamy, R., 2017. The impact of sustainable manufacturing practices on sustainability performance, Empirical evidence from Malysia. International Journal of Operations and Production Management 37 (2), 182–204.
Aurez, V., Bonvallet, K., Kucab, L., Lafore F., Mugnier, E., Sahakian R., & Sims E. (2018). Etude sur le réemploi des équipements électriques et électroniques professionnels à l'export. *Ernst & Young et Associés France*.
Barletta, I., Despeisse, M., Johansson, B., 2018. The proposal of an environmental break-even point as assessment method of product-service systems for circular economy. Procedia Cirp 72, 720–725.
Barravecchia, F., Franceschini, F., Mastrogiacomo, L., Zaki, M., 2021. Research on product-service systems: topic landscape and future trends. Journal of Manaufacturing Technology Management 32 (9), 208–238.
Barrie, J., Cruickshank, H.J., 2017. Shedding light on the last mile: A study on the diffusion of Pay As You Go Solar Home Systems in Central East Africa. Energy Policy 107, 425–436.
Blüher, T., Riedelsheimer, T., Gogineni, S., Klemichen, A., Stark, R., 2020. Systematic literature review—effects of PSS on sustainability based on use case assessments. Sustainability 12 (17), 6989.
Bocken, N.M.P., Mugge, R., Bom, C.A., Lemstra, H.-J., 2018. Pay-per-use business models as a driver for sustainable consumption: Evidence from the case of HOMIE. Journal of Cleaner Production 198, 498–510.
Brouillat, E., 2009. Recycling and extending product-life: an evolutionary modelling. Journal of Evolutionary Economics 19 (3), 437–461.
Confente, I., Buratti, A., Russo, I., 2015. The role of servitization for small firms: drivers versus barriers. International Journal of Entrepreneurship and Small Business 26 (3), 312–331.

Doni, F., Corvino, A., Martini, S.B., 2019. Servitization and sustainability actions. Evidence from European manufacturing companies. Journal of environmental management 234, 367–378.
Dubruc, N., Peillona, S., Farah, A., 2014. The impact of servitization on corporate culture. Procedia CIRP 16, 289–294.
Eccles, R.G., Ioannou, I., Serafeim, G., 2014. The Impact of Corporate Sustainability on Organizational Processes and Performance. Management Science 60 (11), 2835–2857.
Edbring, E.G., Lehner, M., Mont, O., 2016. Exploring consumer attitudes to alternative models of consumption: motivations and barriers. Journal of Cleaner Production 123, 5–15.
Elkington, J., Rowlands, I.H., 1999. Cannibals with forks: The triple bottom line of 21st century business. Alternatives Journal 25 (4), 42.
Forti V., Baldé C.P., Kuehr R., & Bel G. (2020). The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. *United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA),* Bonn/Geneva/Rotterdam.
Gaiardelli, P., Resta, B., Martinez, V., Pinto, R., Albores, P., 2014. A classification model for product-service offerings. Journal of Cleaner Production 66, 507–519.
Gao, J., Bansal, P., 2013. Instrumental and Integrative Logics in Business Sustainability. Journal of Business Ethics 112 (2), 241–255.
Gassmann, O., Frankenberger, K., Csik, M., 2014. The Business Model Navigator: 55 Models that will Revolutionise Your Business. Pearson UK.
Gebauer, H., Gustafsson, A., Witell, L., 2011. Competitive advantage through service differentiation by manufacturing companies. Journal of Business Research 64 (12), 1270–1280.
Gomes, E., Lehman, D.W., Vendrell-Herrero, F., Bustinza, O.F., 2021. A history-based framework of servitization and deservitization. International Journal of Operations & Production Management 41 (5), 723–745.
Hao, Z., Liu, C., Goh, M., 2021. Determining the effects of lean production and servitization of manufacturing on sustainable performance. Sustainable Production and Consumption 25, 374–389.
Iivonen, K., 2018. Defensive responses to strategic sustainability paradoxes: have your coke and drink it too! Journal of Business Ethics 148 (2), 309–327.
Kolleck, A., 2021. Does Car-Sharing Reduce Car Ownership? Empirical Evidence from Germany. *Sustainability* 13 (13), 7384.
Kouhizadeh, M., Zhu, Q., Sarkis, J., 2020. Blockchain and the circular economy: potential tensions and critical reflections from practice. Production Planning & Control 31 (11–12), 950–966.
Kühl, C., Bourlakis, M., Aktas, E., Skipworth, H., 2019. How does servitisation affect supply chain circularity? – A systematic literature review. Journal of Enterprise Information Management 33 (4), 703–728.
Kuo, T.C., 2011. Simulation of purchase or rental decision-making based on product service system. International Journal of Advanced Manufacturing Technology 52 (9–12), 1239–1249.
Kurpiela, S., Teuteberg, F., 2022. Strategic planning of product-service systems: A systematic literature review. Journal of Cleaner Production 338, 130528.
Lindahl, M., Sundin, E., Sakao, T., 2014. Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases. Journal of Cleaner Production 64, 288–296.
Meredith, J., 1998. Building operations management theory through case and field research. Journal of Operations Management 16 (4), 441–454.
Mosch, P., Schweikl, S., Obermaier, R., 2021. Trapped in the supply chain? Digital servitization strategies and power relations in the case of an industrial technology supplier. International Journal of Production Economics 236, 108141.
Ockwell, D., Atela, J., Mbeva, K., Chengo, V., Byrne, R., Durrant, R., Kasprowicz, V., Ely, A., 2019. Can Pay-As-You-Go, Digitally Enabled Business Models Support Sustainability Transformations in Developing Countries? Outstanding Questions and a Theoretical Basis for Future Research. Sustainability 11 (2015), 1–21.
Parida, V., Sjödin, D.R., Wincent, J., Kohtamäki, M., 2014. Mastering the transition to product-service provision: Insights into business models, learning activities, and capabilities. Research-Technology Management 57 (3), 44–52.
Reim, W., Parida, V., Örtqvist, D., 2015. Product-Service Systems (PSS) business models and tactics – A systematic literature review. Journal of Cleaner Production 97, 61–75.
Salas-Zapata, W.A., Ortiz-Muñoz, S.M., 2019. Analysis of meanings of the concept of sustainability. Sustainable Development 27 (1), 153–161.
Schulz, F.C., 2022. The circular economy and economic growth – An irreconcilable tradeoff? Resources, Conservation & Recycling 183 (106351), 1–2.
Stasko, T.H., Buck, A.B., Gao, H.O., 2013. Carsharing in a University Setting: Impacts on Vehicle Ownership, Parking Demand, and Mobility in Ithaca, NY. Transportation Policy 30, 262–268.
Tukker, A., 2004. Eight types of product-service system: Eight ways to sutainability? Experiences from suspronet. Business Strategy and the Environment 260, 246–260.
Vandermerwe, S., Rada, J., 1988. Servitization of business: Adding value by adding services. European Management Journal 6 (4), 314–324.
Visintin, F., 2012. Providing integrated solutions in the professional printing industry: The case of Océ. Computers in Industry 63 (4), 379–388.
Walker, K., Yu, X., Zhang, Z., 2020. All for one or all for three: Empirical evidence of paradox theory in the triple-bottom-line. Journal of Cleaner Production 275, 1–12.
Yang, M., Evans, S., 2019. Product-service system business model archetypes and sustainability. Journal of Cleaner Production 220, 1156–1166.
Yin, R.K., 2017. Case Study Research and Applications: Design and Methods. SAGE Publications Inc.
Xerox website, retrieved online on February 2022 at: https://www.xerox.com/en-us/about/ehs/equipment-recycling#:~:text=Consumers%20from%20all%20other%20states,will%20cover%20the%20recycling%20costs.&text=If%20your%20Xerox%20product%20was,the%20device%20at%20no%20charge.