# Digital Servitization and Firm Performance: Technology Intensity Approach

**Slavko Rakic[1], Margherita Pero[2], Andrea Sianesi[2], Ugljesa Marjanovic[1]***

*[1]University of Novi Sad*
*Trg Dositeja Obradovica 6, Novi Sad, Republic of Serbia*
*E-mail. slavkorakic@uns.ac.rs; umarjano@uns.ac.rs[1*]; corresponding author**

*[2]Politecnico di Milano*
*Piazza Leonardo da Vinci, Milan, Italy*
*E-mail. margherita.pero@polimi.it; andrea.sianesi@polimi.it*

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*Digital servitization provides radical changes in the offer of products from manufacturing firms. The purpose of this paper is to investigate the impact of digital servitization on manufacturing firm performance and demonstrate the role of technology intensity, product-related services, and digital solutions in different industry sectors. This research collected data from 240 manufacturing firms from the Republic of Serbia under the European manufacturing survey from 2018. Multivariate regression analysis was used to test the impact of product-related services and digital solutions on manufacturing firm performance according to technology intensity. The findings show that the impact of digital servitization is more significant with the higher technology intensity level of the industry sector. Furthermore, the results show that Data-based services based on Big Data Analysis have the highest impact on manufacturing firm performance in all categories of technology intensity. Moreover, results from the fixed panel regression show production managers which combination of product-related services along with digital solutions make the highest financial performance according to the technology intensity of the firm.*

Keywords: *Digital Servitization; Technology Intensity; Firm Performance; European Manufacturing Survey; Big Data Analysis.*

## Introduction

The practical application of services, offered along with products, started in 1850 from Singer and McCormick firms (Baines & Lightfoot, 2013). Nevertheless, the first scientific research about service offerings along with products began thirty years ago in North America (Baines & Lightfoot, 2013). In the scientific community, Vandermerwe and Rada first introduced the term “servitization” (Vandermerwe & Rada, 1988). Servitization has evolved from a simple service offering with products into a strategy that strengthens a firm's position on the market (Kastalli & Van Looy, 2013). Moreover, servitization has opened new research horizons on product-service systems (Tukker, 2004), product-related services (PRS) (Gebauer *et al.,* 2008), servitization maturity models (Adrodegari & Saccani, 2020) and other.

The application of servitization in high economies has increased by 20 % in the last decade (Mastrogiacomo *et al.,* 2019; Neely *et al.,* 2011). One of the best examples of this is China. The first evidence from 2007 shows a 1 % application of servitization, but in four years’ time, the use grew to 20 % (Neely *et al.,* 2011). Furthermore, the application of servitization in 2019 was 38 % in production firms from China (Mastrogiacomo *et al.,* 2019). The others of top five-world economies also have a high percetage of servitised firms; UK has 56 %, USA 53 %, Japan 41 % and Germany 39 % of servitised manufacturing firms (Mastrogiacomo *et al.,* 2019). These five economies have more than 50 % of total GDP in the world. In addition to the growing trend of application of servitization, previous research shows that services have had a positive effect on growth, stability, and competitive advantage of manufacturing firms (Eggert *et al.,* 2014; Kastalli & Van Looy, 2013; Moreno Renata *et al.,* 2019). Despite the above-mentioned positive influence of servitization on manufacturing firms, some cases from the industry resulted in low firm performance based on service application (Li *et al.,* 2015). This phenomenon is known as the "servitization paradox" (Gebauer *et al.,* 2005). Recent studies argue that the digital component of servitization could help manufacturing firms to overcome the service paradox (Frank *et al.,* 2019; Kohtamaki *et al.,* 2020b). The application of digital technologies in the industry has changed the way firms do business so far (Pirola *et al.,* 2020; Ardolino *et al.,* 2018). Accordingly, digital technologies change the form of service offerings for manufacturing firms (Kohtamaki *et al.,* 2019). Additionally, the Industry 4.0 era provides an opportunity for manufacturing firms to develop digital solutions for service offerings (Frank et al., 2019). The application of digital technologies in manufacturing firms results in immense financial benefits (Pirola *et al.,* 2020; Ardolino *et al.,* 2018). The previous study showed a strong relationship between servitization, digitalization, and firm performance (Kohtamaki *et al.,* 2020). Authors argued that 61 % of respondents see a lack of return on investment as a major obstacle when implementing digital solutions in the manufacturing industry (Behrendt *et al.,* 2018). Another study showed that managers have to align their servitization strategy with decisions about the digitalization of their business to achieve success in the application of digital solutions (Ardolino *et al.,* 2018; Kohtamaki *et al.,* 2020b). Production intensity, organization, culture, technology competencies of a firm are presented as some of the most critical requirements for the successful adoption of digital servitization (Theoni Paschou *et al.,* 2020, Zivlak *et al.,* 2021). Previous findings show positive effects of digital technologies such as the Internet of Things, Artificial Intelligence, and Big Data Analysis on the use of digital servitization. On the other hand, research shows that the technology level of the firms is still neglected in the use of digital servitization. Despite the fact that the technological intensity of the firms is a prerequisite for the implementation of new digital technologies and services. Moreover, the adoption of digital solutions in manufacturing firms should be in line with the technology intensity of the firm (Avadikyan *et al.,* 2012, Rakic *et al.,* 2021a). The neglect of technological intensity has proven as a literature gap in the theory of digital servitization (Munch *et al.,* 2022). Therefore, an in-depth understanding of relations between digital servitization and technology intensity is needed to respond to the servitization paradox challenge (Munch *et al.,* 2022). Furthermore, this research fills the gap in the literature with the explanation which combination of servitization and digital servitization make the highest financial performance according to the technology level of the firm. Technology intensity could be defined as the ratio between financial performance and research and development activities, which are incorporated in firms' products in different industries sectors. (Zawislak *et al.,* 2018, Vilkas *et al.,* 2020). In particular, from the perspectives of Research and Development (R&D) the classes can be obtained looking at the utilization of R&D: when it is below 1.0 %, then companies can be classified as having low-technological intensity, between 1.0 % and 7 % medium technological intensity and higher than 7 % high technological intensity (Loschky Alexander, 2010). According to the literature gap, this research provides insights into how manufacturing firms from developing economies use digital servitization in the different levels of technology intensity. Additionally, this research opens a new perspective of the servitization view on how manufacturing firms from low economies could become a part of the value chain of high economies. Based on the literature background, authors proposed the following research question:

*RQ: What are the effects of servitization and digital servitization on the firm's performance in relation to the technology intensity of the firm?*

To answer this question, authors collected data from 240 manufacturing firms from Serbia under the European manufacturing survey (EMS) from 2018. Multiple hierarchical regression analysis was used to test the impact of product-related services and digital solutions on manufacturing firm performance according to technology intensity. Additionally, for in-depth analysis authors employ fixed-panel regression for the 55 manufacturing firms, which were in the EMS sample in 2015 and 2018. The paper provides insights into the importance of technology intensity for digital servitization. Given the gaps identified in the literature, the purpose of this manuscript is to explore the impact of digital servitization on the performance of manufacturing firms according to technological intensity. This study presents relationships between product-related services, digital solutions, manufacturing technological intensity, and the firm's performance. On the one hand, our findings suggest that the impact of digital solutions based on Big Data Analysis increases with the higher technology intensity level of the industry sector. On the other hand, this research presented which product-related services and digital solutions have a negative impact on financial performance. Furthermore, these findings provide an understanding of the relationship between digital servitization and technology intensity, which had not been previously examined in the literature of servitization. Therefore, this research provides information on which digital solutions could solve the challenge of servitization paradox. Additionally, results show which digital solution firms must avoid in their offer if they want positive effects of digital servitization.

The remainder of the manuscript is constructed as follows: Section 2 presents the literature background and describes the proposed model that was used in this paper. In Section 3, the authors present the data sample and methodology. Section 4 presents the results, and Section 5 provides a discussion from the aspect of the theoretical and practical implications. Finally, Section 6 presents the conclusion of this paper with the identified limitations and propositions for further research.

## Literature Review

### Product-Related Services and Firm Performance

The evaluation of servitization opens the scientific field of product-service systems (Beuren *et al.,* 2013). Product-service systems could be defined as the innovation strategy, which transforms firms from product offer to the offer of services along with products in order to achieve customer loyalty (Manzini, E. *et al.,* 2001). Moreover, Tukker (2004), in his study, presented product-related services (PRS) as a part of product-service systems. PRS could be defined as services that complement products with added value for customers (Oliva and Kallenberg, 2003). Therefore, PRS is a significant component of growth and success of manufacturing firms (Oliva & Kallenberg, 2003). The research community presented many classifications of PRS (Almeida & Miguel, 2009). Baines and Shi classification is the most cited one (Baines & Shi, 2015). They divided PRS into basic, intermediate, and advanced services. For instance, installation, maintenance, and training are considered basic or traditional services, and software development, modernization, or remote customer support as advanced services (Rasay *et al.,* 2019; Dachs *et al.,* 2014; Kinkel *et al.,* 2011). Since 2006, the scientific community, which conducts the European Manufacturing Survey (EMS), has followed the development of PRS (Bikfalvi *et al.,* 2013; Dachs *et al.,* 2014; Kinkel *et al.,* 2011; Marjanovic *et al.,* 2020). This community argues that developed countries (e.g., Germany, Italy) have adopted PRS in manufacturing firms at a higher level in comparison with the developing countries (e.g., Croatia, Serbia) (Bikfalvi *et al.,* 2013; Marjanovic *et al.,* 2020). The reason for this is the challenges in the adoption of PRS in manufacturing firms with a low level of technology and innovation (Moreno Renata *et al.,* 2019). Nevertheless, the previous study showed that the adoption of PRS in developing countries could have a better effect on the manufacturing firms' performance than in developed countries (Moreno Renata *et al.,* 2019). The best examples from the past are China and Brazil, which successfully applied PRS with significant financial returns (Neely *et al.,* 2011; Paslauski *et al.,* 2017).

Previous research shows that diversification impacts between revenue from products and revenue from services are in the same range (50 % - 50 %), which enables firm growth on the market (Baines and Shi, 2015). Moreover, many studies presented the positive impact of PRS on manufacturing firm performance (see Table 1), such as share of revenue (Eggert *et al.,* 2014), return on services (Moreno Renata *et al.,* 2019) and cost and income (Zahringer *et al.,* 2011). Furthermore, the application of the PRS in their manufacturing firms increased the competitive advantage of these firms in the global market (Moreno Renata *et al.,* 2019). Hence, this opens the question could digital servitization increase the position of manufacturing firms from the low economies in the global market.

Table 1

**Empirical Research on the Impact of PRS on Manufacturing Firm Performance**

| Authors (Year) | Sample | Measures |
|---|---|---|
| (Gebauer *et al.,* 2007) | Machinery and equipment manufacturing industries (case studies from China) | – Ratio of service revenue |
| (Fang *et al.,* 2008) | Chemical products, Industrial machinery, Electronic equipment and Transportation equipment (477 United States) | – Firm value |
| (Zahringer *et al.,* 2011) | Manufacture of machines (Zwick GmbH & Co. KG) | – Financial aspects: costs and income |
| (Eggert *et al.,* 2014) | Mechanical engineering industry (513 German firms) | – Share of revenue<br>– Profit |
| (Visnjic *et al.,* 2016) | SIC 10-39 (113 firms OSIRIS database) | – Ratio between market capitalization and the book value of total assets |
| (Marjanovic *et al.,* 2020) | NACE Rev 2.2 (474 Croatian, Serbian and Slovenian firms) | – Share of revenue |
| (Moreno Renata *et al.,* 2019) | ISIC 25-30 (539 firms from 22 developed countries) | – Sales increase<br>– Return on sales |

Common to the research presented in Table 1 is that they take financial aspects as measures of manufacturing firm performance. The previous studies argue that there are many factors for measure the impact of servitization such as customer loyalty, benefit for products, business growth, financial indicators, etc. (Adrodegari & Saccani, 2020). Nevertheless, financial indicators are most often used to measure the impact of servitization due to the possibility of their quantitative interpretations (Kohtamaki *et al.,* 2020b). Moreover, in many cases (i.e. 20 % of servitization studies) (Calabrese *et al.,* 2019), they use the share of revenue as an indicator of manufacturing firm performance (Eggert *et al.,* 2014; Gebauer *et al.,* 2007; Marjanovic *et al.,* 2020). In line with the aforementioned research, the authors decided to employ the share of revenue as the dependent variable in this study. Successful application of the PRS is dependent on industrial characteristics (Fang *et al.,* 2008). Previous studies focus on one manufacturing firm (Zahringer *et al.,* 2011) or on all industrial sectors (Visnjic et al., 2016). The measure of the impact depending on the technology intensity has been neglected (Avadikyan *et al.,* 2012). Given the gap presented in the literature, this research provides insights into the impact of PRS on manufacturing firm performance depending on technological intensity of the manufacturing industry (i.e. low, medium-low, medium-high and high technology) as provided by UNIDO (United Nations Industrial Development Organization, 2020).

**Digital Solutions and Firm Performance**

Industry 4.0 employs new digital technologies in the production of business models (Lalic *et al.,* 2019; Medic *et al.,* 2019**)**. Moreover, the latest technologies open up the opportunity for manufacturing firms to increase their share of the market (Ardolino *et al.,* 2018). The studies of the application of digital technologies in service offerings, also known as digital servitization, have grown in number in the last five years (Pirola *et al.,* 2020; T. Paschou *et al.,* 2020). Digital servitization is defined as the provision of digital solutions along with products to achieve a competitive advantage (Kohtamaki *et al.,* 2020b). A digital solution is an advanced service coupled with digitalization (Cenamor *et al.,* 2017; Lerch & Gotsch, 2015). Prior research presented that 66 % of manufacturing firms mention digital solutions as one of the top priorities (Behrendt et al., 2018). The implementation of new digital solutions offers substantial efficiency gains to both providers and customers in the manufacturing industry (Kohtamaki *et al.,* 2020b). However, the process of integrating digital technologies into companies requires managers to adapt their business strategy by integrating new technologies into their business models (Ardolino *et al.,* 2018). Therefore, manufacturing companies are trying to get their competitive advantage with an upgrade of PRS with digital solutions (Cenamor *et al.,* 2017). Interestingly, the marginal cost of digital solutions is lower than with PRS (Marjanovic *et al.,* 2019). Consequently, digital solutions have a crucial role in improving the innovation and financial performance of the manufacturing sector (Martin-Pena, M. *et al.,* 2019). Moreover, a number of studies have tested the impact of digital solutions on the manufacturing firm performance (see in Table 2), by using the share of revenue (Marjanovic *et al.,* 2019), revenues and share price evolution (Vendrell-Herrero *et al.,* 2017) and returns on assets growth (Kohtamaki *et al.,* 2020b).

Table 2

**Empirical Research on the Impact of Digital Solutions on Manufacturing Firm Performance**

| Authors (Year) | Sample | Measure |
|---|---|---|
| (Chi *et al.,* 2016) | Seven manufacturing sectors (138 manufacturing firms from China) | – Return on assets<br>– Ratio of operating income to assets |
| (Vendrell-Herrero *et al.,* 2017) | Printing and reproduction of recorded media (case studies from United States and United Kingdom) | – Revenues and profit margin evolution<br>– Revenues and share price evolution |
| (Marjanovic *et al.,* 2019) | NACE Rev 2.2 (240 manufacturing firms from Serbia) | – Share of revenue |
| (Martin-Pena *et al.,* 2019) | NACE Rev 2.2 (828 manufacturing firms from Spain) | – Total sales |
| (Kohtamaki *et al.,* 2020b) | Four manufacturing sectors (131 Swedish manufacturing firms) | – Return on assets growth |
| (Kharlamov & Parry, 2020) | Printing and reproduction of recorded media (258 firms from United Kingdom) | – Return on assets<br>– Profit margin |
| (Abou-Foul *et al.,* 2020) | SIC Code 7 – 32 (185 firms from Germany, United Kingdom, United States, Spain, France, Italy. Sweden and Switzerland) | – Share of revenue<br>– Return on sales<br>– Return on investemnts |
| (Coreynen *et al.,* 2020) | Seven business industries (137 firms from Belgium (42% of manufacturing firm)) | – Technological turbulence<br>– Competitive intensity |

The research presented in Table 2 employs in many cases financial aspects as the measure of manufacturing firm performance. Moreover, this is in line with previous research of PRS, which is shown in Table 1. In this study, the authors used the share of revenue from services as a proxy for the performance.

The application of adequate digital technologies, according to the industry, is a prerequisite for successful digital servitization (Ardolino *et al.,* 2018). An earlier study argued that consolidating PRS offerings is very important for the expansion of digital solutions (Bustinza *et al.,* 2018). Organizational factors, such as resources and commitment of production managers, are essential for employing digital solutions (Bustinza *et al.,* 2018). Moreover, Frank et al. (2019) found that the technology level of production is an essential criterion for the selection of adequate digital solutions for a firm. Furthermore, early studies presented that services based on Big Data Analysis or the Internet of Things have a strong correlation with the technology level of a firm (Feng & Shanthikumar, 2018; Paschou *et al.,* 2020). According to the classification of UNIDO, the authors will employ digital solutions in the three different categories of technology intensity (United Nations Industrial Development Organization, 2020).

### Product-Related Services and Digital Solutions

Gebauer first mentions product-related services as innovation through services offered in manufacturing firms (Gebauer *et al.,* 2008). On the other side, Industry 4.0 concepts influence the use of digital technologies in service offers, which results in digital solutions (Zivlak *et al.,* 2021). Moreover, the results show that digital solutions have emerged from the use of digital technologies in the offer of product-related services (Lerch & Gotsch, 2015). Previous research shows that product-related services such as installation, maintenance, product design, and take-bake services represent services that are traditional and closely related to product characteristics (Bikfalvi *et al.,* 2013). On the other side, product-related services such as training, remote support for clients, modernization, and software development represent services that are advanced and not closely related to product characteristics (Bikfalvi *et al.,* 2013). Furthermore, results show that advanced services, which are not closely related to product characteristics, have more opportunities for transformation into digital services (Rakic *et al.,* 2021b). For example, manufacturing firms easier transform training to be online training than maintenance to be predictive maintenance (Rakic *et al.,* 2021b). According to the traditional product-related services, this research employs digital services, which include digital technologies in their offer (Lerch & Gotsch, 2015). Digital services for product utilization (e.g. online training) represent the use of digital technologies in traditional training (Jager, 2020). Digital services for customized product configuration or product design represent the use of digital technologies in the traditional service of product design (Jager, 2020). Digital/remote monitoring of operating status represents the use of digital technologies in traditional remote support for clients. Mobile devices for diagnosis, repair, or consultancy represent the use of digital technologies in traditional maintenance (Jager, 2020). Data-based services based on big data analysis represent the additional option for traditional service software development (Jager, 2020). Additionally, previous research, which measures the impact of product-related and digital services on the manufacturing firm performance, measured only the impact of one of these two service groups (Marjanovic *et al.,* 2020). This research first measures the impact of product-related services on manufacturing firm performance, and then the impact of product-related services along with digital services on firm performance. In this way, results show how the application of digital technologies in product-related services affects the financial performance of the firm according to the technology level of the firm.

**Servitization Paradox**

Most of the studies in the servitization literature show positive effects of service offerings along with products on firm performance (Eggert *et al.,* 2011; Moreno Renata *et al.,* 2019; Visnjic *et al.,* 2016). However, some studies show unexpected returns from service offerings (Li *et al.,* 2015). The results presented in these studies indicate negative financial implications from servitization (Johnstone *et al.,* 2014). For instance, a study of bankruptcy in manufacturing firms argued that servitized firms have more chances to fail in business than non-servitized firms (Benedettini *et al.,* 2015). In addition, servitized firms face greater risks from the environment and internal organization (Benedettini *et al.,* 2015). Kohtamaki et al. (2020a) found that one of the main problems of negative implications of services is the inadequate representation of the service offered according to industry. Most firms would like to provide more services to achieve competitive advantage (Jovanovic *et al.,* 2016); however, they are not at a sufficient level of maturity to be able to deliver these services (Gebauer *et al.,* 2005). That is why the servitization paradox is vital to be explored further (Gebauer et al., 2005), and researchers should ask the following question "*How to solve this challenge?*"

One of the essential components of the digitalization strategy and application of Industry 4.0 concepts is digital service (Frank *et al.,* 2019, Cwiklicki & Wojnarowska, 2020). Thus, it could be argued that digital services could be a solution to the service paradox in the manufacturing industry (Gebauer *et al.,* 2020). The reason for this is a lower implementation cost of digital solutions in comparison to the traditional solutions (Marjanovic *et al.,* 2019). Furthermore, digital solutions provide more opportunities for firms to manage their resources, and with the proper organization of production, firms could overcome the service paradox (Gebauer *et al.,* 2020, Kohtamaki *et al.,* 2020a). Firms should mainly focus on digital solutions such as artificial intelligence, Internet of Things and Big Data Analysis to solve challenges of the servitization paradox (Gebauer *et al.,* 2020; Kohtamaki *et al.,* 2020a; Marjanovic *et al.,* 2018). Hence, it's very important to find which services provide positive and which provide a negative impact on firm performance. With these information production managers could avoid some services with negative implication on performance and increase the offer of services which support firm growth.

**Research Model and Hypotheses**

The use of PRS in emerging economies with low-technology intensity presents an opportunity for manufacturing firms to get closer to the competitors from the developed countries (Paslauski *et al.,* 2017). The evidence from Brazilian low-technology firms presented a strong relationship between the use of PRS and customer loyalty (Zawislak *et al.,* 2013). The use of PRS could be the main divergence between firms with low technology, which would enable them to achieve competitive advantage (Juan Fernandez, 2014). Previous research from firms with low-technology intensity presented the positive effect of PRS on manufacturing firm performance (Marjanovic *et al.,* 2020). Moreover, they showed that advanced PRS have a positive impact when services are directly invoiced (Marjanovic *et al.,* 2020). Furthermore, they presented that traditional PRS have a positive impact when services are indirectly invoiced (Marjanovic *et al.,* 2020). According to evidence from the previous studies of PRS in manufacturing firms with low-technology intensity, the authors proposed H1a:

*H1a: Product-related services have a positive effect on the performance of manufacturing firms with low technological intensity.*

The results from the industry with medium-low technology intensity show a strong relationship between PRS and product offer (Kastalli & Van Looy, 2013). Moreover, the previous study argued that a small number of offered PRS have high financial returns (Kastalli & Van Looy, 2013). The evidence from the German industry shows that firms with medium-low technology which employ services supporting clients' actions, have a higher percentage of profit growth (Eggert *et al.,* 2014). Furthermore, services, which support the supplier's product, could be the best option to introduce PSS in manufacturing firms (Eggert *et al.,* 2014). Another study demonstrated that manufacturing firms must adopt adequate PRS for their sector (Kinkel *et al.,* 2011). Moreover, the research showed that in firms with medium-technology intensity, the share of revenue from services is higher if they are directly accounted for product price (Kinkel *et al.,* 2011). Previous research also presented that firms with fewer than 50 employees have the most significant return from PRS (Kinkel *et al.,* 2011). According to evidence from the previous studies of PRS in the manufacturing firms with medium-low technological intensity, the authors proposed H1b:

*H1b: Product-related services have a positive effect on the performance of manufacturing firms with medium-low technological intensity.*

The largest number of PRS related studies has been conducted within the manufacturing firms with medium-high and high technology intensity (Moreno Renata *et al.,* 2019). Software development as an advanced PRS is considered as the one, which contributes to the highest increase in revenue for firms with high technological intensity (Kinkel *et al.,* 2011). The previous evidence presented that manufacturing firms from the United States have the highest increase in return on services (Moreno Renata *et al.,* 2019). Among the European countries, the Netherlands and Denmark have the most significant share of revenue from services in manufacturing firms with high technological intensity (Dachs *et al.,* 2014). Moreover, these countries have the highest percentage of directly invoiced services (Dachs *et al.,* 2014). The next step for increasing revenue from service for high-tech firms is the orientation from product-oriented services to performance-based services (Jovanovic *et al.,* 2016). According to evidence from the previous studies of PRS in the manufacturing firms with medium-high and high technology intensity, the authors proposed H1c:

*H1c: Product-related services have a positive effect on the performance of manufacturing firms with medium-high technological intensity.*

Studies conducted in the low-tech industry (i.e., printing) examined the impact of digital solutions on firm performance (Kharlamov & Parry, 2020; Vendrell-Herrero *et al.,* 2017). For example, Vendrell-Herrero et al. (2017) found a positive impact of digital solutions on the share of revenue from services. For instance, the evidence from Italy shows that low-tech firms developed 73 % of digital solutions for their customers (Bustinza *et al.,* 2018). Furthermore, small and medium enterprises from Italy showed a strong relationship between implementing digital solutions and organizational changes at the firm level (Bustinza *et al.,* 2018). The evidence from the United Kingdom printing industry shows a positive effect of digital solutions on the productivity and finance of firms (Kharlamov & Parry, 2020). Thus, the present study proposes the following hypothesis:

*H2a: Digital solutions, along with product-related services, have a positive effect on the performance of manufacturing firms with low technological intensity.*

Previous research from Spanish manufacturing medium-low-tech sectors showed a significant impact of digital servitization on firm performance (Martin-Pena *et al.,* 2019). The results showed that digital solutions have the highest impact on total sales of the rubber industry for medium-low-tech firms (Martin-Pena *et al.,* 2019). Furthermore, a prior study showed that digital solutions for utilization and customized design of products have a positive impact on the share of revenue from services (Marjanovic *et al.,* 2019). Evidence from Italy showed that the industry of basic metal prefers to offer digital solutions developed by its suppliers (Bustinza *et al.,* 2018). Moreover, these results provide positive correlations between commitment in the application of new technologies and the successful implementation of digital solutions (Bustinza *et al.,* 2018). According to the evidence from previous studies of digital solutions in the manufacturing firms with medium-low technological intensity, the authors proposed:

*H2b: Digital solutions, along with product-related services, have a positive effect on the performance of manufacturing firms with medium-low technological intensity.*

The previous studies found the most robust relationship between digitalization, servitization, and firm performance of the high-tech firms (Kohtamaki *et al.,* 2020b). Moreover, the technology push is presented as a requirement for the implemented process-oriented digital solutions (Frank *et al.,* 2019). The evidence from Spain showed the most substantial impact of digital solutions on firms from the chemical and electrical industry (Martin-Pena *et al.,* 2019). Furthermore, the electronic industry from Italy presented a strong relationship between firm agility and implementation of digital solutions (Bustinza *et al.,* 2018). The findings from Swedish manufacturing firms showed ahigh impact of digital solutions on the cash flow of high-tech firms (Kohtamaki *et al.,* 2020b). According to the evidence from the previous studies of digital solutions in manufacturing firms with medium-high and high technological intensity,the authors proposed:

*H2c: Digital solutions, along with product-related services, have a positive effect on the performance of manufacturing firms with medium-high and high technological intensity.*

According to the literature background and presented hypotheses, the authors proposed the following research model.

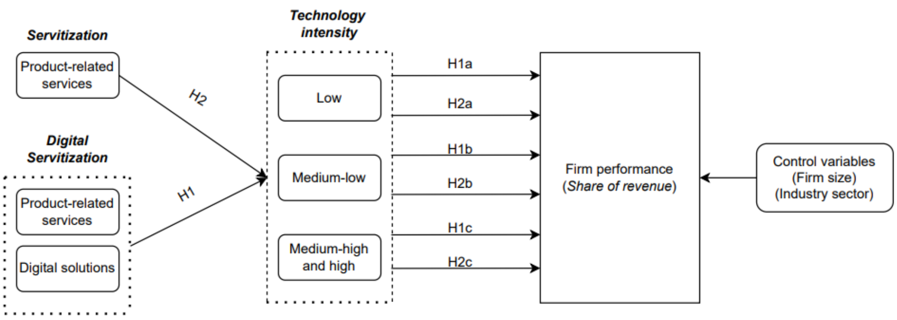


**Figure 1.** Research Model

## Methodology

### Research Model and Hypotheses

The data for this empirical study originate from the European Manufacturing Survey (EMS) (Jager, 2020). The EMS is administered by the Fraunhofer ISI and conducted in 15 European countries (Jager, 2020). EMS is a consistent, triennial questionnaire to screen the innovation potential of the manufacturing sector of European enterprises at the firm level. Developing countries need to upgrade their level of servitization for solving the servitization paradox (Szasz *et al.,* 2017). Hence, we used the Serbian dataset 2018 edition for this research. The survey was sent out to senior managers of firms with 20 or more employees. A random stratified sample was used for the sampling method using three-stratum criteria: firm size, industry sector and district in the Republic of Serbia. 1048 manufacturing firms from the Republic of Serbia were in the sampling frame. The data was collected using the adapted Dillman's (2014) method, resulting in a 34.8 % response rate. The first iteration with respondents was a phone call with production managers of the firms. After that, the survey with the cover letter was sent via post to encourage involvement. The questionnaire was addressed to the production and financial managers to provide relevant information about the firms. The first reminder was sent after seven and the second one after 14 days. The final sample included 240 manufacturing firms from the Republic of Serbia. The information from this sample was with complete information on all variables. The sample represents 27 manufacturing firms with more than 250 employees, 103 manufacturing firms with between 50 and 249 employees, and 110 manufacturing firms with fewer than 50 employees. The manufacturing firms in the sample employ 123 workers on average (SD=208). The sample selection bias analyses were performed to provide the representativeness of the sample. The one-sample t-test, which compared firms from the population (i.e. respondents and non-respondents), did not present statistically significant divergence between firms. The authors observed variables such as firm size (t=-.195, p=0.845), industry sector (t=1.224, p=0.222), and district in the Republic of Serbia (t=-1.723, p=0.086). Thus, it could be concluded that firms from the population, which are not in the sample, cannot negatively affect the representativeness of the sample. For data analysis, the manufacturing firms were divided into three groups of industry with different technology intensity according to the UNIDO classification for developing countries (United Nations Industrial Development Organization, 2020). Table 3 shows the classification of manufacturing sectors according to technology intensity and share in the total sample. The manufacture of food production has the highest share of the total sample with 16.3 %. Further, the production of fabricated metal products, except machinery and equipment, has 15 % of the total sample. They represent low and low-medium-tech firms with the highest share of the total sample. Production of electrical equipment, and machinery and equipment n.e.c. with 6.3 % of the sample represents medium-high firms with the highest share. Ultimately, the production of computer, electronic, and optical products with 2.1 % of the sample represents high-tech firms with the highest share. To calculate the relationships between PRS, digital solutions, and financial benefit, the authors employed hierarchical multiple regression. Regression analysis is often used in empirical research of servitization (Kohtamaki *et al.,* 2020b). Moreover, the proposed research model has two levels of the measures; first block which explain the impact of product-related services on firm performance and second which measure product-related services along with digital solutions on firm performance. According to these two types of block author, employ multiple hierarchical resgression. For the in depth, analysis authors employ fixed-panel regression to measure effects of PRS and digital solutions from 55 manufacturing firms The fixed-panel regression panel allows tracking of identical manufacturing firms over time with controlling external influences (Oscar Torres-Reyna, 2007). The advantages of this analysis can be seen in the fact that avoidance of bias in response is removed, the effects of time-invariant characteristics are removed in order to be able to estimate the net effects of predictors on the variable outcome. This longitudinal study can contribute to a better understanding of which sectors have proven to be the most successful for the application of digital services according to the technology intensity the firm.

Table 3

**Classification of Manufacturing Sectors According to Technology Intensity and Share in Total Sample**

| NACE Rev 2.2 | Manufacturing industry | Share in total sample (%) | Technology intensity |
|---|---|---|---|
| 10 | Food products | 16.3 % | Low |
| 11 | Beverages | 2.5 % | Low |
| 12 | Tobacco products | 0.4 % | Low |
| 13 | Textiles | 2.1 % | Low |
| 14 | Wearing apparel | 5.8 % | Low |
| 15 | Leather and related products | 2.9 % | Low |
| 16 | Wood and products of wood and cork | 4.6 % | Low |
| 17 | Paper and paper products | 2.5 % | Low |
| 18 | Printing and reproduction of recorded media | 3.8 % | Low |
| 19 | Coke and refined petroleum products | 0.8 % | Medium-low |
| 20 | Chemicals and chemical products | 2.1 % | Medium-high |
| 21 | Basic pharmaceutical products and preparations | 0.8 % | High |
| 22 | Rubber and plastic products | 8.8 % | Medium-low |
| 23 | Other non-metallic mineral products | 4.6 % | Medium-low |
| 24 | Basic metals | 2.1 % | Medium-low |
| 25 | Fabricated metal products, except machinery and equipment | 15.0 % | Medium-low |
| 26 | Computer, electronic and optical products | 2.1 % | High |
| 27 | Electrical equipment | 6.3 % | Medium-high |
| 28 | Machinery and equipment n.e.c. | 6.3 % | Medium-high |
| 29 | Motor vehicles, trailers and semi-trailers | 4.2 % | Medium-high |
| 30 | Other transport equipment | 0.4 % | Medium-high |
| 31 | Furniture | 3.8 % | Low |
| 32 | Other manufacturing | 1.3 % | Low |
| 33 | Repair and installation of machinery and equipment | 0.8 % | Medium-low |

**Measures**

**Dependent Variable**

To calculate the dependent variable (i.e. firm performance), the authors used the dataset from the survey – the share of revenue from service. Furthermore, previous research in the literature presented the share of revenue as a measure of profitability (Eggert *et al.,* 2014; Marjanovic *et al.,* 2019; Vendrell-Herrero *et al.,* 2017). Figure 1 summarizes the model, predictors, and the dependent variable used in the study.

**Independent Variable**

Regarding the independent variables, the authors considered two types of predictors. In the first model, the authors measured the impact of a PRS (predictor 1) on the performance of firms separated into three groups of industry according to technology intensity. PRS is one of the often used service ratios that compute the share of turnover from service (Gebauer *et al.,* 2007., In the second model, the authors measured the impact of all digital solutions (predictor 2) along with the PRS (predictor 1) on firm performance. Digital solutions are used as predictors in studies, which measure the relation between digital servitization and firm performance (Kohtamaki *et al.,* 2020b; Martin-Pena *et al.,* 2019). Furthermore, the authors carried out an analysis of how each digital solution affects the performance of firms separated into three groups of industry. With all this information, the authors presented which digital solutions along with PRS have the most beneficial effect on firm performance according to technological intensity

**Control Variable**

The authors employed two control variables: firm size and industry sector. These variables control the impact of alternate variables on the relations between PRS and digital solutions on firm performance. Firm size (i.e. the number of employees) is the often used control variable in previous research on the servitization impact (Eggert *et al.,* 2014; Kohtamäki *et al.,* 2020b; Martin-Pena *et al.,* 2019). Previous studies also presented the industry sector as the potential control variable (Martin-Pena *et al.,* 2019). The NACE Rev 2.2 (Eurostat, 2008) classification was used to describe the industry sector. The results of the regression models are presented in Tables 4 and 5.

**Results**

The analysis of results will present the results of the two models, first the impact of PRS on firm performance, and second the impact of digital solutions along with PRS on firm performance. Table 4 summarizes the results of the first model. The obtained results present the positive and significant effects of PRS on firm performance. Furthermore, $R^2$ for low-technology intensity is 0.655, for medium-technology intensity $R^2$ is 0.217, and finally, for medium-high and high technology intensity, $R^2$ is 0.617.

Table 4

**Results of First Model**

| Variables | H1a | H1b | H1c |
|---|---|---|---|
| *Control* | | | |
| Firm size | -.071 | 0.129 | -0.084 |
| Industry sector | .149 | 0.089 | -0.187 |
| *Product-related service* | | | |
| Installation, start-up | .160 | -.042 | .274 |
| Maintenance and repair | .045 | -.045 | .042 |
| Training | .018 | .392** | .076 |
| Remote support for clients | -.001 | .223 | -.059 |
| Design, consulting, project planning | .115 | .101 | .079 |
| Software development | -.689 | -.029 | .649*** |
| Revamping or modernization | 1.071*** | -.091 | -.158 |
| Take-back services | -.103*** | -.032 | -.156 |
| R | .809 | .466 | .786 |
| $R^2$ | .655 | .217 | .617 |
| Sig. | 0.001 | 0.05 | .001 |

*Note **p<0.01; ***p<0.001*

Although the overall results of the model in three different categories present a positive and significant effect on manufacturing firm performance, we can see that some services make a negative impact on firm performance. The software development has a strong negative impact on firm performance for low-tech firms. Moreover, take-back services make a significant negative impact on low-tech firms. Additionally, for the medium-low firms, there are five product-related services, which provide a negative impact on their performance. Revamping or modernization and take-back services make a strong negative impact on firm performance for firms with medium-high and high technology intensity levels. Table 5 summarizes the results of the second model. The results obtained by hierarchical multiple regression show an additional impact on firm performance. The introduction of digital solutions increases the PRS impact on firm performance. The $R^2$ changes from 0.655 (without the application of digital solutions; $p<.001$) to 0.801 (with the application of digital solutions, $p<.001$) for low-technology firms. The $R^2$ changes from 0.217 (without the application of digital solutions; $p<.01$) to 0.376 (with the application of digital solutions; $p<.01$) for medium-technology firms. The $R^2$ changes from 0.617 (without the application of digital solutions; $p<.001$) to 0.805 (with the application of digital solutions, $p<.001$) for medium-high and high technology firms.

Table 5

**Results of Second Model**

| Variable | H2a | H2b | H2c |
|---|---|---|---|
| *Control* | | | |
| Firm size | -.071 | 0.129 | -.084 |
| Industry sector | .149 | 0.089 | -.187 |
| *Product-related service* | | | |
| Installation, start-up | .103 | .060 | .390** |
| Maintenance and repair | .024 | -.152 | .064 |
| Training | .064 | .377** | .048 |
| Remote support for clients | -.048 | .208 | .126 |
| Design, consulting, project planning | .068 | .047 | .018 |
| Software development | -.816*** | -.168 | .633*** |
| Revamping or modernization | 1.104*** | -.217 | .011 |
| Take-back services | -.073 | -.120 | -.194 |
| *Digital Solutions* | | | |
| Digital services for product utilization | .177 | .194 | -.216 |
| Digital services for customized product configuration or product design | .141 | .060 | .003 |
| Digital/remote monitoring of operating status | -.040 | -.168 | -.150 |
| Mobile devices for diagnosis, repair or consultancy | -.066 | . 009 | -.276** |
| Data-based services based on big data analysis | .321*** | .470*** | .313*** |
| R | .895 | .613 | .897 |
| $R^2$ | .801 | .376 | .805 |
| Sig. | .000 | 0.01 | .001 |

*Note **p<0.01; ***p<0.001*

Notwithstanding the overall results of the second model present a positive and significant effect on manufacturing firm performance; we can see that some services make a negative impact on firm performance. The software development has a significant negative impact on firm performance for low-tech firms. Additionally, two digital solutions also provide a negative impact on low-tech firms. Furthermore, four PRS and one digital solution make a strong negative impact on medium low-tech firms. Mobile devices for diagnosis, repair, or consultancy has a significant negative impact on firm performance for medium-high and high-tech firms. Further, two digital solutions and one PRS have a strong negative impact on medium-high and high-tech firms.

Using hierarchical multiple regression, the authors measured the relation between digital solutions, PRS, and firm performance according to the technology intensity of the firms. Thus, the authors found support for H1a for the overall model, especially for revamping or modernization (β=1.071, p<0.001). Furthermore, the authors found support for H1b for the overall model, especially for training (β=0.392, p<0.01) and for the overall model for H1c especially for software development (β=0.649, p<0.001). The main hypothesis H1 presents a positive and significant impact of PRS on firm performance, the $R^2$ value is 0.329, for p<0.001.

The second model finds support for the overall model H1a, especially for revamping or modernization (β=1.104, p<0.001) and digital solutions based on Big Data (β=0.321, p<.001). The authors found support for the overall model H2b, especially for training (β=0.377, p<0.01) and digital solutions based on Big Data (β=0.470, p<0.001). For overall model H2c, the authors especially found support for installation (β=0.390, p<0.01), software development (β=0.633 p<0.001), and digital solutions based on Big Data (β=0.313, p<0.001). The main hypothesis in the second model H2 presents a positive and significant impact of PRS on firm performance, the $R^2$ value is 0.437, for p<0.001. The results show that with the increase in the technological intensity level of firms, the impact of digital solutions on performance increases. Moreover, the results showed an R2 change of 0.144 for low-tech firms, 0.159 for med-tech firms, and 0.188 for high-tech firms. Furthermore, only digital solutions based on Big Data have a positive and significant impact on firm performance for all firms regardless of technology intensity. Nevertheless, for the in-depth understanding of the digital servitization impact, we must additionally analyse the special cases of some services, which make a negative and strong impact on firm performance.

According to the research question, Table 6 summarizes the results of fixed-panel regression from 55 manufacturing firms with data conducted in EMS 2015 and EMS 2018. The obtained results present the positive and significant effects of PRS and digital solutions on firm performance over the years.

Table 6

**Results of Fixed-Panel Regression**

| ***Variable*** | ***Measure*** |
|---|---|
| *Product-related services* | |
| Installation, start-up | .295 |
| Maintenance and repair | -1.919* |
| Training | 3.284*** |

| *Variable* | *Measure* |
|---|---|
| Remote support for clients | .321 |
| Design, consulting, project planning | .413 |
| Software development | .434 |
| Revamping or modernization | -2.865** |
| Take-back services | 1.231 |
| *Digital solutions* | |
| Digital services for product utilization | -.919 |
| Digital services for customized product configuration or product design | -.806 |
| Digital/remote monitoring of operating status | 2.558* |
| Mobile devices for diagnosis, repair or consultancy | 2.327* |
| Data-based services based on big data analysis | 1.725* |
| R | 0.519 |
| $R^2$ | 0.352 |
| Sig. | 0.001 |

*Note *p<0.5, **p<0.01; ***p<0.001*

Results from the fixed-panel regression show positive and significant results for the training as a product-related service (β=3.284, p<0.001) and Digital/remote monitoring of operating status (β=2.558, p<0.0), Mobile devices for diagnosis, repair, or consultancy (β=2.327, p<0.0), and Data-based services based on big data analysis (β=1.725, p<0.0) as digital solutions. On the other hand, results show that maintenance and repair and revamping or modernization make negative and significant effects on the firm performance. All other services have non-significant effects. The overall model shows a positive and significant impact on manufacturing firm performance for R2 value 0.353, and p<0.001. Additionally, these results show that firms from the sector of installation of industrial machinery and equipment make the highest financial returns from service investments.

The general results provide a positive framework of digital servitization, but in some cases, we could see that digital servitization supports the servitization paradox. In order to give additional value for the science and practice community, the authors will be detailed discussion these paradigms.

## Discussion

### Theoretical Implications

The manuscript presents a new approach to servitization based on technology intensity. The main contribution of the research is the finding that some digital solutions (e.g. Big Data Analysis) could be a solution to the servitization paradox. The authors also established a strong effect of technology intensity on relations between digital servitization and firm performance. The findings provide an in-depth understanding of which services have the highest impact depending on the technology level of the firm. The results show that digital solutions increase the impact of PRS on firm performance in the overall models. Additionally, results confirm previous findings which show that product-related services which are closely related to product characteristics (e.g. installation, maintenance and repair, producer design, and take-back services) have a negative impact on the digital servitization of the firms (Rakic *et al.,* 2021b). Furthermore, some services such as Remote support for clients or Revamping and Modernization make directly negative impact on the financial performance. However, this services increase customer satisfaction and loyalty and in indirectly way they make reflection on financial performance. In addition, results confirm that software development as a service supports positive results of the manufacturing firm performance (Marjanovic *et al.,* 2020). On the other hand, results provide which PRS and digital solution, manufacturing firms must avoid if they want a positive impact of servitization according to the technology intensity. Furthermore, digital solutions based on Big Data Analysis have the highest impact on the share of the revenue from service irrespective of technology intensity. This deepens the significance of Big Data Analysis in the servitization literature (Opresnik & Taisch, 2015; Lehrer *et al.,* 2018). The results confirm previous studies that presented a positive relation between servitization and firm performance (Gebauer *et al.,* 2012; Kharlamov & Parry, 2020; Visnjic *et al.,* 2016). Furthermore, the results present benefit of digital solutions for manufacturing firms. These findings confirm that some digital services could be a solution to the paradox of digitalization (Gebauer *et al.,* 2020). Moreover, the results provide evidence from developing countries, which are revealed as the research gap in the servitization literature (Szasz *et al.,* 2017). In the previous literature, China and Brazil were presented as developing countries that changed their business models via servitization (Gebauer *et al.,* 2007; Zawislak *et al.,* 2013). Therefore, the new digital servitization provides great opportunities for less developed countries to enter the value chain of developed countries (Marjanovic *et al.,* 2019). On the other hand, the use of PRS and digital solutions is not in line with their effect on firm performance. For instance, the use of digital solutions based on Big Data has the lowest share of use. However, this service provides the highest impact on firm performance. These findings show the lack of vision in service offer from manufacturing firms in developing countries (Benedettini *et al.,* 2015; Szasz *et al.,* 2017). Finding from this study support previous findings which show that firms with low-tech could improve their finical performance with the employment of digital solutions (Kharlamov & Parry, 2020; Vendrell-Herrero *et al.,* 2017). Additionally, results confirm that product-related services along with digital solutions could improve financial performance for the manufacturing sector of the rubber or basic metal industry (Bustinza et al., 2018). Finally, results confirm that technology push could improve the effects of process-oriented digital solutions with the help of software development and big data analysis for the high-tech firms (Kohtamaki *et al.,* 2020b). For the in-depth understanding of the solving problem of servitization paradox, results from the fixed-panel regression show which digital solutions could make long-term effects (Gebauer *et al.,* 2020). Moreover, results show that manufacturing firms from the installation of industrial machinery and equipment have the highest effect on the manufacturing firm performance through the years. However, the question for further research is why manufacturing firms provide services that incur negative financial benefits. Future research needs to involve other effects of servitization to understand the offer of services that provide negative results; nevertheless, maybe these services provide positive effects on customer loyalty or business growth.

### Practical Implications

Immense competition on the market and constantly changing market conditions have forced manufacturing firms to innovate in order to maintain their competitive edge. Previous literature did not explain which combinations of traditional and digital services contribute to firm performance. It did not answer the question if manufacturing firms can achieve profit growth via digital service innovations. This study provides useful information for production managers on how to improve their business models through innovations via digital solutions. Moreover, the results show which combination of traditional and digital services provides turnover growth according to the technology level of the firm. Overall, the empirical results of 240 Serbian industrial firms across 23 industries support the findings that digital solutions facilitate revenue growth from services. In particular, to further increase their revenue streams, manufacturing firms with low technological intensity need to employ services such as revamping or modernization along with digital solutions based on Big Data. Furthermore, our research indicates that manufacturing firms with low-medium technology intensity can successfully increase their share of turnover from services with a combination of training and Big Data services. When it comes to revenue growth for a manufacturing firm with medium-high and high technology intensity, managers should be aware that digital solutions based on Big Data, along with installation and software development, increase their impact. The results show that manufacturing firms do not use adequate services according to technological intensity. Second, the use of inadequate services according to technological intensity can be a reason why manufacturing firms cannot get closer to developed countries in terms of the share of turnover from service offerings. Furthermore, this research highlights which product-related services or digital solutions are inadequate according to the technology intensity and industry sectors. These findings support the production manager to avoid mentioned services (e.g. software development for low-tech firms or Mobile devices for diagnosis, repair, or consultancy for high-tech firms) which results in a negative impact on financial performance. Manufacturing firms from emerging economies are not sufficiently devoted to the service business model and that is the main obstacle in the successful implementation of digital servitization. Table 7 summarizes the best combination of product-related and digital solutions according to the technology level of the firm.

Table 7

**The Optimal Combination of Traditional and Digital Services**

| Technology intensity | Product-related services (H1) | Product-related services and digital solutions (H2) |
|---|---|---|
| Low-tech firms | Revamping or modernization | Revamping or modernization<br>Data-based services based on big data analysis |
| Med-tech firms | Training | Training<br>Data-based services based on big data analysis |
| High-tech firms | Software development | Installation, start-up<br>Software development<br>Data-based services based on big data analysis |

### Conclusion

This research examined the impact of digital servitization on manufacturing firm performance. The results demonstrate the role of technology intensity, product-related services, and digital solutions in different industry sectors. The data for this research was obtained through EMS. The results show which digital solutions, along with PRS, have a more beneficial effect on manufacturing firm performance. Moreover, the results show which combinations of digital solutions along with PRS produce the best results according to the technology intensity of an industry. Hence, the results show that the manufacturing firms with the highest share of turnover from services applied appropriate digital services to their industry.

This manuscript shows how the use of digital solutions in the manufacturing industry affects firm performance. The main contribution of this paper is the understanding of how and which digital solutions could support manufacturing firms to solve the servitization paradox. Moreover, this paper shows that digital solutions based on Big Data Analysis will be the most important digital services for the manufacturing industry of developing countries in the future. Furthermore, this research supports prior research, which shows that digital solutions will be a driver that provides transformation from the product-service system to the digital product-service system. This approach could be helpful to managers of manufacturing firms. With this information, managers can better shape the service portfolio for their customers when offering products with digital solutions. Hence, they could put emphasis on PRS and digital solutions that add value to firm performance. On the other side, they could avoid services, which result in a negative impact. Additionally, these findings show how technology push could improve the impact of product-related services and digital solutions. Results provide an optimal combination of product-related services and digital solutions in the manufacturing industry of developing countries. Results show how technology intensity for the firm could address the challenge of servitization and digitalization paradox. Finally, the results provide insight from the longitudinal data from the EMS survey in 2015 and 2018. These results show that firms from the industry of installation of industrial machinery and equipment have the highest opportunity to achieve positive financial performance from the services.

The research described in this paper has limitations with regard to the sample. We used only data from the Serbian manufacturing firms. Therefore, this sample could restrict the generalization of the results. Thus, future research should investigate digital servitization in different countries and compare results between developed and developing countries. Manufacturing firms are separated into three groups according to technological intensity. However, causal links between manufacturing firms in the same group of technological intensity are not the same for every industry. In the future, researchers will need to analyse the impact of PRS along with digital solutions separately for every manufacturing sector. With this information, production managers can design the best package of services with the product for their sector. This research only measures relations between services and financial performance. Future research needs to evaluate the non-financial effects (e.g. human resources and organizational factors) of the services of manufacturing firms (Johnstone *et al.,* 2014). These findings could provide production managers with an overview of services that increase customer satisfaction.

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**Authors' Biographies**

**Slavko Rakic** received his PhD degree in the field of Industrial Engineering/Engineering Management from the University of Novi Sad, Faculty of Technical Sciences. He is currently a Teaching Assistant at the Department of Industrial Engineering and Management, University of Novi Sad. His research interest focuses on digital servitization, Industry 4.0, and e-learning. His research appears in various international journals and books. Slavko is a project member of the European Manufacturing Survey and IFIP WG5.7 SIG on "Service Systems Design, Engineering, and Management".

**Margherita Pero**, Ph.D. is an Associate Professor at the Department of Management, Economics, and Industrial Engineering of Politecnico di Milano. She teaches Business processes reengineering and operations and supplies chain management at the School of Management of Politecnico di Milano. She is the director of the FlexEMBA program at MIP – Politecnico di Milano Graduate School of Business. She is the author of more than 100 papers at the national and international levels. Her main research interests are related to production planning, supply chain design and management, and supply chain management-new product development coordination.

**Andrea Sianesi** is a Full Professor at the Department of Management, Economics, and Industrial Engineering of Politecnico di Milano. He teaches Production Management and Production and logistics systems management. He is President of Fondazione Politecnico di Milano (the University foundation) and of PoliHub (the University incubator and accelerator of startups). Former Dean and President of the Board of MIP Politecnico di Milano from 2015 to 2019. His research interests are related to production planning, supply chain strategy, and supply chain management.

**Ugljesa Marjanovic** has earned his PhD degree in Industrial Engineering and Management at the University of Novi Sad, Serbia. Currently, Dr. Marjanovic is an Associate Professor of Industrial Engineering and Management at the University of Novi Sad. Ugljesa held visiting posts at Bloomsburg University and Penn State University. His research, teaching, and advisory activities are at the intersection of innovation, industrial engineering, strategy, and management. His preferred research methods are field surveys, interviews, and observations, as well as multivariate statistical analysis. Ugljesa is an Editor-in-Chief for the International Journal of Industrial Engineering and Management and a full member of IFIP WG5.7.

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