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Servitisation and performance in the business-to-business context: the moderating role of Industry 4.0 technologies

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Abstract

Purpose – This article aims to contribute to the digital servitisation literature by investigating the interrelations amongst Industry 4.0 technologies, servitisation and the performance of manufacturing small and medium-sized enterprises (SMEs).
Design/methodology/approach – The research uses survey data drawn from 200 manufacturing SMEs operating in the metals and machinery sector in Italy.
Findings – The study shows that Industry 4.0 technologies – Internet of Things (IoT), advanced simulation, cloud computing and Big Data Analytics (BDA) – positively moderate the relationship between servitisation and the performance of SMEs.
Research limitations/implications – The study supports the need for firm managers of manufacturing SMEs to align servitisation and technological investments, suggesting that the synergic deployment of Industry 4.0 technologies supports servitisation performance.
Practical implications – The study supports the need for firm managers operating in business-to-business contexts to align their technological investments and servitisation strategies, suggesting that the synergic deployment of these Industry 4.0 technologies empower the effectiveness of servitisation strategies in terms of performance achieved.
Originality/value – The study highlights the moderating role played by specific Industry 4.0 technologies in the servitisation–performance relationship, opening avenues for future research exploring the mechanisms that underpin this complex relationship.

Keywords Industry 4.0, Servitisation, Performance, Digitalisation, Manufacturing firms
Paper type Research paper

1. Introduction

Servitisation of manufacturing is a well-known phenomenon, the evolution of which has been widely analysed over 3 decades of research (Baines *et al.*, 2017; Raddats *et al.*, 2019; Fliess and Lexutt, 2019). Initially defined as the process of increasing value by adding services to a

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manufacturing firm's offerings (Vandermerwe and Rada, 1988), multifaced and heterogeneous conceptualisations of servitisation have been proposed over the years (Fliess and Lexutt, 2019). In their recent literature review, Brax *et al.* (2021) identified three main conceptualisations in the literature: (a) the *transition* of the firm's position in the industry value chain (Ziaee Bigdeli *et al.*, 2018); (b) the *extension* of the firm's offering portfolio (Zhou *et al.*, 2020); and (c) an organisational *transformation* (Brax, 2005). This last research stream captures the transformational process through which companies shift from a product-centric to a service-centric business model and logic (Kowalkowski *et al.*, 2017b; Fliess and Lexutt, 2019).

In this field, a stream called "*digital servitisation*" has emerged as a relatively new analysis perspective exploring the combined effect of servitisation and digitalisation (Kohtamäki *et al.*, 2019; Kharlamov and Parry, 2021; Paschou *et al.*, 2020; Solem *et al.*, 2021). Through digital technologies, firms can offer new or more advanced services (Kohtamäki *et al.*, 2019; Alcácer and Cruz-Machado, 2019) but also facilitate the transition toward service-oriented business models or even to radical servitisation strategies (Grubic and Jennions, 2018; Kohtamäki *et al.*, 2019; Paiola and Gebauer, 2020; Paiola *et al.*, 2022). Recent articles have also shown the influence of digitalisation on the relationship between servitisation and performance (Martín-Peña *et al.*, 2020; Kharlamov and Parry, 2021; Abou-Foul *et al.*, 2021). Despite the growing number of studies, the interplay between digitalisation and servitisation still remains a research priority (Raddats *et al.*, 2019), and, in particular, the impact of Industry 4.0 technologies needs further investigation, also because a better understanding of benefits of such technologies could help manufacturing firms to evaluate opportunities and challenges of digital transformation (Khin and Kee, 2022).

Industry 4.0 refers to various technologies that are driving the digital transformation of manufacturing firms (Müller, 2019; Ortt *et al.*, 2020; Szasz *et al.*, 2021). Seminal studies have suggested that some Industry 4.0 technologies, such as the Internet of Things (IoT), Big Data Analytics (BDA), software simulation and cloud computing, are more related to servitisation (Coreynen *et al.*, 2017; Ardolino *et al.*, 2018; Frank *et al.*, 2019a; Paiola *et al.*, 2022). Such technologies can be functional to innovative or advanced services in line with existing service-oriented strategies (e.g. Frank *et al.*, 2019a; Coreynen *et al.*, 2017; Ardolino *et al.*, 2018; Paiola and Gebauer, 2020). For instance, IoT and BDA can be used to collect customer information and disseminate customer-related knowledge within the organisation, supporting the service orientation of companies (Fliess and Lexutt, 2019). Moreover, these technologies can also enable entirely new service-based business models (Kohtamäki *et al.*, 2019; Paiola and Gebauer, 2020; Vendrell-Herrero *et al.*, 2017; Paschou *et al.*, 2020; Frank *et al.*, 2019a; Porter and Heppelmann, 2015), allowing companies to shift their value proposition to a service offering or even start selling service packages instead of products. For instance, through the integrated use of IoT, BDA and cloud computing, an established machinery manufacturer could produce plants that could be remotely controlled and managed, finally adopting a pay-per-use business model (Bortoluzzi *et al.*, 2020; Paiola and Gebauer, 2020). So far, digital servitisation literature has explored the influence of digitalisation on the relationship between servitisation and performance considering, though, wide groups of digital technologies ranging from social media to customer relationship management software rather than focussing on Industry 4.0 (e.g. Kohtamäki *et al.*, 2020; Martín-Peña *et al.*, 2020; Abou-Foul *et al.*, 2021). The few existing studies on Industry 4.0 have qualitatively explored the relationship between servitisation and some technologies (e.g. Frank *et al.*, 2019a; Paiola *et al.*, 2022), whereas digital servitisation has not yet specifically investigated the influence of Industry 4.0 endowments on the relationship between servitisation and performance in the context of manufacturing SMEs. This study responds to recent calls for quantitative research in this area (Kowalkowski *et al.*, 2017b; Fliess and Lexutt, 2019) by analysing a sample of 200 Italian manufacturing SMEs operating in the metals and machinery sector. In doing so, the study sheds light on the influence of servitisation and a specific group of Industry 4.0 technologies, namely, IoT, simulation, cloud computing and BDA, on firm performance and investigates the moderating role of such technologies on the relationship between servitisation and firm performance.

This research, therefore, contributes to digital servitisation by complementing and extending past studies underlining the impact of digitalisation on the relationship between servitisation and performance, which mainly referred to large groups of digital technologies including also technologies such as social media, customer relationship management, automation and others (Kharlamov and Parry, 2021; Fliess and Lexutt, 2019; Kohtamäki *et al.*, 2020; Martín-Peña *et al.*, 2020; Paschou *et al.*, 2020; Abou-Foul *et al.*, 2021) rather than focussing on Industry 4.0 technologies (Bortoluzzi *et al.*, 2020). In particular, we examine the role of Industry 4.0 technologies that are functional to servitisation: IoT, simulation, cloud and BDA (e.g. Frank *et al.*, 2019a; Paiola *et al.*, 2021; Kohtamäki *et al.*, 2020; Lexutt, 2020). Moreover, we respond to recent calls for more quantitative studies on Industry 4.0 technologies in relation to servitisation (Kohtamäki *et al.*, 2020; Paschou *et al.*, 2020; Paiola *et al.*, 2021), given that the current literature on this topic is mainly qualitative (Lexutt, 2020; Ardolino *et al.*, 2018; Frank *et al.*, 2019a; Paiola *et al.*, 2021; Cimini *et al.*, 2021a). Hence, we contribute to the ongoing debate on the mechanisms through which such technologies translate into superior service value for companies (Müller, 2019). Our analysis shows that servitisation can help manufacturing firms to drive value from Industry 4.0 adoption.

The article is organised as follows. The next section illustrates the research hypotheses, followed by an explanation of the methodology. Then, the results and discussion are presented, including theoretical and practical implications. Finally, conclusions include limitations and future research directions.

2. Theoretical background and research hypotheses

2.1 The relationship between servitisation and performance

The debate on the relation between servitisation and performance is open and multi-faceted (Fliess and Lexutt, 2019), as the literature has provided controversial findings (Baines *et al.*, 2017; Wang *et al.*, 2018). This might be explained in part by the different measurements used to assess performance and servitisation (Wang *et al.*, 2018; Ziaee Bigdeli *et al.*, 2018; Lexutt, 2020; Bustinza *et al.*, 2019), an aspect that makes comparisons between samples and results difficult. However, recent reviews have attempted to summarise the findings in the field (Wang *et al.*, 2018; Brax *et al.*, 2021).

The extensive literature on servitisation has identified several potential advantages of service-based strategies (e.g. Baines *et al.*, 2017; Neely, 2008), which can be financial (e.g. more stable revenue streams and higher profitability), strategic (e.g. a more sustainable competitive advantage resulting from difficult-to-imitate services tailored to the specific needs of clients), marketing-related (e.g. more insights into customers' needs, increased customer loyalty and higher levels of client retention), social and environmental benefits (e.g. reduced waste during production due to streamlined activities along the supply chain) (Wang *et al.*, 2018; Baines *et al.*, 2017; Zhang *et al.*, 2022). Conversely, servitisation can also lead to negative outcomes, such as financial losses (Visnjic *et al.*, 2016), additional costs and potential drawbacks (Valtakoski, 2017) and strategic failures (Brax *et al.*, 2021). Sometimes, servitisation requires manufacturers to innovate business models, which entails additional costs or leads them into segments and markets where they lack confidence and experience (Cusumano *et al.*, 2015; Frank *et al.*, 2019a). This is particularly true when servitisation moves beyond the simple increase of service orientation or service portfolios, representing a "transformational process of shifting from a product-centric business model to a service-centric approach" (Kowalkowski *et al.*, 2017b, p. 7). In this sense, managing the transition from products to services may imply difficulties that may result in the so-called "service paradox" (Baines *et al.*, 2017; Brax, 2005). According to Brax *et al.* (2021), the servitisation–performance relationship is threatened by two main paradoxes: the financial paradox, which occurs when a firm, despite substantial investments and additional costs to extend the service business, does not achieve the expected returns (Neely, 2008), and the organisational paradox, which occurs when the firm incurs a risk of failure during the process due to organisational rigidities (Brax, 2005; Brax *et al.*, 2021).

The extant literature has widely discussed the conditions under which manufacturing firms may benefit from servitisation (Baines *et al.*, 2017; Wang *et al.*, 2018). The factors that may explain different outcomes include firm capabilities (Wang *et al.*, 2018), organisational configuration (Bustinza *et al.*, 2019), other strategic decisions (Bustinza *et al.*, 2019), the role of customers (Johansson *et al.*, 2019) and the industries and geographical regions of firms (Wang *et al.*, 2018). Indeed, studies have shown that servitisation-performance relationship is non-linear (Zhou *et al.*, 2020; Brax *et al.*, 2021). According to Brax *et al.* (2021), this relationship is generally positive when the servitisation level is low and companies have limited service portfolios and low service turnover. However, the relationship can decline, leading to company failure (Brax *et al.*, 2021). Meanwhile, a positive relationship emerges when the level of servitisation is high, with companies offering advanced services and refocussing the entire organisation to serve the transition from a product to a service centric approach, the so-called excellence driven servitisation (Brax *et al.*, 2021, p. 537). This condition, however, is fulfilled when companies also show a managerial service orientation, organisational capabilities and an organisational structure supporting this process (Lexutt, 2020). Despite the open debate on possible drawbacks, we rely on the extant literature that considers all the potential advantages of servitisation to formulate our first research hypothesis:

H1. The higher the servitisation, the better the performance of manufacturing firms.

2.2 The relationship between industry 4.0 and performance

A research stream studying the impacts of Industry 4.0 on performance has emerged over the last few years (Kohtamäki *et al.*, 2020; Dalenogare *et al.*, 2018), initially exploring the expected impacts (e.g. Chauhan and Singh, 2019; Büchi *et al.*, 2020) and then considering real and operational performance indicators (e.g. Szasz *et al.*, 2021; Tortorella *et al.*, 2019; Bettiol *et al.*, 2021). Industry 4.0 refers to a various group of technologies that go beyond the simple information and communication systems, but there is no universally accepted definition or clear measurement of Industry 4.0 (Culot *et al.*, 2020). Industry 4.0 can positively affect new product development, product capability enhancement and production process improvements, also leading to profound organisational changes and completely renewed firm strategies and business models (Govindarajan and Immelt, 2019; Porter and Heppelmann, 2015; Cimini *et al.*, 2021b; Culot *et al.*, 2020; Müller *et al.*, 2021). Expected benefits include reduced production costs and waste, improved production flexibility and quality, increased operational efficiency, customer satisfaction and value creation-related performance management (e.g. Müller *et al.*, 2021; Alcácer and Cruz-Machado, 2019; Sauter *et al.*, 2015; Szasz *et al.*, 2021) as well as opportunity creation (Büchi *et al.*, 2020). However, the literature has suggested that performance impacts vary depending on the technologies analysed (Tortorella *et al.*, 2019) as both internal and external barriers can emerge during the selection and adoption process undermining their potential positive impact (Chauhan *et al.*, 2021; Savastano *et al.*, 2022). Moreover, as there is no single technological solution or combination fitting all-sized firms, SMEs select and incrementally implement the most relevant Industry 4.0 technologies to improve their products, processes and businesses (Chiarvesio and Romanello, 2018). Previous studies have suggested that the isolated initiative of implementing a single Industry 4.0 technology does not necessarily lead to positive impacts, as the most tangible benefits come from the synergy associated with their combined use (Porter and Heppelmann, 2015; Alcácer and Cruz-Machado, 2019; Frank *et al.*, 2019b; Büchi *et al.*, 2020; Bettiol *et al.*, 2021). A consensus has been reached on the dominant role of IoT, which entails the embedding of radio frequency identification tags, smart sensors and connectivity components that enable parts, components, products, devices and machinery to interact with each other and also with external systems to provide additional information and new functionalities to users (Ng and Wakenshaw, 2017; Sauter *et al.*, 2015; Rüßmann *et al.*, 2015). In addition, IoT lays the foundations for Big Data collection, sharing and analytics (Porter and Heppelmann, 2015), and, when combined with the cloud, can be used to improve product innovation and process optimisation (Jerningan *et al.*, 2016). Simulation may rely on data collected through IoT devices, thus reducing product design and development costs whilst improving product quality and process efficiency (Mourtzis *et al.*, 2014). IoT can also be implemented in processes, allowing high levels of automation, robotisation and remote management and control of plants, adopting a factory-of-the-future perspective (Culot *et al.*, 2020).

Büchi *et al.* (2020) showed that the breadth, intended as the number, of Industry 4.0 technologies a company possesses and the pervasiveness of their use have a synergic impact on opportunity creation. However, when observing real performance indicators rather than expected ones, results might change. Szasz *et al.* (2021) found that Industry 4.0, which considers advanced technologies, technologies related to the smart factory of the future and the shift towards automation and robotisation, impacted cost, quality, delivery and flexibility performance. Tortorella *et al.* (2019) differentiated between Industry 4.0 technologies that support manufacturing processes and those that support product and service development, reaching different conclusions: process-related Industry 4.0 technologies positively impact operational performance indicators, whilst product-related technologies have no direct impact. In their study, instead, product and service development technologies, including IoT and BDA, moderated the relationship between lean practices and operational performance indicators. Similarly, Bettiol *et al.* (2021) observed different impacts of specific groups of Industry 4.0 technologies on knowledge-related performance indicators: robotics and augmented reality enhanced operations and job-related learning; IoT, BDA and cloud improved servitisation; and additive manufacturing technologies played a key role in customer involvement. Hence, the breadth of Industry 4.0 is generally positively related to both real operational performance indicators and expected impacts related to the number of opportunities identified (Bettiol *et al.*, 2021; Büchi *et al.*, 2020; Szasz *et al.*, 2021), although Tortorella *et al.* (2019) found that product and service-related technologies did not have a direct effect on operational performance. Accordingly, we formulated our second research hypothesis in relation to firm performance as follows:

H2. The higher the breadth of Industry 4.0 technologies, namely, IoT, simulation, cloud and BDA, the better the performance of manufacturing firms.

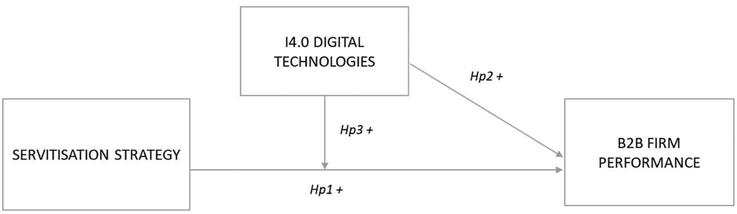
2.3 The moderating role of industry 4.0 technologies in the relationship between servitisation and performance

Studies on digital servitisation have clearly indicated that some Industry 4.0 technologies can support servitisation pathways (e.g. Coreynen *et al.*, 2017; Paiola and Gebauer, 2020; Frank *et al.*, 2019a; Kowalkowski *et al.*, 2017a; Rymaszewska *et al.*, 2017; Raddats *et al.*, 2022). Such technologies can be used to both extend current service offerings (e.g. Ardolino *et al.*, 2018; Coreynen *et al.*, 2017; Frank *et al.*, 2019a) and to support the development of innovative digital- and service-based business models (Ng and Wakenshaw, 2017; Kamp and Parry, 2017; Paiola and Gebauer, 2020). Focussing on four manufacturing SMEs, Coreynen *et al.* (2017) observed that different advanced technologies enabled manufacturing companies to follow distinct servitisation pathways. Although considering traditional communication technologies rather than pure Industry 4.0, their results indicate that these pathways may lead to different service levels, which the provider further integrates into the customer's processes, thereby increasing its competitive advantage over competitors. In a qualitative study, Paiola and Gebauer (2020) identified three different areas of impact of IoT technologies, thus identifying three types of service-based business models expressing different strategic orientations. Ardolino *et al.* (2018) discussed how firms can leverage some Industry 4.0 technologies —– IoT, cloud computing and predictive analytics — to pursue specific servitisation strategies. Likewise, Frank *et al.* (2019a) examined different combinations of servitisation and levels of adoption of Industry 4.0 technologies, which resulted in different types of business model innovation. Although servitisation without digitalisation is possible, the most interesting combination was obtained with high levels of digitisation and servitisation, leading manufacturers to offer digitally enabled solutions that provided value for both the firms and customers (Frank *et al.*, 2019a). Fliess and Lexutt (2019) showed that advanced technologies, such as smart products, remote monitoring and BDA, as well as systematic information gathering and sharing, can be used to disseminate customer information and knowledge within the organisation, strongly contributing to servitisation success. In addition, Paiola *et al.* (2021) reported that Industry 4.0 technologies, particularly IoT, the cloud, artificial intelligence and BDA, can enable a service-oriented value proposition for the purposes of digital servitisation, although two factors impact the process of value creation and capture: the technological preparedness of the firm and the characteristics of the type of offering. To succeed in digital servitisation, companies need to develop a proper combination of skills (Cimini *et al.*, 2021a) and to manage the interconnections between technology implementation and organisational change (Cimini *et al.*, 2021b). Prior knowledge of technologies allows the company to choose technological solutions that are aligned with the strategy of the firm, a pre-condition for success (Kane *et al.*, 2015; Paiola *et al.*, 2021). As previous studies have shown that digitalisation can moderate the relationship between servitisation and firm performance (Kharlamov and Parry, 2021; Abou-Foul *et al.*, 2021), Industry 4.0 technologies that are functional to servitisation are likely to have a similar effect. As observed by Bortoluzzi *et al.* (2020), companies that simultaneously implemented a combination of specific Industry 4.0 technologies, namely, IoT, simulation, cloud and BDA, along with their servitisation achieved better results in terms of customer loyalty and product positioning than companies that used no technologies.

Based on the literature mentioned above, which suggests that synergies between servitisation and the endowment of Industry 4.0 technologies that are related to product innovation and service can positively impact firm performance, we formulated our third hypotheses as follows:

H3. The breadth of Industry 4.0 technologies, namely, IoT, simulation, cloud and BDA, has a positive moderating effect on the relationship between servitisation and the performance of manufacturing firms.

Figure 1 provides a graphical representation.



Source(s): Authors' own elaboration

Figure 1. Graphical representation

3. Methodology

3.1 Data collection and sample characteristics

To test our hypotheses, we developed a survey using Computer-Assisted Telephone Interviewing (CATI) by contacting a population of 736 SMEs with business-to-business (B2B) models in the metals and machinery sector in Friuli Venezia Giulia. We chose this industry as a relevant context of analysis for two reasons: (a) companies have traditionally shown a tendency toward servitisation; and (b) a tendency to adopt more than one Industry 4.0 technology (Federmeccanica, 2017). We targeted SMEs, as defined by the European Commission's Recommendation 96/280/EC, because they represent 95% of the population in the regional sector.

To guarantee the quality of the research, we followed Dillman's protocol. We sent to each firm a pre-notice email and a personalised cover letter ensuring anonymity during data analysis, explaining that data was collected for several unrelated studies and would be analysed to address future regional sectoral policies (Podsakoff *et al.*, 2012). Data collection was endorsed by the regional cluster agency of metals and machinery, which increases the participation rate and the motivation of respondents to make cognitive efforts to answer questions in an optimal way (Krosnick, 1999). We chose CATI method due to the complexity and duration of the survey to increase content validity as trained researchers assisted respondents during the process (Podsakoff *et al.*, 2012).

Survey responses were collected from April to June 2018. A total of 229 SMEs completed the survey, corresponding to a response rate of 31.1%, which is acceptable for this type of research (Dillman, 2000). After excluding incomplete responses, we obtained a final dataset to 200 responses. Table 1 provides a description of the sample.

We assessed non-response bias by comparing early and late respondents as the latter are considered to be more like non-respondents (Armstrong and Overton, 1977). We carried out *t*-tests on the export sales on the total sales ($p = 0.283$), the growth rate over the past three years ($p = 0.703$) and firm age ($p = 0.060$), founding not significant differences between the two sub-samples.

Characteristics	Mean	Standard deviation	Min	Max
Age	27.91	14.73	4.00	100.00
Turnover (Millions of Euro)	6.19	7.48	0.082	48.28
Employees	34.85	37.44	2	191
Foreign sales on total sales (%)	35.17	35.00	0	100
Industry 4.0 technologies adoption				
		N		%
Non adopters		81		40.5
Adopters		119		59.5
Industry 4.0 technologies				
		N		%
Internet of Things		55		27.5
Simulation		74		37.0
Cloud computing		34		17.0
Big Data Analytics		35		17.5

Source(s): Authors' own elaboration

Table 1.
Sample description

3.2 Questionnaire and measures

The survey instrument was developed in several stages following appropriate procedures and based on insights gained from in-depth interviews with managers of small companies (Denicolai *et al.*, 2021). We pre-tested the survey with two entrepreneurs, two industry experts and three researchers to obtain feedbacks on the clarity of the questions. Some wording was then modified to avoid misunderstanding. The final questionnaire was organised in six separate thematic sessions and included a total of 50 open and closed questions. The average completion time was 25–40 min. Respondents included entrepreneurs and managers, such as chief executive officers, chiefs of accounting, production and quality managers, sales managers and financial managers. To ensure an accurate level of knowledge related to the survey content, the respondent for each firm was identified with the assistance of the metals and machinery's cluster manager, who is in charge of assisting firms with their digital transformation process.

Table 2 provides a detailed description of the variables included in the analysis. Our dependent variable, firm performance, was measured with a self-assessed five-point Likert scale. Based on Hult *et al.* (2008), respondents were asked to subjectively rank their firms' overall effectiveness performance over the past five years. In the management literature, perceived performance measures are widely accepted because they increase the propension of respondents to properly answer the question (Hult *et al.*, 2008). Moreover, in the servitisation literature, perceived performance measures seem to be more frequent than objective ones, and the effects tend to be stronger in traditional manufacturing sectors, such as equipment and machinery (Wang *et al.*, 2018; Ziaee Bigdeli *et al.*, 2018).

Independent variables were measured as follows. We based the servitisation variable on the definition provided by Kowalkowski *et al.* (2017b, p. 7) as "the transformational process of shifting from a product-centric business model and logic to a service-centric approach". We measured it using a self-assessed five-point Likert scale assessing the last five years. Consequently, our measure captured the recent transition toward a revised business model based on services rather than a more incremental increase of the service offering. A reverse question, not included in our model, referring to de-servitisation was asked as a control item to verify the accuracy of the responses. Single item scales can be almost as effective as multi-scale constructs when the construct is unambiguous and the variable to be operationalised has a clear interpretation (Denicolai *et al.*, 2021), as it was confirmed during the pre-test of this survey.

Industry 4.0: The selection of Industry 4.0 technologies was the result of a twofold process. Starting from the list proposed by Rüßmann *et al.* (2015), we identified the service-related Industry 4.0 technologies based on previous literature, including IoT, simulation and BDA (Coreynen *et al.*, 2017; Ardolino *et al.*, 2018). Next, in-depth interviews were conducted with four entrepreneurs to validate this initial selection and to understand the mechanisms underpinning this relationship. Through a focus group with entrepreneurs, researchers and sector experts, we validated the final selection of four main technologies: IoT, advanced simulation, cloud computing, and BDA. The final selection was then also confirmed by recent studies highlighting that these four technologies are particularly functional to servitisation (Frank *et al.*, 2019a; Bortoluzzi *et al.*, 2020; Paiola *et al.*, 2021). This exploratory phase showed that such technologies have a synergic effect when adopted together to support radical servitisation strategies. Industry 4.0 technologies were measured as the sum of the four selected technologies. Each variable was a dummy variable, coded as zero to indicate that the technology was not implemented and one to indicate that it was implemented. The four dummies were then summed to obtain an indicator of Industry 4.0, ranging from 0 (no technologies adopted) to 4 (four technologies adopted), following similar approaches used in recent studies (e.g. Martín-Peña *et al.*, 2020; Büchi *et al.*, 2020). The Chi-square test confirmed that the averages and correlations amongst technologies differed, thus supporting the sum of

Variable	Definition	Encoding
Firm performance	Self-assessment on 1–5 point Likert scale of overall effectiveness performance over the last 5 years (perception)	1 Extremely negative 2 Negative 3 Neither negative nor positive 4 Positive 5 Extremely positive
Servitisation	Self-assessment on 1–5 point Likert scale of the transformational process of shifting from a product-centric business model and logic to a service-centric approach over the last five years	1 Strongly disagree 2 Somewhat disagree 3 Neither agree nor disagree 4 Somewhat agree 5 Strongly agree
Industry 4.0 technologies	Sum of the following Industry 4.0 technologies: Internet of Things, Simulation, Cloud computing and Big Data Analytics	0–4
Product type	Typology of the product	1 (Machinery and finished products) 0 (Components manufactures)
Market diversification	Number of sectorial markets served by the firm	Continuous variables
Sector maturity	Self-assessment on 1–5 point Likert scale of the maturity of the sector (perception)	1 Very low 2 Low 3 Neither low nor high 4 High 5 Very high
Employees	Number of employees within the firm (firm size)	Continuous variables
Customers concentration	Percentage of the first three customers on the firm turnover	Continuous variables
Country	Number of countries in which the firm sold its products and/or services	Continuous variable
Age	Number of years from firm inception	Continuous variable
Slack resources	Ratio current total assets to current total liabilities	Continuous variable

Source(s): Authors' own elaboration

Table 2.
Variable description and encoding

technologies (Guide and Ketokivi, 2015). The combination of multiple technologies at once represents an advanced level of adoption of Industry 4.0 technologies (Frank *et al.*, 2019a).

Control variables. We controlled for *firm size* and *firm age*, as larger firms could possess more resources and capabilities, resulting in better performance, whereas mature firms could have inertia and sunk costs that deter innovative strategies and negatively impact performance (Valtakoski and Witell, 2018; Aboul-Foul *et al.*, 2021). Based on previous studies, we also controlled for geographical *market scope* as a proxy of internationalisation (Valtakoski and Witell, 2018) and *slack resources* (Aboul-Foul *et al.*, 2021). Finally, we controlled for environmental variables related to *sector maturity* (Wang *et al.*, 2018; Fliess and Lexutt, 2019; Aboul-Foul *et al.*, 2021) and other influential variables related to *product type*, *market diversification* and relative *concentration of main customers*.

3.3 Methods

We performed multivariate linear regression models using IBM SPSS® (v. 25) to test how the specific endowment of Industry 4.0 technologies influences the relationship between servitisation and the performance of firms (Büchi *et al.*, 2020). This approach is, particularly, suitable for our study because it is a sequential process that involves the entry of predictor variables in to the analysis in steps whose order is based on theory (Henderson and Velleman, 1981).

We used both procedural remedies and statistical tests to address common method bias, which can be problematic in surveys (Guide and Ketokivi, 2015). As underlined by Podsakoff *et al.* (2012), procedural remedies are effective to maintain the content validity of the item as a priority when self-perceived measures are used (MacKenzie *et al.*, 2011). In particular, we used proximal and psychological separation of items, we guaranteed the anonymity of the respondents and we increased the motivation to exert cognitive efforts to provide optimal answers by explaining that data would also be analysed for policy purposes (Krosnick, 1999; Podsakoff *et al.*, 2003). To guarantee the proximal separation of items, we separated the independent and dependent variables into different sections of the surveys (Podsakoff *et al.*, 2003). For instance, the servitisation measure was placed 33 questions apart from the performance-related question. Also, data collection through telephonic interviews prevented respondents from returning to previously answered questions and, consequently, from changing their answers to make them more consistent. Moreover, we also guaranteed psychological separation by camouflaging our interest in main predictors by embedding them in the context of other questions (Podsakoff *et al.*, 2012).

Next, we controlled for common method bias for the variable *"Servitisation"* through an instrumental variable approach based on two stage regressions (Podsakoff *et al.*, 2012; Gaggero *et al.*, 2019). As an instrumental variable, we selected the importance of the *level of service offered to the clients*, which satisfied two conditions: (a) the relevance condition and (b) exogeneity to the model (Gaggero *et al.*, 2019). In the first-stage, our instrumental variable is found highly statistically significant, with a *p-value* < 0.01. This finding points in favour of a strong correlation between *servitisation* and the *level of service,* lending support to the instrument relevance condition of *level of service*. In the second-stage, the *level of service* was statistically insignificant from zero (*p-value* 0.906), sustaining the presumption that the variable is exogenous thus the level *of service* has no explanatory power in the model and corroborates the full exogeneity and validity of this variable as instrument for *servitisation*, mitigating the risk of common method bias (Guide and Ketokivi, 2015).

4. Results

Table 3 shows the Pearson correlations. Servitisation was positively related to increased firm performance ($p < 0.05$), whereas Industry 4.0 technologies were not significant. The control variables were not statistically correlated with firm performance, except for age, which was statistically and negatively correlated with the perceived performance ($p < 0.01$).

Table 4 presents the results of the empirical analysis. Three multiple regression models were used to test our research hypotheses. Model 1 only included the control variables. The relationship between age and firm performance was statistically significant and negative (−0.211; $p < 0.01$), whilst the one with slack resources was statistically significant and positive (0.098; $p < 0.05$).

In addition to control variables, Model 2 included also the two independent variables: servitisation and Industry 4.0 technologies. The relationship between servitisation and firm performance was statistically significant and positive (0.156; $p < 0.05$), providing empirical support for Hypothesis 1. This result corroborates prior findings (Ziaee Bigdeli *et al.*, 2018; Lexutt, 2020) and recent studies suggesting a positive relationship when servitisation is not proxied as service revenues, performance is measured through non-financial indicators and the empirical context relates to traditional manufacturing (Wang *et al.*, 2018). Instead, the relationship between Industry 4.0 technologies and firm performance was not statistically significant, thus Hypothesis 2 is not supported. Past studies showed that the breadth of

Table 3. Means, standard deviations and correlations

	Mean	SSD	1	2	3	4	5	6	7	8	9	10	11
1. Firm performance	3.65	0.91	1										
2. Servitisation	2.87	1.39	0.142*	1									
3. Industry 4.0 technologies	0.99	1.03	0.114	−0.046	1								
4. Product type	0.53	0.50	−0.037	0.042	−0.136	1							
5. Market diversification	2.08	1.98	0.005	0.091	−0.032	0.256**	1						
6. Sector maturity	3.57	1.18	0.016	−0.093	−0.115	−0.021	0.045	1					
7. Employees	34.85	37.44	−0.049	0.036	0.102	−0.156*	0.029	0.042	1				
8. Customers concentration	49.38	26.45	0.059	−0.052	−0.067	0.227**	−0.138	−0.025	−0.145*	1			
9. Country	11.50	17.27	0.032	0.002	0.182**	−0.367**	−0.088	0.094	0.507**	−0.396**	1		
10. Age	27.91	14.73	−0.193**	0.037	−0.123	−0.021	0.079	0.198**	0.134	−0.187**	0.058	1	
11. Slack resources	2.28	1.67	0.128	0.051	−0.053	0.108	0.007	0.112	−0.141*	0.126	−0.120	0.219**	1

Note(s): SD: standard deviation
*Correlation is significant at the 0.05 level; **correlation is significant at the 0.01 level (two-tailed test)
Source(s): Authors' own elaboration

	Model 1	Model 2	Model 3
Constant	3.223 (0.000)	2.786 (0.000)	3.047 (0.000)
Independent variables			
Servitisation		0.156 (0.027)**	0.005 (0.957)
Industry 4.0 tech sum		0.099 (0.165)	−0.235 (0.162)
Control variables			
Product type	−0.107 (0.452)	−0.055 (0.478)	−0.052 (0.498)
Market diversification	0.023 (0.505)	0.036 (0.626)	0.031 (0.671)
Sector maturity	0.026 (0.632)	0.063 (0.384)	0.068 (0.340)
Employees	−0.035 (0.632)	−0.050 (0.543)	−0.069 (0.402)
Customer concentration	0.001 (0.623)	0.048 (0.545)	0.049 (0.530)
Country	0.004 (0.372)	0.068 (0.457)	0.073 (0.425)
Age	−0.211 (0.002)***	−0.228 (0.003)***	−0.230(0.002)***
Slack resources	0.098 (0.015)**	0.092 (0.021)**	0.177 (0.015)**
Moderating effect			
Servitisation x Industry 4.0 tech sum			0.393 (0.029)**
Model fit			
Adjusted R-Square	0.040	0.063	0.081
N	200	200	200

Note(s): The dependent variable is firm performance. Coefficients are standardised. Metals and machinery sector is the reference industry
(p values in parentheses)
$p < 0.1$ (*), $p < 0.05$ (**); $p < 0.01$ (***)
Source(s): Authors' own elaboration

Table 4. Multiple regression models

Industry 4.0 technologies positively impact performance outcomes (Büchi *et al.*, 2020; Bettiol *et al.*, 2021). However, studies have reported contrasting results so far, perhaps due to the different measures used for both technologies and performance (Szasz *et al.*, 2021). In particular, Tortorella *et al.* (2019) found no direct effect of product and service-related technologies (e.g. IoT, BDA) on performance, compared to process-related technologies. Our results are aligned with this view, as the selected Industry 4.0 technologies can be more related to servitisation (Coreynen *et al.*, 2017; Ardolino *et al.*, 2018).

Model 3 included the interaction effect. As for the moderating effect of Industry 4.0, the positive and statistically significant coefficient of the interaction term (0.393; $p < 0.05$) indicates that the relationship between servitisation and firm performance is stronger when the manufacturing company has a superior breadth of Industry 4.0. Therefore, Hypothesis 3 is supported. Our findings show that Industry 4.0 technologies achieve their full potential when functionally integrated into the organisation and aligned with servitisation (Paiola *et al.*, 2021) and, thus, with this specific firm strategy (Kane *et al.*, 2015). This interaction leads to positive outcomes for firms, as previously speculated by explorative qualitative studies conducted in the field (Paschou *et al.*, 2020; Kowalkowski *et al.*, 2017a; Coreynen *et al.*, 2017; Frank *et al.*, 2019a; Paiola *et al.*, 2021).

The moderating effect plot (Figure 2) of Industry 4.0 technologies further confirms Hypothesis 3. The curve's slope is positive for firms with more Industry 4.0 technologies, making the relationship between servitisation and performance significantly positive.

Two control variables, slack resources and age, were statistically significant in all the models. In line with previous evidence (Abou-Foul *et al.*, 2021), our analysis showed that the higher the slack resources, the better the firm performance. As expected, younger companies

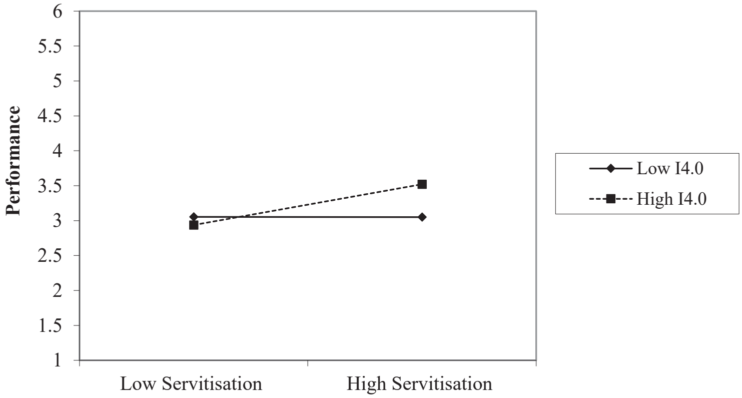


Figure 2. Moderating effect

Source(s): Authors' own elaboration

performed better, because in periods characterised by fast technological changes, they might benefit from more flexible organisational structures and be less impacted by sunk costs caused by previous investments (Valtakoski and Witell, 2018).

The robustness check of the model was tested through several statistical analyses, including the comparative fit index (CFI), Tucker–Lewis Index (TLI) and Adjusted R-square. The goodness of fit of the models is adequate. Both CFI and TLI are equal to 1, whilst the Adjusted R-square is equal to 0.081. In addition, the variance inflation factor (VIF) index confirms the absence of common method bias; in fact, all VIF values are less than the 2.5 threshold, refuting concerns about multicollinearity distorting the results (Allison, 1999).

5. Discussion

This study responds to recent calls for quantitative research on the role of Industry 4.0 in the servitisation literature (Kowalkowski *et al.*, 2017b; Fliess and Lexutt, 2019). Our results indicate that servitisation is positively related to the firm performance. In addition, manufacturing companies with superior endowment of Industry 4.0 technologies, intended as the joint adoption of IoT, simulation, cloud and BDA, can achieve more benefits from servitisation. The findings have both theoretical and practical implications.

5.1 Theoretical implications

This study contributes to the digital servitisation literature as follows. First, by quantitatively testing a sample of 200 manufacturing SMEs, it advances our understanding of the performance benefits of radical servitisation for SMEs (Coreynen *et al.*, 2017; Kowalkowski *et al.*, 2017b), contributing to the long-standing debate on the performance implications of servitisation strategies (Baines *et al.*, 2017). Our results show that SMEs, despite having limited resources or experience, can benefit from a radical servitisation (Coreynen *et al.*, 2017; Kowalkowski *et al.*, 2017b), consistently with the reflections of Brax *et al.* (2021), who emphasise that service and organisational paradoxes can be overcome when manufacturing companies achieve an excellence-driven or radical servitisation, as in our context.

Second, our study provides fresh empirical evidence regarding the role of Industry 4.0 technologies in the digital servitisation context (e.g. Paschou *et al.*, 2020; Fliess and Lexutt, 2019; Lexutt, 2020). Our results show that a superior endowment of Industry 4.0 technologies strengthens the relationship between servitisation and firm performance, whilst not having a direct effect on performance. The lack of a direct effect might depend on the selected Industry 4.0 technologies which, according to past studies on lean practices, are service-related and have an interacting effect on performance, rather than a direct one (Tortorella *et al.*, 2019). Alternatively, this could be interpreted in relation to the overall effectiveness performance measure used, which is more strategic rather than operational. Thus far, studies have shown that the breadth of Industry 4.0 positively impacts operational indicators, which are mainly related to cost reduction, quality improvement, delivery performance and flexibility increases (Szàsz *et al.*, 2021; Büchi *et al.*, 2020), rather than referring to overall effectiveness performance. This might explain why these technologies have no direct effect.

The moderating effect extends prior qualitative evidence suggesting a convergence between radical servitisation and advanced levels of digitalisation (Ardolino *et al.*, 2018; Frank *et al.*, 2019a; Kohtamäki *et al.*, 2020; Kharlamov and Parry, 2021) by quantitatively confirming that a superior endowment of specific Industry 4.0 technologies supports the transformation from product to service-based business models and logics, leading to positive performance outcomes. Hence, we suggest to analyse potential synergies associated with the combined use of Industry 4.0 technologies rather than focussing only on single technological applications. Moreover, our study shows that Industry 4.0 does not impact firms' outcomes unless they are deployed through effective and consistent strategies (Kane *et al.*, 2015). Our results underline the importance to establish a fit between strategy and technology in order to benefit from the investments in Industry 4.0 and achieve superior performance results.

5.2 Practical implications

From the practitioners' perspective, the study provides insights on the extent to which servitisation can help manufacturing firms to derive value from Industry 4.0 investments. Our empirical analysis underlines that some Industry 4.0 technologies can support or revitalise the servitisation of manufacturing SMEs. However, to achieve the expected performance returns, managers should be ready to invest in more than one Industry 4.0 technology. Besides carefully planning and considering barriers and challenges that might arise during the implementation process (Chauhan *et al.*, 2021), investments in technologies must also be aligned with the firm's strategy (Kane *et al.*, 2015). In fact, the synergic adoption of such technologies can have a twofold effect. On the one hand, their implementation can increase and enhance the service offering to better serve and satisfy customers' needs. On the other hand, by interacting with each other, such technologies can also become sources of data that can be strategically analysed to improve products and production. This might create a virtuous circle, leading the manufacturer to produce "on demand" in a long-term sustainable way, accelerating the re-design of the business model. From this perspective, managers can exploit the potential of Industry 4.0 through the synergic use of technologies aligned with a transformation toward servitisation. However, to reduce the failure risk we recommend verifying in advance that the firm has the resources and capabilities needed to successfully redefine internal and external processes and, if necessary, the relations within the value chain. Since both servitisation and Industry 4.0 are resource- and skill-demanding processes (Zhang *et al.*, 2022; Brax, 2005; Mourtzis *et al.*, 2014; Müller *et al.*, 2021; Marcon *et al.*, 2022), *a priori* evaluations and planning are necessary to overcome the unprofitable period that reflects the "service paradox" and achieve the combination of excellence-driven servitisation and technology endowment that will benefit the SME (Brax *et al.*, 2021; Kowalkowski *et al.*, 2017b).

From policymakers' perspective, supportive programmes — in terms of financial and tax incentives — can definitively help SMEs to increase their technological endowment. However, SMEs that pursue a combination of Industry 4.0 and servitisation may require resources and specific capabilities to successfully achieve the organisational transformation. In response, policymakers should consider providing SMEs with adequate ecosystems of supportive actors (e.g. technology parks and research centres) and activities (e.g. applied research) that can spread innovation and technology amongst SMEs to help them to identify or develop the best technological combination for the firm based on its characteristics, markets and resources (Müller *et al.*, 2021).

6. Conclusions, limitations and future research directions

This study finds that manufacturing SMEs can achieve better performance through radical servitisation, and this result is prominent for firms with superior endowments of Industry 4.0 technologies related servitisation, such as IoT, simulation, cloud computing, and BDA.

Our study has limitations that present opportunities for future research. First, the sample comprises SMEs geographically concentrated in the Friuli Venezia Giulia region in Italy. Although the representative sample is equal to 27.5% of the population of metals and machinery small companies in the region, the sample comes from a specific geographical area and one country. A one-country sample is a common limitation in management research; however, future studies could investigate this topic amongst companies located in different countries to establish the cross-country validity of our findings. Second, the majority of companies surveyed in our study operated in business-to-business contexts in the metals and machinery sector. Although this limitation is partially mitigated as this industry is vast and multifaceted, other contexts should be investigated such as different manufacturing sectors that are less accustomed to servitisation (e.g. furniture) or business-to-consumer enterprises.

Additional limitations stem from the measurements of our dependent and independent variables. The dependent variable was measured on a self-assessment single-item scale, which has a range of benefits (e.g. reduce the demands on participants, is associated with lower levels of mental fatigue, increased response rates, increased survey efficiency) but can undermine the validity and reliability of results (Sarstedt and Wilczynski, 2009). Although we acknowledge that accurately addressing common method bias in survey research remains an issue when involving one informant per firm (Guide and Ketokivi, 2015), we used procedural and statistical remedies to mitigate common method bias risks (Podsakoff *et al.*, 2012). Besides, we also assessed and found significant positive correlations with financial indicators of firm performance (e.g. Ebitda/Sales) showing a degree of convergent validity (Wall *et al.*, 2004). In order to improve the strength of relationships and the goodness of fit of the model, further studies might analyse this conceptual framework by using different measures or multidimensional constructs of performance, including both operational and strategic indicators.

Servitisation was measured based on the definition proposed by Kowalkowski *et al.* (2017b), which mostly captures radical servitisation, whereas Industry 4.0 technologies were measured as the sum of four selected technologies that are more related to servitisation (i.e. IoT, simulation, BDA and cloud computing). Building on our results, future studies could investigate Industry 4.0 impacts in relation to the different nuances of servitisation strategies existing in the literature (Wang *et al.*, 2018; Kowalkowski *et al.*, 2017b; Lexutt, 2020) by looking also at how technologies can support the emergence of new service-business models and the related impacts (Raddats *et al.*, 2019), thus extending seminal qualitative studies exploring this issue (Coreynen *et al.*, 2017; Ardolino *et al.*, 2018; Frank *et al.*, 2019a). Moreover, a multidimensional measurement of our key construct (Industry 4.0) would be beneficial to increase the reliability of findings, such as studies considering different groups of technologies. However, to the best of our knowledge, this study provides initial quantitative evidence on these interactions and paves the way for future studies deepening the mechanisms through which service-based business models and different types of servitisation strategies can be enhanced by different groups of Industry 4.0 technologies, also in relation to different performance types (Kohtamäki *et al.*, 2019; Paiola and Gebauer, 2020; Paiola *et al.*, 2022). For instance, scholars could investigate the role of Industry 4.0 technologies that are more related to production and operations improvements (e.g. automation, robotics) in relation to de-servitisation and service-dilution strategies of manufacturing firms (Fliess and Lexutt, 2019), giving a substantial contribution to advance our understanding of the role of such technologies in manufacturing industries that are price-sensitive and highly competitive. Technologies like automation, robotics and 3 days printing, in fact, entail different logics and rational both during the selection and implementation processes, and might support completely different servitisation strategies. Building on our findings, future studies might also focus on *how* Industry 4.0 technologies interact with each other and the related impacts, thus helping to advance the field.

Finally, firm age deserves further attention, especially in terms of its impact on firms' performances in turbulent times, deployments of servitisation strategies and investments in Industry 4.0 technologies. We must also acknowledge that data were collected when Industry 4.0 had just started to spread, and our moderation might reflect a particular advantage for first adopters. The results might change once Industry 4.0 technologies have become well established (Fliess and Lexutt, 2019). Further studies at different times and in different contexts should be conducted to explore this issue.

References

Abou-Foul, M., Ruiz-Alba, J.L. and Soares, A. (2021), "The impact of digitalization and servitization on the financial performance of a firm: an empirical analysis", *Production Planning and Control*, Vol. 32 No. 12, pp. 975-989.

Alcácer, V. and Cruz-Machado, V. (2019), "Scanning the industry 4.0: a literature review on technologies for manufacturing systems", *Engineering Science and Technology, an International Journal*, Vol. 22 No. 3, pp. 899-919.

Allison, P.D. (1999), "Multicollinearity", in *Logistic Regression Using the SAS System: Theory and Application*, pp. 48-51.

Ardolino, M., Rapaccini, M., Saccani, N., Gaiardelli, P., Crespi, G. and Ruggeri, C. (2018), "The role of digital technologies for the service transformation of industrial companies", *International Journal of Production Research*, Vol. 56 No. 6, pp. 2116-2132.

Armstrong, J.S. and Overton, T.S. (1977), "Estimating nonresponse bias in mail surveys", *Journal of Marketing Research"*, Vol. 14 No. 3, pp. 396-402.

Baines, T., Ziaee Bigdeli, A., Bustinza, O.F., Shi, V.G., Baldwin, J. and Ridgway, K. (2017), "Servitization: revisiting the state-of-the-art and research priorities", *International Journal of Operations and Production Management*, Vol. 37 No. 2, pp. 256-278.

Bettiol, M., Capestro, M., Di Maria, E. and Micelli, S. (2021), "Disentangling the link between ICT and Industry 4.0: impacts on knowledge-related performance", *International Journal of Productivity and Performance Management*, Vol. 71 No. 4, pp. 1076-1098, doi: 10.1108/IJPPM-10-2020-0573.

Bortoluzzi, G., Chiarvesio, M., Romanello, R., Tabacco, R. and Veglio, V. (2020), "Industry 4.0 technologies and the servitization strategy: a good match?", *Sinergie Italian Journal of Management*, Vol. 38 No. 1, pp. 55-72.

Brax, S. (2005), "A manufacturer becoming service provider–challenges and a paradox", *Managing Service Quality: An International Journal*, Vol. 15 No. 2, pp. 142-155.

Brax, S.A., Calabrese, A., Ghiron, N.L., Tiburzi, L. and Grönroos, C. (2021), "Explaining the servitization paradox: a configurational theory and a performance measurement framework", *International Journal of Operations and Production Management*, Vol. 41 No. 5, pp. 517-546.

Büchi, G., Cugno, M. and Castagnoli, R. (2020), "Smart factory performance and Industry 4.0", *Technological Forecasting and Social Change*, Vol. 150, pp. 119-790.

Bustinza, O.F., Lafuente, E., Rabetino, R. and Vaillant, Y. (2019), "Make-or-buy configurational approaches in product-service ecosystems and performance", *Journal of Business Research*, Vol. January, pp. 1-9.

Chauhan, C. and Singh, A. (2019), "A review of Industry 4.0 in supply chain management studies", *Journal of Manufacturing Technology Management"*, Vol. 31 No. 5, pp. 863-886.

Chauhan, C., Singh, A. and Luthra, S. (2021), "Barriers to industry 4.0 adoption and its performance implications: an empirical investigation of emerging economy", *Journal of Cleaner Production*, Vol. 285, 124809.

Chiarvesio, M. and Romanello, R. (2018), "Industry 4.0 technologies and internationalization: insights from Italian companies", *International Business in the Information and Digital Age. Progress in International Business Research*, Vol. 13, pp. 357-378.

Cimini, C., Adrodegari, F., Paschou, T., Rondini, A. and Pezzotta, G. (2021a), "Digital servitization and competence development: a case-study research", *CIRP Journal of Manufacturing Science and Technology*, Vol. 32, pp. 447-460.

Cimini, C., Boffelli, A., Lagorio, A., Kalchschmidt, M. and Pinto, R. (2021b), "How do industry 4.0 technologies influence organisational change? An empirical analysis on Italian SMEs", *Journal of Manufacturing Technology Management*, Vol. 32 No. 3, pp. 695-721.

Coreynen, W., Matthyssens, P. and Van Bockhaven, W. (2017), "Boosting servitization through digitization: pathways and dynamic resource configurations for manufacturers", *Industrial Marketing Management*, Vol. 60, pp. 42-53.

Culot, G., Nassimbeni, G., Orzes, G. and Sartor, M. (2020), "Behind the definition of Industry 4.0: analysis and open questions", *International Journal of Production Economics*, Vol. 226, 107617.

Cusumano, M.A., Kahl, S.J. and Suarez, F.F. (2015), "Services, industry evolution, and the competitive strategies of product firms", *Strategic Management Journal*, Vol. 36 No. 4, pp. 559-575.

Dalenogare, L.S., Benitez, G.B., Ayala, N.F. and Frank, A.G. (2018), "The expected contribution of Industry 4.0 technologies for industrial performance", *International Journal of Production Economics*, Vol. 204, pp. 383-394.

Denicolai, S., Zucchella, A. and Magnani, G. (2021), "Internationalization, digitalization, and sustainability: are SMEs ready? A survey on synergies and substituting effects among growth paths", *Technological Forecasting and Social Change*, Vol. 166, 120650.

Dillman, D.A. (2000), *Mail and Internet Surveys: the Tailored Design Method*, Wiley, New York, Vol. 2.

Federmeccanica (2017), "L'industria Metalmeccanica in Cifre", available at: http://www.federmeccanica.it/images/files/industria-metalmeccanica-in-cifre-giugno-2017.pdf.

Fliess, S. and Lexutt, E. (2019), "How to be successful with servitization – guidelines for research and management", *Industrial Marketing Management*, Vol. 78, pp. 58-75.

Frank, A.G., Mendes, G.H., Ayala, N.F. and Ghezzi, A. (2019a), "Servitization and Industry 4.0 convergence in the digital transformation of product firms: a business model innovation perspective", *Technological Forecasting and Social Change*, Vol. 141 April, pp. 341-351.

Frank, A.G., Dalenogare, L.S. and Ayala, N.F. (2019b), "Industry 4.0 technologies: implementation patterns in manufacturing companies", *International Journal of Production Economics*, Vol. 210, pp. 15-26.

Gaggero, A.A., Ogrzewalla, L. and Bubalo, B. (2019), "Pricing of the long-distance bus service in Europe: the case of Flixbus", *Economics of Transportation*, Vol. 19, 100120.

Govindarajan, V. and Immelt, J.R. (2019), "The only way manufacturers can survive", *MIT Sloan Management Review*, Vol. 60 No. 3, pp. 24-33.

Grubic, T. and Jennions, I. (2018), “Remote monitoring technology and servitized strategies – factors characterizing the organizational application”, *International Journal of Production Research* May, pp. 1-17.

Guide, V.D.R. Jr and Ketokivi, M. (2015), “Notes from the Editors: redefining some methodological criteria for the journal”, *Journal of Operations Management*, Vol. 37 No. 1, pp. v-viii.

Henderson, H.V. and Velleman, P.F. (1981), “Building multiple regression models interactively”, *Biometrics*, Vol. 37 No. 2, pp. 391-411.

Hult, G.T.M., Ketchen, D.J., Griffith, D.A., Chabowski, B.R., Hamman, M.K., Dykes, B.J. and Cavusgil, S.T. (2008), “An assessment of the measurement of performance in international business research”, *Journal of International Business Studies*, Vol. 39 No. 6, pp. 1064-1080.

Jerningan, S., Ransbotham, S.A.M. and Kiron, D. (2016), “Data sharing and analytics drive success with IoT”, *Sloan Management Review*, Vol. 58 No. 1, pp. 1-17.

Johansson, A.E., Raddats, C. and Witell, L. (2019), “The role of customer knowledge development for incremental and radical service innovation in servitized manufacturers”, *Journal of Business Research*, Vol. 98 May, pp. 328-338.

Kamp, B. and Parry, G. (2017), “Servitization and advanced business services as levers for competitiveness”, *Industrial Marketing Management*, Vol. 60, pp. 11-16.

Kane, G.C., Palmer, D., Phillips, A.N., Kiron, D. and Buckley, N. (2015), “Strategy, not technology, drives digital transformation”, *MIT Sloan Management Review and Deloitte University Press*, Vol. 14, pp. 1-25.

Kharlamov, A.A. and Parry, G. (2021), “The impact of servitization and digitization on productivity and profitability of the firm: a systematic approach”, *Production Planning and Control*, Vol. 32 No. 3, pp. 185-197.

Khin, S. and Kee, D.M.H. (2022), “Factors influencing Industry 4.0 adoption”, *Journal of Manufacturing Technology Management*, Vol. 33 No. 3, pp. 448-467.

Kohtamäki, M., Parida, V., Oghazi, P., Gebauer, H. and Baines, T. (2019), “Digital servitization business models in ecosystems: a theory of the firm”, *Journal of Business Research*, Vol. 104, pp. 380-392.

Kohtamäki, M., Parida, V., Patel, P.C. and Gebauer, H. (2020), “The relationship between digitalization and servitization: the role of servitization in capturing the financial potential of digitalization”, *Technological Forecasting and Social Change*, Vol. 151, pp. 1-9.

Kowalkowski, C., Gebauer, H. and Oliva, R. (2017a), “Service growth in product firms: past, present, and future”, *Industrial Marketing Management*, Vol. 60, pp. 82-88.

Kowalkowski, C., Gebauer, H., Kamp, B. and Parry, G. (2017b), “Servitization and deservitization: overview, concepts, and definitions”, *Industrial Marketing Management*, Vol. 60, pp. 4-10.

Krosnick, J.A. (1999), “Survey research”, *Annual Review of Psychology*, Vol. 50 No. 1, pp. 537-567.

Lexutt, E. (2020), “Different roads to servitization success–A configurational analysis of financial and non-financial service performance”, *Industrial Marketing Management*, Vol. 84, pp. 105-125.

MacKenzie, S.B., Podsakoff, P.M. and Podsakoff, N.P. (2011), “Construct measurement and validity assessment and behavioral research: integrating new and existing techniques”, *MIS Quarterly*, Vol. 35 No. 2, pp. 293-334.

Marcon, É., Marcon, A., Ayala, N.F., Frank, A.G., Story, V., Burton, J., Raddats, C. and Zolkiewski, J. (2022), “Capabilities supporting digital servitization: a multi-actor perspective”, *Industrial Marketing Management*, Vol. 103, pp. 97-116.

Martín-Peña, M.L., Sánchez-López, J.M. and Díaz-Garrido, E. (2020), “Servitization and digitalization in manufacturing: the influence on firm performance”, *Journal of Business and Industrial Marketing*, Vols *35/3*, pp. 564-574.

Mourtzis, D., Doukas, M. and Bernidaki, D. (2014), “Simulation in manufacturing: review and challenges”, *Procedia CIRP*, Vol. 25, pp. 213-229.

Müller, J.M. (2019), "Business model innovation in small-and medium-sized enterprises: strategies for industry 4.0 providers and users", *Journal of Manufacturing Technology Management*, Vol. 30 No. 8, pp. 1127-1142.

Müller, J.M., Buliga, O. and Voigt, K.I. (2021), "The role of absorptive capacity and innovation strategy in the design of industry 4.0 business Models-A comparison between SMEs and large enterprises", *European Management Journal*, Vol. 39 No. 3, pp. 333-343.

Neely, A. (2008), "Exploring the financial consequences of the servitization of manufacturing", *Operations Management Research*, Vol. 1 No. 2, pp. 103-118.

Ng, I.C. and Wakenshaw, S.Y. (2017), "The Internet-of-Things: review and research directions", *International Journal of Research in Marketing*, Vol. 34 No. 1, pp. 3-21.

Ortt, R., Stolwijk, C. and Punter, M. (2020), "Implementing Industry 4.0: assessing the current state", *Journal of Manufacturing Technology Management*, Vol. 31 No. 5, pp. 825-836.

Paiola, M. and Gebauer, H. (2020), "Internet of things technologies, digital servitization and business model innovation in BtoB manufacturing firms", *Industrial Marketing Management*, Vol. 89, pp. 245-264.

Paiola, M., Schiavone, F., Khvatova, T. and Grandinetti, R. (2021), "Prior knowledge, industry 4.0 and digital servitization. An inductive framework", *Technological Forecasting and Social Change*, Vol. 171, 120963.

Paiola, M., Agostini, L., Grandinetti, R. and Nosella, A. (2022), "The process of business model innovation driven by IoT: exploring the case of incumbent SMEs", *Industrial Marketing Management*, Vol. 103, pp. 30-46.

Paschou, T., Rapaccini, M., Adrodegari, F. and Saccani, N. (2020), "Digital servitization in manufacturing: a systematic literature review and research agenda", *Industrial Marketing Management*, Vol. 89, pp. 278-292.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y. and Podsakoff, N. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *Journal of Applied Psychology*, Vol. 88 No. 5, pp. 879-903.

Podsakoff, P.M., MacKenzie, S.B. and Podsakoff, N.P. (2012), "Sources of method bias in social science research and recommendations on how to control it", *Annual Review of Psychology*, Vol. 63, pp. 539-569.

Porter, M.E. and Heppelmann, J.E. (2015), "How smart, connected products are transforming companies", *Harvard Business Review*, Vol. 93 No. 10, pp. 96-114.

Raddats, C., Kowalkowski, C., Benedettini, O., Burtond, J. and Gebauer, H. (2019), "Servitization: a contemporary thematic review of four major research streams", *Industrial Marketing Management*, Vol. 83, pp. 207-223.

Raddats, C., Naik, P. and Bigdeli, A.Z. (2022), "Creating value in servitization through digital service innovations", *Industrial Marketing Management*, Vol. 104, pp. 1-13.

Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P. and Harnisch, M. (2015), *Industry 4.0: the Future of Productivity and Growth in Manufacturing Industries*, Boston Consulting Group, pp. 1-9, available at: http://www.inovasyon.org/pdf/bcg.perspectives_Industry.4.0_2015.pdf.

Rymaszewska, A., Helo, P. and Gunasekaran, A. (2017), "IoT powered servitization of manufacturing– an exploratory case study", *International Journal of Production Economics*, Vol. 192, pp. 92-105.

Sarstedt, M. and Wilczynski, P. (2009), "More for less? A comparison of single-item and multi-item measures", *Die Betriebswirtschaft*, Vol. 69 No. 2, p. 211.

Sauter, R., Bode, M. and Kittelberg, D. (2015), "How Industry 4.0 is changing how we manage value creation. Horvàth and Partners, Management Consultants", *White Paper*, p. 1, available at: https://www.horvath-partners.com/fileadmin/horvath-partners.com/assets/05_Media_Center/PDFs/englisch/Industry_4.0_EN_web-g.pdf.

Savastano, M., Cucari, N., Dentale, F. and Ginsberg, A. (2022), "The interplay between digital manufacturing and dynamic capabilities: an empirical examination of direct and indirect effects on firm performance", *Journal of Manufacturing Technology Management*, Vol. 33 No. 2, pp. 213-238.

Solem, B.A.A., Kohtamäki, M., Parida, V. and Brekke, T. (2021), "Untangling service design routines for digital servitization: empirical insights of smart PSS in maritime industry", *Journal of Manufacturing Technology Management*, Vol. 33 No. 4, pp. 717-740.

Szász, L., Demeter, K., Rácz, B.G. and Losonci, D. (2021), "Industry 4.0: a review and analysis of contingency and performance effects", *Journal of Manufacturing Technology Management*, Vol. 32 No. 3, pp. 667-694.

Tortorella, G.L., Giglio, R. and Van Dun, D.H. (2019), "Industry 4.0 adoption as a moderator of the impact of lean production practices on operational performance improvement", *International Journal of Operations and Production Management*, Vol. 39 Nos 6/7/8, pp. 860-886.

Valtakoski, A. (2017), "Explaining servitization failure and deservitization: a knowledge-based perspective", *Industrial Marketing Management*, Vol. 60, pp. 138-150.

Valtakoski, A. and Witell, L. (2018), "Service capabilities and servitized SME performance: contingency on firm age", *International Journal of Operations and Production Management*, Vol. 38 No. 4, pp. 1144-1164.

Vandermerwe, S. and Rada, J. (1988), "Servitization of business: adding value by adding services", *European Management Journal*, Vol. 6 No. 4, pp. 314-324.

Vendrell-Herrero, F., Bustinza, O.F., Parry, G. and Georgantzis, N. (2017), "Servitization, digitization and supply chain interdependency", *Industrial Marketing Management*, Vol. 60, pp. 69-81.

Visnjic, I., Wiengarten, F. and Neely, A. (2016), "Only the brave: product innovation, service business model innovation, and their impact on performance", *Journal of Product Innovation Management*, Vol. 33 No. 1, pp. 36-52.

Wall, T.D., Michie, J., Patterson, M., Wood, S.J., Sheehan, M., Clegg, C.W. and West, M. (2004), "On the validity of subjective measures of company performance", *Personnel Psychology*, Vol. 57 No. 1, pp. 95-118.

Wang, W., Lai, K.H. and Shou, Y. (2018), "The impact of servitization on firm performance: a meta-analysis", *International Journal of Operations and Production Management*, Vol. 38 No. 7, pp. 1562-1588.

Zhang, J., Qi, L., Wang, C. and Lyu, X. (2022), "The impact of servitization on the environmental and social performance in manufacturing firms", *Journal of Manufacturing Technology Management*, Vol. 33 No. 3, pp. 425-447.

Zhou, D., Yan, T., Zhao, L. and Guo, J. (2020), "Performance implications of servitization: does a Manufacturer's service supply network matter?", *International Journal of Production Economics*, Vol. 219, pp. 31-42.

Ziaee Bigdeli, A., Bustinza, O.F., Vendrell-Herrero, F. and Baines, T. (2018), "Network positioning and risk perception in servitization: evidence from the UK road transport industry", *International Journal of Production Research*, Vol. 56 No. 6, pp. 2169-2183.

Further reading

Agarwal, G.K., Simonsson, J., Magnusson, M., Hald, K.S. and Johanson, A. (2022), "Value-capture in digital servitization", *Journal of Manufacturing Technology Management*, Vol. 33 No. 5, pp. 986-1004.

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