Kaunas University of Technology
School of Economics and Business

Role of Servitization in the Relationship between Digitalization and Financial Performance of European Manufacturing Companies

Master’s Final Degree Project

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Kaunas, 2022

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Innovation Management and Entrepreneurship (6211LX031)

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Summary

Manufacturing companies facing commoditization of their products and stagnating markets transform their offerings by adding services to differentiate themselves and create an additional, continuous revenue stream. Simultaneously, digitalization offers the possibility to enhance the business model or elements of it. Digital technologies allows to broaden a company's ecosystem, automate processes to increase efficiency, and create new ways of delivering value. Both, servitization and digitalization of manufacturing companies have gained increasing attention in research and at the convergence, the field of digital servitization emerged.

While both servitization and digitalization are seen as promising opportunities, companies engaging in servitization or digitalization frequently report lower than expected performance. These cases are described by the servitization or digitalization paradox, which are situations in which initial investments in either servitization or digitalization achieve good results, but subsequent larger investments do not achieve the desired financial performance. Simultaneously, adding services based on digital technologies is seen as a promising way to capture value from digitalization. This promising relationship between servitization and digitization and the simultaneous paradoxical relationship to company performance lead to the research aim of this thesis, which concerns the assessment of the interplay of servitization and digitalization as well as their effect on company financial performance. While previous quantitative research in the individual fields resulted in granular models that allow the identification of the servitization and digitalization paradox, quantitative studies on the interrelationship of servitization and digitalization remain on a high level.

In order to assess the relationship between servitization and digitalization on a more granular level, typologies for both servitization and digitalization from existing literature are explored and the effects of different types of services or digitalization efforts on company performance are evaluated. The resulting structural model relates different levels of sophistication of services to the digitalization of different elements of the business model. The effect on company performance is measured by multiple indicators for company financial performance to also assess impacts on single indicators such as revenue growth or profitability.

To evaluate the created model, secondary data from the European Manufacturing Survey from Lithuania, Slovakia, Slovenia, Croatia, and Austria is used and analyzed through partial least squares structural equation modeling. This study focuses on the industry groups of the NACE divisions 25 – 30.

The results obtained show the servitization paradox in that services supporting the product have a negative impact on profitability, while services supporting customer processes have a positive impact on profitability. At the same time, services supporting the product lead to more services supporting customer processes, which can be explained by companies developing service capabilities through simpler services and subsequently using them in more complex service offerings. With regard to digitalization, it is found that although the digitalization of manufacturing processes has a positive

effect on the efficiency of companies, an effect on profitability or growth is not visible. In addition, no relationship to servitization can be established. The digitalization of design and development processes, on the other hand, has a positive effect on both profitability and the provision of services to support customer processes. However, the effect mediated by services on financial performance is not significant. The use of digital technologies in products has a positive effect on services to support customer processes and, through this mediation, a positive indirect effect on profitability. In terms of direct effects, the digitalization of products has a negative effect on revenue growth.

In summary, it can be stated that servitization plays an important role, in the effect of product digitalization on financial performance in particular. In order to be able to use services to create value from digital products, it is advisable for companies to build up service capabilities. Companies should be prepared for initial services not generating high profitability and for digitalized products not immediately contributing to revenue growth.

Rose, Lennart. Servitizacijos vaidmuo santykyje tarp skaitmenizacijos ir Europos gamybos įmonių finansinių pasiekimų. Magistro baigiamasis projektas. vadovas Prof. dr. Mantas Vilkas. Ekonomikos ir verslo fakultetas, Kauno technologijos universitetas.

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Santrauka

Gamybos įmonės, siekiančios išvengti produktų komoditizacijos, papildo produktus paslaugomis, kad išsiskirtų ir sukurtų papildomą pajamų srautą. Skaitmeninimas suteikia galimybę patobulinti verslo modelį ar jo elementus. Skaitmeninės technologijos leidžia išplėsti įmonės ekosistemą, automatizuoti procesus, ir sukurti naujus vertės teikimo būdus. Tiek servitizacija, t.y. producktų papildumas paslaugomis, tiek gamybos įmonių skaitmeninimas sulaukė vis daugiau dėmesio moksliniuose tyrimuose, o jiems persidengus atsirado skaitmeninės servitizacijos sritis.

Nors tiek servitizacija, tiek skaitmeninimas laikomi daug žadančiomis galimybėmis, servitizacija ar skaitmeninimu užsiimančios įmonės dažnai praneša apie prastesnius nei tikėtasi veiklos rezultatus. Tokia situacija nusakoma servitizacijos arba skaitmeninimo paradokso sąvoka, kuris stebimas, kai pradinės investicijos į servitizaciją arba skaitmeninimą duoda gerų rezultatų, tačiau vėlesnės didesnės investicijos nepasiekia norimų finansinių rezultatų. Tuo pat metu skaitmeninėmis technologijomis grindžiamų paslaugų teikimas laikomas perspektyviu būdu gauti skaitmeninimo teikiamos vertės. Šis perspektyvus servitizacijos ir skaitmeninimo ryšys ir kartu paradoksalus santykis su įmonės veiklos rezultatais lemia šio darbo tyrimo tikslą, susijusį su servitizacijos ir skaitmeninimo sąveikos bei jų poveikio įmonės finansiniams rezultatams vertinimu. Nors ankstesnių kiekybinių tyrimų atskirose srityse rezultatas - apibendrinti modeliai, leidžiantys nustatyti servitizacijos ir skaitmeninimo paradoksą, kiekybiniai servitizacijos ir skaitmeninimo sąveikos tyrimai tebėra aktualūs.

Siekiant tiksliau įvertinti servitizacijos ir skaitmeninimo ryšį, nagrinėjamos tiek servitizacijos, tiek skaitmeninimo tipologijos ir vertinamas skirtingų tipų paslaugų ar skaitmeninimo pastangų poveikis įmonės veiklos rezultatams. Sudarytas struktūrinis modelis susieja skirtingus paslaugų sudėtingumo lygius su įvairių verslo modelio elementų skaitmeninimu. Poveikis įmonės veiklos rezultatams matuojamas keliais įmonės finansinės veiklos rodikliais, kad būtų galima įvertinti ir poveikį pavieniams rodikliams, pavyzdžiui, pajamų augimui ar pelningumui.

Sukurtam modeliui įvertinti naudojami antriniai Lietuvos, Slovakijos, Slovėnijos, Kroatijos ir Austrijos Europos gamybos tyrimo duomenys, kurie analizuojami taikant struktūrinių lygčių modeliavimo prieigą. Šiame tyrime daugiausia dėmesio skiriama NACE 25-30 skyrių pramonės grupėms.

Gauti rezultatai patvirtina servitizacijos paradoksą, nes produktus palaikančios paslaugos turi neigiamą poveikį pelningumui, o klientų procesus palaikančios paslaugos turi teigiamą poveikį pelningumui. Tuo pat metu produktus palaikančios paslaugos lemia daugiau klientų procesus palaikančių paslaugų, o tai galima paaiškinti tuo, kad įmonės, teikdamos paprastesnes paslaugas, išvysto paslaugų teikimo gebėjimus, o vėliau juos panaudoja teikdamos sudėtingesnes paslaugas. Kalbant apie skaitmeninimą, nustatyta, kad nors gamybos procesų skaitmeninimas turi teigiamą poveikį įmonių efektyvumui, poveikis pelningumui ar augimui nėra pastebimas. Be to, negalima nustatyti jokio ryšio su servitizacija. Kita vertus, projektavimo ir kūrimo procesų skaitmeninimas daro teigiamą poveikį ir pelningumui, ir paslaugų, skirtų klientų procesams palaikyti, teikimui Skaitmeninių technologijų naudojimas produktuose daro teigiamą poveikį paslaugoms, skirtoms

klientų procesams palaikyti, o joms medijuojant - teigiamą netiesioginį poveikį pelningumui. Kalbant apie tiesioginį poveikį, produktų skaitmeninimas turi neigiamą poveikį pajamų augimui.

Apibendrinant galima teigti, kad servitizacija atlieka svarbų vaidmenį, ypač kalbant apie produktų skaitmeninimo poveikį finansiniams rezultatams. Kad galėtų naudotis paslaugomis skaitmeninių produktų vertei kurti, įmonėms patartina kurti paslaugų teikimo pajėgumus. Įmonės turėtų būti pasirengusios tam, kad pradinės paslaugos neduos didelio pelningumo ir kad skaitmeninti produktai ne iš karto prisidės prie pajamų augimo. Tačiau paslaugoms sudėtingėjant, skaitmeninimo lygiui didėjant, atsiskleidžia teigiamas poveikis financiniams rezultatams.

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List of Abbreviations and Terms

Abbreviations:

AGV	Automated Guided Vehicle
AI	Artificial intelligence
AVE	Average Variance Extracted
CB-SEM	Covariance-based Structural Equation Modeling
CRM	Customer Relationship Management
Dig_D&D	Digitalization of Design and Development (Measurement Construct)
Dig_Man	Digitalization of Manufacturing (Measurement Construct)
Dig_Prod	Product Digitalization (Measurement Construct)
EDI	Electronic Data Interchange
EMS	European Manufacturer Survey
ERP	Enterprise Resource Planning
FEM	Finite Element Method
HTMT	Heterotrait-Monotrait
IB	Installed Base
ICT	Information and Communication Technology
IoT	Internet of Things
IPS^2	Industrial product service systems
ISIC	International Standard Industrial Classification of All Economic Activities
IT	Information Technology
MES	Manufacturing Execution System
NACE	European Classification of Economic Activities
PLM	Product Lifecycle Management
PLS-SEM	Partial Least Squares Structural Equation Modelling
R&D	Research and Development
Rev_Grow	Revenue Growth (Measurement Construct)
Rev_Emp	Revenue per Employee (Measurement Construct)
RFID	Radio Frequency Identification
ROS	Return on Sales (Measurement Construct)
SME	Small and Medium Sized Enterprises

SSC Services supporting the customer’s process

SSP Service supporting the manufacturers product

VR/AR Virtual Reality / Augmented Reality

Terms:

Business Model	*“[…] design or architecture of the value creation, delivery, and capture mechanisms [a company] employs”* (Teece, 2010, p. 172)
Digitalization	*“[d]igitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business*” (Gartner, 2021)
Digital Servitization	*“[t]he transition toward smart solutions (product-service-software systems) that enable value creation and capture through monitoring, control, optimization, and autonomous function. Digital servitization emphasizes value creation through the interplay between products, services, and software”* (Kohtamäki et al., 2021, p. 5)
Servitization	*“A transformation from a product-centric to a service-centric business model and logic”* (Kohtamäki et al., 2021, p. 4)
Service supporting the product	Services supporting the manufacturer's product have a product as the recipient of the service and are characterized by less interaction and shared value creation with the customer. SSPs are usually standardized (Mathieu, 2001a).
Service supporting the customer’s process	Services that support the customer's process have as the recipient of the service a person who uses the manufacturer's product. These services are distinguished by strong interaction with the customer, close customer relationships, and shared value creation. Typically, SSCs are highly individualized (Mathieu, 2001a).

Introduction

Servitization has received increasing prominence in the academic research community over the past three decades since this concept has been coined by Vandermerwe & Rada (1988). Similarly, digitalization has become a popular topic for manufacturing companies, for instance in relation to Industry 4.0. The convergence of these fields has aroused the interest of researchers in recent years and has led to studies around capability development, network effects, and organizational performance.

Relevance

Servitization describes a shift in business models of companies that previously focused on manufacturing towards offering additional value through services, support, knowledge, and self-service. Manufacturing companies aim to achieve differentiation and additional revenues by broadening their service offering. Due to the close relation of these services to the manufacturer's products, the field of servitization is closely linked to hybrid offerings (Ulaga & Reinartz, 2011) and industrial product service systems (IPS[2]) (Meier et al., 2010; Tukker, 2015). Servitization has led to multiple research directions concerning the impact of servitization on financial performance, marketing as well as customer relationships, and innovation pathways (Kindström & Kowalkowski, 2014).

In recent years, research on servitization has been linked to digitalization as an enabler of new services and business models. Among the first popular mentions of the link between servitization and digitalization are Allmendinger & Lombreglia (2005) who explore service possibilities enabled through connected devices. Kohtamäki et al. (2020) note that servitization is also a promising pathway to capture value from digitalization. Through a broad range of digital technologies, digitalization can be implemented to support different elements of value creation, value delivery, and value capture.

Problem Analysis

Most papers on the convergence of digitalization and servitization have been published from 2015 onwards (Paschou et al., 2020) and so far, research has mostly focused on single aspects and case studies. In a literature review on digital servitization, Paschou et al. (2020) gather potential benefits digital technology-enabled services provide for manufacturers, customers as well as society, and the environment. These offer further research directions, among others on the interplay of digitalization and different kinds of services. Although initial publications have described digitalization and servitization as promising opportunities (Allmendinger & Lombreglia, 2005; Vandermerwe & Rada, 1988), companies have frequently been struggling to achieve expected results. The challenges arising from servitization and digitalization as well as their potentially negative impact on company performance have been described as the service paradox or servitization paradox (Brax et al., 2021; Gebauer et al., 2005) and the digitalization paradox (Gebauer et al., 2020). These paradoxes describe a situation in which a company initially achieves good returns through initial servitization or digitalization steps. However, subsequent larger investments frequently do not lead to expected returns.

Recent studies in the field of digital servitization found evidence that servitization can help to capture value from digitalization (Abou-foul et al., 2021; Kohtamäki et al., 2020; Martín-Peña et al., 2020; Zhou et al., 2021). Although these studies provide insights into the interrelationship between servitization and digitalization, they do not make full use of the already established typologies from previous research on the individual research fields of servitization or digitalization. As a result, the existing research lacks a granularity that would be desirable, especially due to the typically evolutionary development of service offerings and the contrasting disruptive characteristics of digitalization (Chen et al., 2021). Translated into practice, research on this interrelationship can indicate how companies should align their digitalization and servitization efforts to improve financial outcomes.

Furthermore, results in recent research are to a certain degree contradictory in terms of the impact on company performance. This can partly be attributed to a variety of performance measures used in these studies. Therefore, a review of the measures used for company performance in previous studies as well as an alignment of the methodology for this thesis with the standards from research on strategic management (Combs et al., 2005) contributes to the advancement of the theory.

In summary, the identified research gap is that quantitative studies on the relationship between servitization and digitalization either generalize the two constructs or only consider selected aspects of these phenomena. To obtain a complete picture of the effects of digitalization and servitization on the financial performance of manufacturing companies, the focus of this study is to develop and apply a granular structural model. Consequently, the following questions constitute the research questions of the thesis: How do digitalization and servitization directly influence financial performance? How does digitalization indirectly through servitization influence financial performance?

Object of Research

The object of research is the interrelationship of servitization, digitalization, and company financial performance in European manufacturing companies.

Research Aim

The research aim is to evaluate both the direct effects of servitization and digitalization on company financial performance as well as the mediating effect of servitization on the interrelationship between digitalization and company financial performance.

Research objectives

1. To review and summarize the role of servitization in the relationship between digitalization and firms' financial performance based on prior research
2. To define a research model to analyze the impact of servitization and digitalization on financial performance and the mediating effect of servitization on the relationship between digitalization and financial performance
3. To ground a methodology that allows testing the role of servitization in the relationship between digitalization and firms' financial performance
4. To present the results of the role of servitization in the relationship between digitalization and firms' financial performance and relate the results to previous research results

Research Methodology

This thesis follows a quantitative research approach. Within the problem analysis, recent findings, as well as research gaps in the fields of servitization, digitalization, and digital servitization, are identified. Recent publications have called for a more granular approach and to investigate different forms of digitalization and servitization with standardized measures for servitization, digitalization, and performance (Brax et al., 2021) as current findings show partly contradictory outcomes. Therefore, in the subsequent chapter, different typologies for digitalization, servitization, and organizational performance are evaluated for their suitability for the described research aim. Simultaneously, previous findings on their interrelationship are discussed to derive hypotheses for the structural equation model. Within chapter 3, the research methodology to be applied as well as the dataset used are described. This thesis is based on the 2018 European manufacturer survey and the analysis is performed using a Partial Least Squares Structural Equation Model (PLS-SEM).

1. Problem Analysis

Both the literature on servitization as well as on digitalization have grown during the last years and the convergent field of digital servitization is currently gaining increased attention. An analysis of articles and conference papers in the fields of economics, econometrics and finance, engineering, social sciences as well as in business, management and accounting in the Scopus database revealed the following developments.

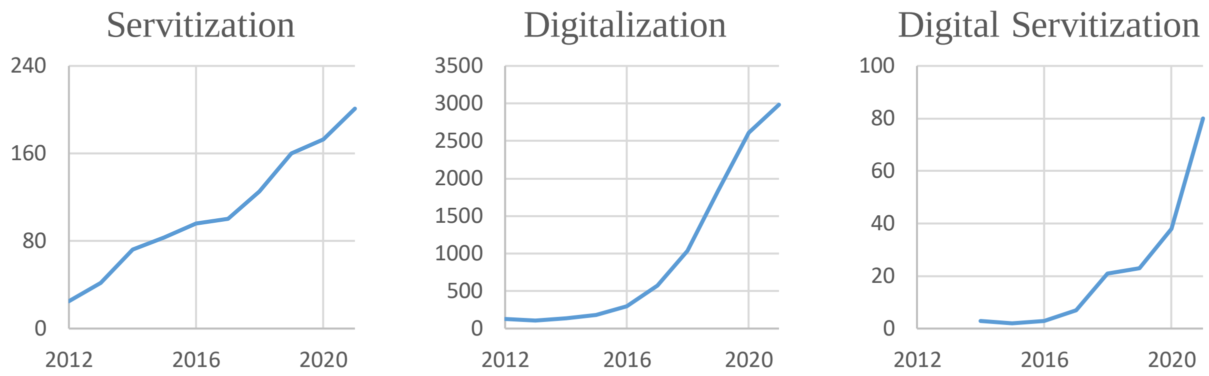

Figure 1. Publication volume per year of articles and conference proceedings with the keywords servitization, digitalization, and digital servitization on Scopus (data retrieved Jan. 2022)

As Figure 1 shows, research domains related to digitalization have gained significant attention from 2016 onwards while servitization has been a field of interest also beforehand. Publications for digital servitization doubled from 2020 to 2021. In the following, relevant data sources and literature concerning these fields are reviewed to refine the research question.

1.1. Overcoming the Servitization Paradox to Benefit from Increasing Servitization

According to the World Bank (2021), services (according to numbers 50-99 of the International Standard Industrial Classification of All Economic Activities (ISIC) Rev. 3) accounted for 65% of the global value added, while manufacturing (ISIC Rev. 3 numbers 15-37) contributed about 14.5% of value added. Since 1997, the share of services has risen from 59%, while the share of manufacturing slightly decreased from 17.5%. As shown in Figure 2, services have proved to develop more stable, especially during global crises as in 2001 and 2009. Similarly, companies with a high level of servitization expect a lower impact of the Covid-19 pandemic on their product and service sales (Kowalkowski et al., 2021).

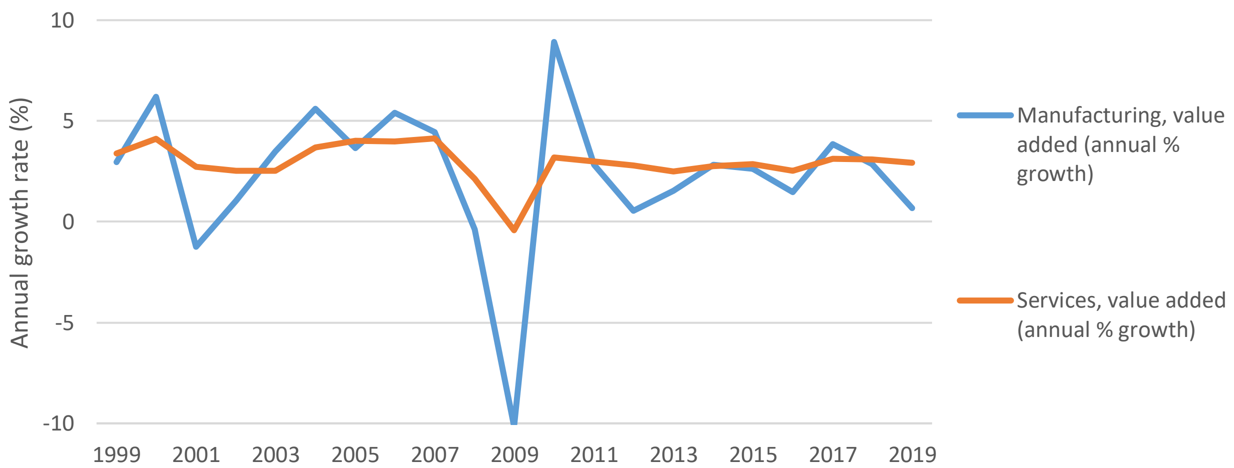

Figure 2. Annual growth of worldwide value added through manufacturing (ISIC Rev. 3, No 15-37) and services (ISIC Rev. 3 No 50-99) in % based on World Bank (2021)

1.1.1. Defining Servitization

Increasing the range of service offerings has been a promising strategy for manufacturing companies to increase returns in markets where equipment sales stagnate, differentiation is increasingly hard to maintain and customers outsource non-core activities (Mathieu, 2001b; Reinartz & Ulaga, 2014) as well as to generate stable revenues, for example, through installed base services (Oliva & Kallenberg, 2003). Furthermore, customers can gain flexibility by buying a service instead of a product and outsourcing processes outside of their core competencies (Oliva & Kallenberg, 2003). Finally, through more effective monitoring of devices and enabling circular business models, servitization can have a positive societal and environmental impact. Interestingly, the positive environmental and societal impact is found often in conjunction with the engineering-related term Industrial Product Service Systems (IPS[2]) (Tukker, 2015) while the term servitization is often linked to strategy and business performance (Paschou et al., 2020).

The trend of increasing service offerings is described by the term servitization, which refers to the transition of a manufacturing company from a product-centric to a service-centric orientation (Kowalkowski et al., 2017) in which the manufacturer's products are embedded in the service offerings. Within this transition, the speed, the path of transformation as well as the level of integration and the complexity of the service offering differ between companies. In the literature on servitization, this has led to different approaches for categorizing services and measuring the degree of servitization (Brax et al., 2021; Rabetino et al., 2021). The choice of typology for servitization has varied depending on the researched topic, such as company performance, network effects, innovation capability, and digitalization.

Most commonly the categorization of services distinguishes between simpler services and more advanced offerings. Simpler services are based on manufacturing capabilities, require fewer insights into customer processes and transfer less operational risk from the customer to the manufacturer. Since these services are easier to implement for a manufacturer they are seen as the starting point of servitization pathways and act as a basis for more advanced service offerings (Eggert et al., 2014; Mathieu, 2001a; Oliva & Kallenberg, 2003), which for instance require deeper insights into customer processes and closer relationships with the customers, and transfer operational risk to the manufacturer.

1.1.2. Identifying and Overcoming the Servitization Paradox

Despite the potential benefits that have been found for servitization, studies have revealed several barriers to implementing service-related business models, such as the need for higher-skilled employees (Neely, 2008), organizational transformation, different resources, and acceptance within the company's ecosystem (Brax, 2005; Sklyar et al., 2019). Jovanovic et al. (2019), as part of a case study on the internal service ecosystem, found that the internal front- and back-end operations and capabilities should develop along with the sophistication of service offerings. Within her research on the transformation of a manufacturer to a service provider, Brax (2005) identified multiple challenges a manufacturer needs to overcome (Table 1). These challenges show that designing a successful service, explaining its value to customers, and delivering the service as well as co-creating value with the customer substantially differ from delivering a pure product.

These challenges and barriers are part of the reason that, according to Eggert et al. (2014), half of the companies only achieve mediocre results while a quarter loses money through their servitization strategy. In studies measuring the impact of servitization on organizational performance, a U-shaped curve is frequently reported and described as the servitization paradox. Companies initially achieve good returns with service offerings but often face decreasing returns when scaling these services (Kastalli & Looy, 2013). Only after a certain threshold, which in most studies is found at services making up 20 to 30% of the total revenues (Fang et al., 2008), or through more sophisticated services such as services supporting customer's processes (Eggert et al., 2014), services deliver increasing returns.

Table 1. Challenges for manufacturers during the implementation of services (Brax, 2005)

Challenge	**Description**
Marketing challenge	Since the value created by services is not as easily tangible as it is for a physical product, the success of services frequently depends on value co-creation with the customer and services have the potential to cannibalize the product-centered business, marketing of services poses a challenge to manufacturers.
Production challenge	To deliver services successfully, the manufacturer needs a good record of the installed base. Undocumented adaptations or incomplete installed base data leads to more time consumption for service delivery and in turn lower profitability.
Delivery challenge	The provision of services differs significantly from the provision of products, which can lead to lower service quality if services are sold as an add-on to a product and the provision is organized by the business unit responsible for the product.
Product-design challenge	To maximize the value of a service solution, the solution has to be designed in a way that it works with the processes of different customers, is compatible with all relevant products throughout their lifecycle, and supports the customer in achieving their targets. Especially for digitally support services, this requires a consistent strategy and interoperable platform.
Communication challenge	With closer customer relationships and more value co-creation, the manufacturer needs to manage information flows from and to the customer efficiently and capture necessary information in a way that it is accessible for both parties.
Relationship challenge	Unprofessional behavior of service personnel due to a lack of skills and experience can lead to a deteriorating brand image. Similarly, seemingly opportunistic behavior of the manufacturer to gain more knowledge and reduce cost can deteriorate customer relationships.

Similar to the typology and measurement used for servitization, the performance of companies is measured differently depending on the study. While some studies rely on a framework of multiple financial performance indicators, others use a single indicator and others rely on self-reported non-financial performance parameters. In their literature review, Brax et al. (2021) found that this inconsistency in performance measurement is partly responsible for differing results of studies concerning the servitization paradox.

These findings on both the non-linear relationship between servitization and firm performance as well the differing measurements for servitization and company performance in literature call for an evaluation of typologies for the operationalization of servitization and a careful choice of performance measurement.

1.2. Facing Highly Fungible Digital Technologies and the Digitalization Paradox

European enterprises increasingly adopt digital technologies, for instance, to automate processes, develop new ways of customer interaction and gain new insights. While some digital technologies, like internet access and having an own website can be frequently observed, more advanced digital technologies such as Big Data analytics, robotics, and digital integration across company boundaries are still less common as shown in Figure 3. Interestingly, the usage of some technologies differs strongly between countries. While 75% of companies in Finland use cloud computing, only 9% of companies in Bosnia and Herzegovina utilize it. In Italy, 95% of companies provide electronic invoices while in North Macedonia only 7% rely on this technology.

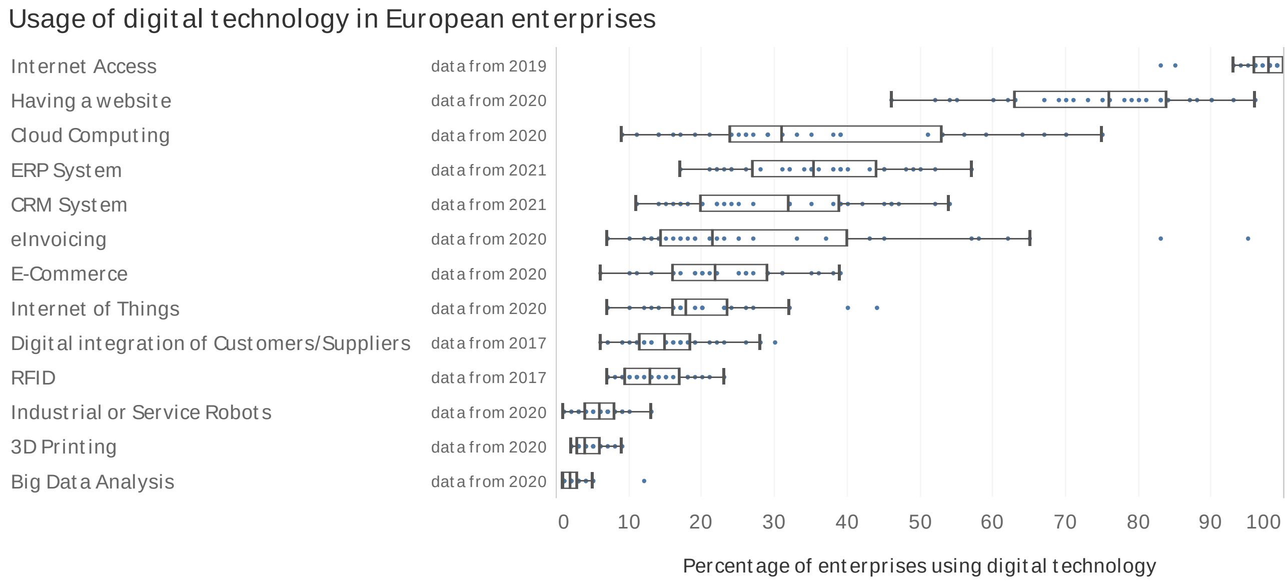

Figure 3. Usage of digital technologies in European enterprises, own figure based on Eurostat (2021)

Distribution of usage of technologies in enterprises by country; Enterprises with above 10 employees are included in the analysis. ERP = Enterprise Resource Planning; CRM = Customer Relationship Management; RFID = Radio Frequency Identification

According to the World Bank (2016), there are three mechanisms by which digital technologies lead to economic growth. First, they connect companies and thus offer them a larger market. Secondly, companies can become more efficient through greater insights and automated processes. Finally, digital technologies lead to innovation and enable new offerings. While the impact on economic growth can be related to digital technologies, the effect is mediated through these mechanisms and how digital technologies are employed in a company.

1.2.1. Defining Digitalization

According to the Gartner dictionary, *"[d]igitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business*" (Gartner, 2021). Taking the elements of the business model by Teece (2010), which are the value proposition, value chain, and revenue model, digitalization has the potential to influence a company's way of doing business in different ways. In terms of the product, the value proposition offered to the customer can be enhanced or fundamentally changed through digital, smart products and services (Porter & Heppelmann, 2014). Depending on the usage of digital technologies and how strongly the company adapts its business model, the solutions range from complementary information technology (IT)-based services to digital product-service systems (Lerch & Gotsch, 2015). This also provides new opportunities for revenue models based on, for example, adding digital services or pay-per-use models. Within the value chain, production as well as sales and distribution can undergo change. The usage of digital technologies for customer interaction allows for new ways of value co-creation and changes customer relationships (Boehmer et al., 2020; Kamalaldin et al., 2020). Furthermore, commercial processes such as market research, solution configuration, sales, and after-sales can be digitally supported (Storbacka, 2011). In production, digitalization enables the integration of value chains and improves the efficiency and flexibility of factories (Björkdahl, 2020). This digitalization of the manufacturing process is closely related to the vision of Industry 4.0 (Kagermann et al., 2013), which is based on cyber-physical systems integrating machinery, control systems, and supply chains.

Due to these different ways in which companies can digitalize, several typologies and constructs have been used in digitalization research to measure and evaluate digitalization. Within the studies related to servitization, digitalization has for example been viewed as the use of Information and Communication Technology (ICT) and advanced manufacturing (Martín-Peña et al., 2020), the use of digital technologies for customer relationship management (CRM) (Kohtamäki et al., 2020), internal and external digitalization (Zhou et al., 2021), intelligence, connect and analytic capabilities (Lenka et al., 2017), and the deployment of a digitalization strategy (Coreynen et al., 2020). These different aspects of digitalization in previous research led to differing results concerning the influence on financial performance.

Changing the perspective from the business model to the underlying digital technology, it becomes apparent that a competence in a single digital technology, for example artificial intelligence or the Internet of Things (IoT), can be used for many different purposes from optimizing manufacturing to altering the value proposition. This applicability of a single technology for multiple purposes is called fungibility (Danneels, 2007). These fungible technologies can be employed for further uses if necessary complementary competencies are built up. If, for example, the value proposition is enhanced through digital technologies, complementary marketing and service competencies are needed to create value. Strategic management theory suggests that fungible resources provide growth potential since there typically is unused productive potential within these resources (Teece, 1982).

1.2.2. Identifying and Overcoming the Digitalization Paradox

Interestingly, companies also face a paradox during digitalization similar to the servitization paradox, namely that small initial investments yield a return, but with increasing investments companies are less likely to achieve their projected revenues (Gebauer et al., 2020). This paradox is described as the digitalization paradox. Most manufacturing companies initially focus on operational efficiency gains through digitalization because these digitalization projects are easier to coordinate and returns are more predictable (Björkdahl, 2020). Enabling growth opportunities through digitalization and data is not only more unpredictable in terms of investment, timing and returns, it also requires more coordination and collaboration.

Based on the resource-based view, an important point to note is that a resource itself does not directly translate into a competitive advantage, but that the resource must be used in combination with the manufacturer's capabilities to achieve a competitive advantage (Ulaga & Reinartz, 2011). Viewing digital technologies as fungible resources, the manufacturer must simultaneously develop the necessary capabilities to turn these resources into a competitive advantage. In terms of gaining operational efficiencies, this seems easiest to do because the required capabilities in manufacturing are close to the core competencies of manufacturing companies. To go beyond these core competencies, for instance into new business models, the manufacturing company also needs to acquire complementary capabilities to leverage digital resources (Kowalkowski et al., 2021).

In terms of digital manufacturing, Savastano et al. (2021) investigated the relationship between high-order dynamic capabilities, digital manufacturing capabilities and firm performance. They found that high-order dynamic capabilities have a positive effect on firm performance. High-order dynamic capabilities are the abilities of a company to adapt to change on an organizational level and consist of sensing and seizing opportunities as well as transforming the organization and its structure (Teece, 2018). The positive effect on firm performance is partially mediated by digital manufacturing capabilities (Savastano et al., 2021). Digital manufacturing capabilities are lower-order dynamic capabilities that are specific to the field of manufacturing. Therefore, companies that have the necessary high-order dynamic capabilities to develop more specific, lower-order dynamic capabilities can benefit stronger from digital technologies. Generalizing this finding and relating it to the growth paths which Gebauer et al. (2020) identified to overcome the digitalization paradox, companies engaging in digitalization need to be able to sense opportunities or triggers, seize them by adopting the necessary resources and adapting the business model, as well as transform the organization accordingly.

By acquiring capabilities to enable new business models, manufacturers gain additional means to capture value from digitalization. One of these means is seen in complementary services offered to customers (Kohtamäki et al., 2020). Especially to deliver more sophisticated services efficiently and adapted to individual customer needs, digitalization plays an important role, for example, through digital platforms (Cenamor et al., 2017). Simultaneously, the use of digital technologies is seen as one of the critical factors affecting the development of service-oriented business models (Adrodegari et al., 2018), and has led to the emergence of the research field of digital servitization. Vandermerwe & Rada (1988) already assumed the importance a digital technology like artificial intelligence (AI) might have on servitization and since 2015 research on the interplay of servitization and digitalization has grown.

1.3. Emergence of Digital Servitization Requires more Quantitative Research

Through the convergence of research on digitalization and servitization, the field of digital servitization emerged. Kohtamäki et al., (2021, p. 5) defined it as *"[t]he transition toward smart solutions (product-service-software systems) that enable value creation and capture through monitoring, control, optimization, and autonomous function. Digital servitization emphasizes value creation through the interplay between products, services, and software".*

As research in this field is nascent, most publications are exploratory and employ case study approaches to identify possible interrelations between the two concepts. The results of these studies show how digitalization enables new service solutions through enabling collaboration, sharing resources, and integrating systems to enable new forms of service delivery (Cenamor et al., 2017; Eloranta & Turunen, 2016; Kamalaldin et al., 2020). Besides the young age of the research field, Paschou et al. (2020) named the complexity of the topic as one reason why researchers select qualitative methods. The broad range of theoretical models developed from qualitative studies has led to multiple models to measure the impact of digital servitization on organizational performance, yet no consensus on the interplay of servitization and digitalization and their effect on organizational performance has been established.

1.3.1. Previous Studies Highlight the Complex Interplay of Digitalization, Servitization, and Company Performance

While the interaction of a manufacturer and a customer in a purely product-based market happens in a mostly transactional way, both servitization and digitalization lead to and require more intensive and long-term relationships. In a case study on the impact of a company's ecosystem on digital servitization, Sklyar et al. (2019) researched how digital services can be embedded in the ecosystem, how centralized orchestration benefits the implementation, and how the internal organization is integrated to deliver the services. They found that for the first step, from a manufacturer to a service provider, customer relationships have to be fostered and in the case of multinational companies local responsiveness to customer needs has to be increased. Moving towards digitalization, the internal organization has to be closer integrated as the digital solutions have to be centrally managed to reach the necessary scale and standardization. Therefore, servitization often evolves according to local customer needs while digitalization is rather centrally orchestrated.

Besides the transformation of customer relationships and internal organization, the development of underlying capabilities plays an important part. Based on the results of Sousa & Da Silveira (2017), Eggert et al. (2011, 2014), and Zhou et al. (2021), it can be deduced that services that are mainly based on the production capability of a manufacturer have a small if not negative effect on company performance. Considering only studies with financial ratios as indicators of company performance, it appears that companies mainly generate additional revenue through these services. This also seems logical in the sense that companies do not exploit far-reaching new capabilities with these services that would lead to a competitive advantage and thus explain an increase in profitability. At the same time, these product-related services can also serve to develop necessary capabilities and knowledge about customer processes for more sophisticated services. In contrast to product-related services, services that support customer processes are based on a set of capabilities that relate to both the product and customer processes. The exploitation of these capabilities in a service offering leads to a competitive advantage and can thus increase profitability.

In terms of digitalization, studies have differentiated between what digital resources are held by the company and in what context these are used. As noted by Ulaga & Reinartz (2011), the acquisition of these resources is necessary, for instance, for digital services, but not sufficient on its own to create value. Building up complementary capabilities is also necessary to use the digital resources. Following the assumption of Björkdahl (2020) that manufacturing companies generally start with the digitalization of production processes because the companies already have complementary capabilities in these areas, at most a small mediating effect of services can be expected for the effect of digitalization in production on company performance. Since automation has already been established in the production sector for some time, it is questionable how great the competitive advantage still is and to what extent more advanced digitalization solutions for horizontal and vertical integration are already being used.

Further examples from Ulaga & Reinartz (2011) show how capabilities related to product development and data acquisition on installed products can have a positive impact on service delivery. In one example, a tire manufacturer used its development capabilities to produce a tire that is easier to rework to achieve a competitive advantage in service. This is an example of building design-to-service capabilities that support value creation with services related to the product. While this solution worked well technically, there was low customer acceptance for a more expensive tire in the initial phase, and the added value could only be exploited in the context of a service-oriented and data-driven business model, fleet management. In two other examples of product-related data acquisition, companies collected equipment operating data, in one case both usage and fault data, and in the other example energy consumption in buildings. Both manufacturers used this information to differentiate themselves from pure service providers or consultants. By collecting device-related data, these manufacturers secured access to an important resource. This data can be used to provide better services, for instance, faster response times in technical service through remote monitoring, better assessment of maintenance needs and thus better cost estimation, or detailed consulting services based on a wealth of data. Since this device-related data is typically not available to external companies, manufacturers can gain a competitive advantage by leveraging this resource through their capabilities. At the same time, these examples also show that manufacturers use these digital solutions to offer very advanced services that already require service capabilities as a foundation.

Chen et al. (2021), based on a literature review and a single case study, also suggested that manufacturers that already provide advanced services may find it easier to move towards smart solutions than manufacturers that focus purely on products. Therefore, it is interesting to look at the impact of simpler services on the delivery of more sophisticated services and in which way the use of digital technologies in different elements of the business model is related to the delivery of and value creation by more sophisticated services. To analyze this relationship quantitatively, servitization should be used as a mediating construct for the effect of digitalization on company performance.

1.3.2. Granular Quantitative Approaches for Digital Servitization Research are Needed

Since both underlying streams, digitalization as well as servitization gain increasing importance in manufacturing companies and at the same time both for digitalization and servitization a performance paradox has been found, research on the interplay of both of these concepts is needed to find potential synergies and pathways to overcome the aforementioned paradoxes. To identify promising pathways, quantitative studies to evaluate the relationship of these two concepts with financial performance are needed.

Notable previous quantitative studies were performed by Martín-Peña et al. (2020) who measured the effect of servitization on organizational performance both directly and mediated through digitalization, Kohtamäki et al. (2020) who measured the impact of digitalization on organizational performance and the moderating effect of servitization in terms of advanced services, and Zhou et al. (2021) who measured the impact of the combinations of basic and advanced services as well as internal and external digitalization on organizational performance. While these studies give insights into the interrelation between servitization and digitalization, they are each limited to one country and except for Zhou et al. (2021), they do not examine different types of servitization, as is the case in earlier studies concerning servitization, and different forms of digitalization.

Research on servitization has shown an evolutionary development of services in a firm, starting from basic product-related services that are the foundation for the implementation of more advanced services. In contrast, digitalization leads to more radical and discontinuous changes in the elements of a company's business model (Chen et al., 2021). This calls for a more granular view of the interplay of combinations of servitization and digitalization. Following the approach by Kohtamäki et al. (2020), who identified servitization as a means to capture value from digitalization, this research aims to provide a more nuanced view of this topic by dividing both servitization and digitalization into different elements. Distinguishing between the digitalization of different elements of the business model allows further exploration of the value capture potential of servitization.

Based on the notion that companies need to employ digital resources through their capabilities to create new value, this research will assess the direct impact digitalization has on company financial performance and how this effect is mediated through services. To account for the evolutionary development of services, different levels of servitization are assessed and how less sophisticated services impact the delivery of more advanced services.

2. Theoretical Solutions for Evaluating the Interplay of Servitization and Digitalization

To provide a nuanced view of digital servitization, a scheme of the structural model to be developed is displayed in Figure 4. Theoretical solutions dividing both digitalization and servitization into different categories are evaluated. Digitalization is divided into the use of digital technologies for different elements of the business model. Both the direct effect on company financial performance as well as the mediated effects through servitization for each of these is to be evaluated. Research in the field of servitization suggests that simpler services act as a foundation for more advanced services (Eggert et al., 2011, 2014; Sousa & da Silveira, 2017). For this reason, both the direct effect of different forms of service on financial performance and the mediated effect of simpler services through more advanced services are examined. Since financial performance cannot be adequately assessed based on a single measurement, the impact on different aspects of financial performance is analyzed (Combs et al., 2005).

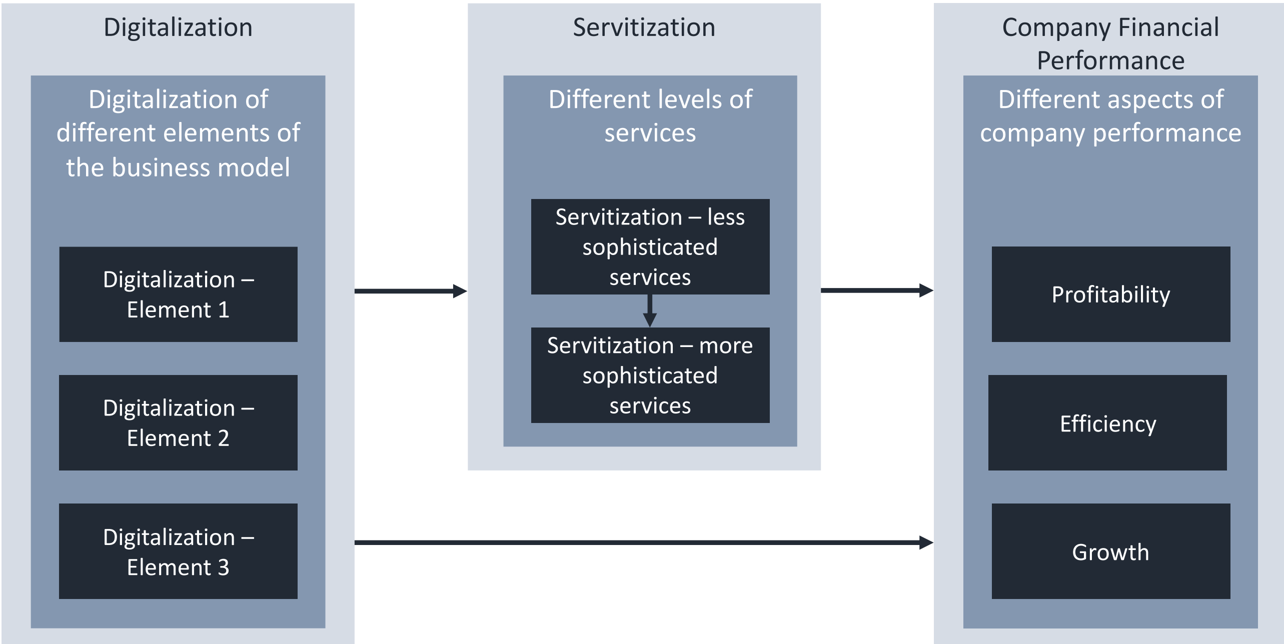

Figure 4. Scheme of the research model

In the following, typologies from previous studies on digitalization and servitization are discussed. This analysis aims at developing a structural equation model that enables the analysis of nuanced effects of digitalization and servitization on financial performance.

2.1. Typologies for Servitization and its Operationalization

Depending on the research objective, a wide range of typologies and measurements for servitization have been used in previous studies. To explore which services enable value capture from digitalization, a typology is needed that distinguishes between simpler and more advanced services. In a literature review, Calabrese et al. (2019) grouped the measurement of servitization into three different dimensions. The first one is the *servitization extension*, which describes the range of different services offered by a company and is most commonly measured based on the number of service types within defined categories a company offers. This measure is used both to describe the transformation of companies within case studies as well as different aspects of company performance achieved through servitization. The second dimension, *servitization infusion*, which is measured based on the share services have in the companies' financial results, is most often used for evaluating the performance result from servitization. As a third dimension, *servitization orientation* is measured through subjective scales to identify the emphasis of a firm on servitization. This dimension is frequently applied for measuring the strategic importance of servitization or the impact on customer relationships. The focus of this research will lie on the effect of different kinds of digitalization on financial performance and the mediating effect of servitization. Therefore, the measurement of the servitization extension allows distinguishing the level of sophistication of services.

Calabrese et al. (2019) argued that the servitization extension should be measured through a standardized framework such as NACE (European Classification of Economic Activities) codes (Commission of the European Communities (Statistical Office/Eurostat), 2008) as so far there has been a wide variety in measurements used. While using the NACE code structure enables to select and compare different industries, it is not granular enough to measure the sophistication of services. For example, there is no differentiation between simpler repair services and more advanced and digitally-enabled performance provision. Therefore, the following chapters describe different models for servitization extension found in the academic literature. Among the most common typologies are the differentiation between services supporting the manufacturer's product (SSP) and services supporting the customer's process (SSC) (Eggert et al., 2011, 2014; Oliva & Kallenberg, 2003), the grouping of complexity into basic, intermediate, and advanced services (Baines & Lightfoot, 2014; Zhou et al., 2021), and dividing the services into groups based on the resources needed to perform the services (Kohtamäki et al., 2013). The first models describe unidimensional measurements while the subsequent models incorporate multiple of the initially described measurements.

2.1.1. Distinguishment of the Target of Services

A frequently applied categorization of services is based on the target of the service. Authors have distinguished between services that target the manufacturer's product, such as repair and maintenance services, and services that target the customer's process in using the manufacturer's product or achieve results for the customer. This concept has been introduced by Mathieu (2001a) based on common themes concerning offered services found in a qualitative study among companies within the microelectronics industry. Since its introduction, this categorization has been applied by multiple authors (Antioco et al., 2008; Eggert et al., 2011, 2014) and is used in multi-dimensional constructs (Coreynen et al., 2017; Oliva & Kallenberg, 2003; Ulaga & Reinartz, 2011).

Services that are targeted at the manufacturer's product are typically less customized and do not require a strong relationship with the customer. They are mostly based on the manufacturer's capabilities in relation to their product, whereas services supporting the customer's process require additional capabilities and knowledge concerning customers' processes. Consequently, a closer customer relationship is required for the successful delivery of these services, which at the same time are more closely adapted to the needs of the customer. An overview of the different services that are grouped as either a service supporting the manufacturer's product (SSP) or a service supporting the customer's process (SSC) is shown and summarized in Table 2.

Table 2. Overview of services categorized as SSP and SSC

Author (year)	Context	SSP	SSC
Mathieu (2001a)	Case study, 22 companies from the European microelectronics industry	Physical distribution Technical support for the manufacturer's product Commercial support	Technical support for the client's application Training Help in the distributor's commercial process
Antioco et al. (2008), also applied by Eggert et al. (2011)	Quantitative study with 137 European manufacturing companies (Antioco et al., 2008) Quantitative study over five years, complete data cases for 414 German manufacturing companies (Eggert et al., 2011)	Product documentation Product transportation/delivery Product installation Help desk/call center Product inspection/diagnosis Product repair/spare parts Product upgrades Product refurbishing Product recycling/machine brokering Preventive maintenance Condition monitoring Process-oriented engineering	Financing services Management of spare parts Process-oriented training Business-oriented training Process-oriented consulting Business-oriented consulting Managing the maintenance function Fully managing product-related operations (outsourcing and ownership of product by vendor)
Eggert et al. (2014)	Quantitative study with longitudinal data on 513 German manufacturing companies	Customer services/hotline Product documentation Product repair and spare parts delivery Product recycling and dismantling Maintenance services	Training Consulting Financing services/leasing Research and development
Summary		Product distribution, documentation, and installation Service hotline Preventive, predictive, and corrective maintenance including spare parts delivery Product refurbishing Product dismantling and recycling	Process- and business-oriented training and consulting Managing clients' functions (e.g., maintenance or product operation) Financing Customer-oriented research and development (R&D)

Especially in manufacturing companies, SSPs are dominant as an entry point into service-oriented business models. As these services are based on the knowledge of the products, few new skills need to be built up to be able to offer these services. Studies incorporating this measurement have found that SSPs help to grow the service volume (Antioco et al., 2008) and can have a positive effect on profitability if the company is strongly innovating products (Eggert et al., 2011) while no profitability impact was found for lower levels of product innovation. A focus on innovating products leads to increased competencies concerning the products which in turn help to successfully market SSPs. Furthermore, SSPs are the basis for the development of SSCs and thereby lead to an increase of SSCs in the company (Eggert et al., 2014).

The profitability impact of SSCs is found to be more dependent on other factors. Eggert et al. (2014) found that initially the profit level of companies engaging in SSCs decreases but profit growth subsequently increases. This can be explained by the necessity to build up additional resources and competencies to be able to provide SSCs. Furthermore, the profitability is moderated by both the share of loyal customers and decentralized decision-making. Serving loyal customers with SSCs is more cost-efficient and therefore leads to higher profitability. This effect also connects the typology of SSPs and SSCs with the distinguishment between transaction-based and relationship-based services discussed in chapter 2.1.2. The moderating effect of decentralized decision-making links to the necessary transformation for providing SSCs, which are more customized to fit the customers' processes. In comparison to SSPs, SSCs have a higher impact on profitability when product innovation is low, meaning that the company develops SSCs in the shift from product to service innovation (Eggert et al., 2011). Instead of having a direct effect on the service share of total revenues, Antioco et al. (2008) observed that SSCs increase product sales. Furthermore, Eggert et al. (2014) noted that SSCs are mediating the revenue and profit effects of SSPs. This supports the assumption that SSPs act as a starting point for servitization and help the manufacturer to build up necessary service capabilities which subsequently are exploited through SSCs.

Concerning the research question, this measurement seems appropriate for distinguishing services if a suitable measurement of digitalization is applied. While SSPs mostly rely on the manufacturers' knowledge of their products and their operational efficiency, SSCs require deeper insights into the customers' processes. Therefore, a measurement of digitalization that distinguishes between the digitalization of product and customer-related processes would complement the differentiation between SSPs and SSCs. Empirical studies have found that this service categorization relates well to a measurement of digitalization that distinguishes between the front- and back-end of the company (Coreynen et al., 2017).

2.1.2. Distinguishment of the Customer Relationship

The transition from selling products to offering a bundle of complementary products and services changes the relationship between the manufacturer and the customer. While selling pure products mostly relies on single transactions, increasing servitization leads to the necessity to build up long-term relationships (Martinez et al., 2010). Although quantitative research on the impact of customer relationships on the performance achieved through servitization is scarce, Kastalli & Looy (2013) found that building up customer proximity positively influences service sales by calculating the share of services that are performed at the customer site and are labor-intensive.

Multiple case studies suggest that in particular in the context of digital servitization, the changing customer relationship plays an important role, as digital technology-supported services are integrated across company boundaries. Rymaszewska et al. (2017) described how the IoT enables new service value creation mechanisms and improvements of existing services while Opresnik & Taisch (2015) observed similar benefits for the use of big data in servitization. Boehmer et al. (2020) discovered that the IoT leads to long-term relationships between the manufacturer and customer through increased information exchange, aligned incentives, and decreasing transaction costs.

Within a purely transactional service provision for a manufacturer's product, the operational risk remains at the customer. Taking corrective maintenance as an example, a transactional service provision would be an on-demand repair at a fixed price level. If the service provision changes to a relational interaction like a full-service contract or a usage-based fee, the operational risk switches to the manufacturer (Gaiardelli et al., 2014). In these cases of result- or performance-based contracts the manufacturer has to perform corrective maintenance as needed without earning additional revenues in case of frequent malfunctions.

To categorize services either as transaction- or relationship-based, both the allocation of operational risk as well as the pricing of the service are used as indicators as shown in Table 3.

Table 3. Categorization of service offerings by the nature of customer interaction, based on Gaiardelli et al. (2014)

	Characteristics	
Nature of interaction	**Risk**	**Price**
Transaction-based	Customer	Fixed (list) price per transaction Mark-up
Relationship-based	Manufacturer / Product service provider	Usage-based Performance-based Result-based

As an information asymmetry typically exists between the customer and manufacturer concerning the operating risk, digital technologies such as remote condition monitoring of equipment can serve to empower manufacturers with the knowledge they need to assess and mitigate this risk (Adrodegari et al., 2018; Reinartz & Ulaga, 2014). Therefore, this categorization would be beneficial to use in combination with a measure for the digital interaction with customers or the digitalization of products. However, in previous quantitative studies on the effect of customer interaction, for instance by Kohtamäki et al. (2013), who have shown that close customer interaction leads to increased sales growth through services, network capabilities are used to evaluate customer interaction and servitization is assessed based on the number of services offered. Since the distinction between relationship- and transaction-based services has not been tested or applied in previous quantitative research, it is not suitable for the intended research model.

2.1.3. Distinguishment of the Value Proposition

Another approach to categorizing service offerings is to distinguish them according to their value proposition, or the way they add value for the customer. In previous studies, different scales were used to group the value proposition, mostly consisting of two or three categories. For example, Reinartz & Ulaga (2014), as part of their model of hybrid offerings categorized services as either input-based or output-based. A frequently used typology in the research stream around product-service systems originates from the findings by Tukker (2004).

Within input-based services, the manufacturer performs a pre-defined deed, such as on-demand preventive maintenance with a predefined number of spare parts or customer training with a fixed number of hours. This service is typically priced at a fixed rate and gross profitability is easily anticipated by the manufacturer. Output-based services on the other hand describe services in which the output to be achieved is agreed upon with the customer and the needed input by the manufacturer can only be estimated ex-ante. The actual input required to fulfill this contract is not pre-defined, varies between customers, and therefore moves the operating risk from the customer to the manufacturer. Within output-based services, some researchers further distinguish between availability and performance provision. Availability services provide the customer with, for example, a specified uptime for a machine or the provision of repair bridging equipment. Within the related field of product-service systems, the closest match to these availability services are use-oriented services. Performance services, or in the terminology of product-service systems result-oriented services, describe services in which the customer pays for an achieved outcome of the usage of a device. In Table 4 different categorizations for input- and output-based services are displayed. These are typically used as one of multiple dimensions in different typologies for servitization.

The service categories from the models of Gaiardelli et al. (2014) and Tukker (2004), who researched product-service systems, differ from the categories used in servitization research and thus highlight some inaccuracies in this typology. For example, remote monitoring is categorized as an output-based service, while the monitoring of the system status achieved by it does not yet achieve an output for the customer. Similar to an inspection, which is grouped as an input-based service, the system status is determined by remote monitoring (European Committee for Standardization, 2018). Only in combination with further services, such as a maintenance contract, an output is achieved for the customer. Therefore, remote monitoring could be evaluated either as a stand-alone input-based service or as a capability for output-based services. Similarly, the categorization of preventive maintenance as output-based is also questionable, as it typically follows a predefined maintenance schedule (European Committee for Standardization, 2018) and could therefore also be input-based. Parida et al. (2014) also mention a lack of distinguishability based on the scale from Tukker (2004) and therefore adapt the scale based on a factor analysis. Since the distinction between input and output-based services in the servitization literature is blurred and depends on detailed contractual agreements between manufacturer and customer, this categorization is not relevant for the intended research model.

Table 4. Categorization of services by their value proposition

Author	**Context**	**Purely input-based**			**Purely output-based**
Reinartz & Ulaga (2014); Ulaga & Reinartz (2011) - value proposition dimension	Case study of 22 large manufacturing companies	**Input-based** - Parts delivery - Inspection - Remanufacturing & Recycling - Training & Consulting		**Output-based** - Remote monitoring - Software customization - Fleet and supply management	
Kindström & Kowalkowski (2014) - Revenue model dimension & Kowalkowski et al. (2015)	Synthesizing research, based on four research projects and ten case companies & 13 case companies	**Input-based** - Engineering - Training & process simulation - Spare parts - Inspections & repair		**Output-based – availability** - Renting & fleet management - Service contracts - Preventive maintenance - Remote monitoring	**Output-based – performance** - Gainsharing & outcome-based contracts - Reconditioning - Systems integration & customized software
Gaiardelli et al. (2014) - Product service offering orientation & Tukker (2004)	Literature review and subsequent application of results in five companies	**Product-oriented** - Installation - Spare parts, maintenance, and repair - Full maintenance contracts - Upgrading/ remanufacturing - Helpdesk - Product-oriented training or consulting		**Use–oriented** - Leasing - Renting - Sharing - Pooling	**Result-oriented** - Pay-per-use - Outsourcing - Pay-per-result
Parida et al. (2014)	Case study with 11 companies	**Add-on services** - E.g. phone support	**Maintenance and product support services** - E.g. installation and maintenance services	**R&D oriented services** - E.g. Prototype design & development	**Functional and operational services** - E.g. operation of customer processes
Summary		**Input-based services:** Services that are closely related to the product; to be purchased by the customer on demand		**Availability services:** Services that provide a customer with a certain capacity/ availability	**Performance/ Result Services:** Services that provide a certain output/ result for the customer

Nevertheless, certain results based on this categorization provide insights that can be transferred to other typologies. Parida et al. (2014) observed that simpler services offered as an add-on to the product do not generate additional revenues, but are necessary for offering more advanced services which in turn enable the manufacturer to capture additional revenues. To facilitate the transformation of a manufacturing company into an IPS^2 provider, underlying capabilities in the fields of business model design, network management, integrated development, and service delivery management need to be built up. In the IPS^2 research field, integrated development, which considers both the product as well as the associated services, plays a central role (Meier et al., 2010). Ulaga & Reinartz (2011) considered this aspect as design-to-service capability.

Further interesting insights from this research stream are transformation patterns as identified by Kowalkowski et al. (2015). Within a case study of 13 companies, they found that most companies made a transition from an equipment provider offering input-based services via availability services to performance-based services. Enablers for this transition were among others close customer relationships, risk mitigation capabilities, and increasing process control through automation. While most companies followed this transformation pattern, a few others modularized and standardized their services and returned to equipment provider services to achieve scale effects.

2.1.4. Distinguishment of Service Complexity

Another frequently applied operationalization of servitization is based on the complexity of the provided services. Baines & Lightfoot (2014) highlighted the customers' viewpoints in their categorization of services into base, intermediate, and advanced services. They emphasized that customers either perform tasks on their own and thus only need base services such as spare part delivery, perform tasks together with the manufacturer and ask for intermediate services, or hand over a task to a manufacturer who performs an advanced service. This directly translates into the organizational stretch the manufacturer has to make beyond the existing production competencies. Base services in this case only require little additional capabilities beyond the production, for instance, logistics and spare part stock management. Advanced services, where, for example, the manufacturer takes over the operation of its products at the customer's site or manages the performance of the products, require in-depth knowledge of the customer's operations and additional resources to manage the performance of the products.

A similar approach has been applied by Sousa & da Silveira (2017) and Zhou et al. (2021), who grouped services into base and advanced services. Zhou et al. (2021) argued that base services are mostly provided on a transactional base and are often free of charge while advanced services allow for value co-creation and create higher returns. While the transactional nature of these services is also frequently mentioned in other classifications, it is debatable to describe base services as mostly non-pecuniary, especially as repair and maintenance services, as well as spare parts, are described as base services. Still, companies might offer some additional services to promote their product without additional charges.

As can be seen in Table 5, the categorization by Baines & Lightfoot (2014) differs from the approach Sousa & da Silveira (2017) and Zhou et al. (2021) take, which is originally based on a typology from Gebauer et al. (2005). Baines & Lightfoot (2014) evaluated the stretch the company must make to provide a certain service and thereby proposed a categorization that is rather similar to the categorization by value proposition from Tukker (2004) and is partly related to the approach by Fang et al. (2008) who measured the relatedness of services to the core product business. On the contrary, the approaches of Sousa & da Silveira (2017) and Zhou et al. (2021) are closely related to a categorization into SSP and SSC. Results from Zhou et al. (2021) showed a weak relationship between basic services and company performance and a stronger positive relationship between advanced services and company performance.

Table 5. Categorization of services by their complexity

Author and context	Context	Base services	Intermediate	Advanced services
Baines & Lightfoot (2014)	Case study of four companies	Providing the product - Product/equipment provision - spare part provision - warranty	Maintaining the product condition - Scheduled maintenance - technical helpdesk - repair - overhaul - delivery to site - operator training, - condition monitoring, - in-field service	Delivering an outcome - Customer support agreement, - risk and reward sharing contract, - revenue-through-use contract
Sousa & da Silveira (2017)	Quantitative study, 931 manufacturing companies (ISIC 25-30) in a global survey	- Maintenance and repair of products - Installation/ implementation - Provision of "spare parts/consumables"		- Rental/lease of products (with responsibility for maintenance, repair, and operation) - Product upgrades (software, product modifications) - Helpdesk/customer support center - Training in using the products - Consultancy services
Zhou et al. (2021)	Quantitative study, 257 Chinese manufacturing companies	- Maintenance and repair of products - Installation/ implementation - Spare parts/consumables		- Rental/lease of products - Product upgrades - Helpdesk/customer support center - Training in using the products - Consultancy services

Sousa & da Silveira (2017) incorporated a measure of manufacturing and service capabilities in their research on the impact on company performance. They found that manufacturing and service capabilities lead to increased basic service offerings while advanced services are related to service capabilities and basic service offerings. While advanced services had a positive impact on profitability, basic services even had a negative impact.

The approaches also differ in their relationship to digitalization. Baines & Lightfoot (2014) took an operations management-focused approach and sought practices and technologies that enable or support the delivery of advanced services. Thereby they noted that ICT is especially useful for product-related purposes, such as location, condition, and use monitoring. Although they also mentioned business processes as well as customer and supplier relationships as critical practices, they did not relate the use of ICT to improve these practices like Zhou et al. (2021) did in their evaluation of internal and external digitalization.

Since both models for complexity-based grouping have been used in prior quantitative research on both servitization and digital servitization, these are well applicable. At the same time, the naming of the categories is relatively ambiguous compared to other typologies and needs further explanation. As this typology bears a strong resemblance to the SSP and SSC typology and is used synonymously by Sousa & da Silveira (2017), for example, it makes sense to merge the typologies and the related research findings.

2.1.5. Multi-Dimensional Categorizations

Besides uni-dimensional categorizations, which are most frequently used for quantitative studies, different qualitative studies provide categorizations using multiple dimensions. These are used to describe pathways companies take during the development and provision of different kinds of services.

In their research on the transition of manufacturing firms from products to services, Oliva & Kallenberg (2003) identified typical development paths manufacturers take when increasing their service offering. These are organized along the two dimensions of the nature of the customer interaction and the target of the provided service.

	Product-oriented services	End-user's process-oriented services
Transaction-based services	*Basic installed base services* Documentation Transport to client Installation/commissioning Product-oriented training Hot line/help desk Inspection/diagnosis Repairs/spare parts Product updates/upgrades Refurbishing Recycling/machine brokering	*Professional services* Process-oriented engineering (tests, optimization, simulation) Process-oriented R&D Spare parts management Process-oriented training Business-oriented training Process-oriented consulting Business-oriented consulting
Relationship-based services	*Maintenance services* Preventive maintenance Condition monitoring Spare parts management Full maintenance contracts	*Operational services* Managing maintenance function Managing operations

Figure 5. The IB service space (Oliva & Kallenberg, 2003, p. 168)

They argued that most manufacturers start by providing basic installed base (IB) services that are sold on a transaction base and are targeted at the manufacturer's product. These are shown in the top left field of their IB service space displayed in Figure 5. From there they move along the dimension of customer interaction towards relationship-based services or implement services that are targeted at the process of the customer. Changing the target of the service to the end-user's process leads to services like consulting for process improvement during the use of the manufacturer's product, which require the manufacturer to build up knowledge of the customer's processes and the capabilities to deliver consulting services. Moving along the dimension of customer interaction leads from IB services towards relationship-based maintenance services like condition monitoring or full-service contracts in which the manufacturer takes over risk. The most sophisticated services are operational services in which the manufacturer manages either the maintenance function at the customer's site or the operation of customer processes.

Based on this framework, they observed that firms that successfully transform from a pure manufacturing company to a service provider start with basic installed base services and move along the two identified dimensions. In turn, companies that attempt to start with advanced services without building basic capabilities typically fail. This underscores the assumption that companies should build capabilities through simpler services and subsequently leverage them for advanced services.

The dimension concerning the target of the service is later also used by Eggert et al. (2011, 2014) and in their case named SSP and SSC. Ulaga & Reinartz (2011) also developed a similar matrix based on interviews of manufacturing firms. While they also used the dimension of SSPs and SSCs, instead of the dimension of customer interaction they distinguished between different value propositions. Similar to the model by Oliva & Kallenberg (2003), manufacturers build up resources and capabilities for service provision and thereby move from simpler Product Life-Cycle Services to more advanced services as shown in Figure 6.

	Service Recipient	
Nature of the Value Proposition	**Service Oriented Toward the Supplier's Good**	**Service Oriented Toward the Customer's Process**
Supplier's promise to perform a deed (input-based)	**1. Product Life-Cycle Services (PLS)** *Definition* •Services to facilitate the customer's access to the supplier's good and ensure its proper functioning during all stages of the life cycle *Examples* •Delivery of industrial cables •Inspection of an ATM machine •Regrooving of an industrial tire •Recycling of a power transformer *Primary Distinctive Capabilities* •Hybrid offering deployment capability •Design-to-service capability *Main Underlying Resources* •Field service organization •Product development and manufacturing assets	**3. Process Support Services (PSS)** *Definition* •Services to assist customers in improving their own business processes *Examples* •Energy efficiency audit for a commercial building •Logistics consulting for material-handling processes in a warehouse *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Hybrid offering deployment capability •Hybrid offering sales capability *Main Underlying Resources* •Installed base product usage and process data •Field service organization •Product sales force and distribution network
Supplier's promise to achieve performance (output-based)	**2. Asset Efficiency Services (AES)** *Definition* •Services to achieve productivity gains from assets invested by customers *Examples* •Remote monitoring of a jet engine •Welding robot software customization *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Execution risk assessment and mitigation capabilities •Hybrid offering sales capabilities *Main Underlying Resources* •Installed base product usage and process data •Product development and manufacturing assets	**4. Process Delegation Services (PDS)** *Definition* •Services to perform processes on behalf of the customers *Examples* •Tire fleet management on behalf of a trucking company •Gas and chemicals supply management for a semi-conductor manufacturer *Primary Distinctive Capabilities* •Service-related data processing and interpretation capability •Execution risk assessment and mitigation capabilities •Design-to-service capability •Hybrid offering sales capabilities •Hybrid offering deployment capability *Main Underlying Resources* •Installed base product usage and process data •Product development and manufacturing assets •Product sales force and distribution network •Field service organization

Figure 6. Classification scheme of industrial services for hybrid offerings; from Ulaga & Reinartz (2011, p. 17)

Although the use of the classification of hybrid offerings is not useful for the research model, as the distinction between input- and output-based services is blurred as described in chapter 2.1.3, the necessary capabilities and resources described for the different services are interesting concerning the effect of digitalization. While simpler product lifecycle services mainly require capabilities and resources related to product design and manufacturing, more advanced services such as asset efficiency services or process support services require capabilities in data acquisition and processing. It can also be seen that the range of capabilities and resources required grows with more sophisticated services. The breadth of capabilities and underlying resources for advanced services such as process delegation services leads to the assumption that digitalization in different areas of the company will influence the delivery and success of the services. Therefore, it seems appropriate to use a typology for digitalization that is as broad as possible to capture the effects of digitalization in design and production steps as well as in the networking of products.

2.1.6. Selection of a Model for Servitization

Among the discussed typologies for servitization, the categorization into SSPs and SSCs (Antioco et al., 2008; Eggert et al., 2011, 2014; Mathieu, 2001a) and the distinguishment between different levels of complexity (Baines & Lightfoot, 2014; Sousa & da Silveira, 2017; Zhou et al., 2021) are the most promising approaches. Both have been used in previous quantitative studies on both servitization and digital servitization and yielded comparable results. In terms of the types of services measured, the two approaches differ only slightly. Baines & Lightfoot (2014) referred to services in which the customer performs a task and only needs the manufacturer for simple operations related to the product as basic services. This leads to great similarities with the concept of SSPs, which are also focused on the product. Advanced services, in which according to Baines & Lightfoot (2014) the manufacturer takes over a task for the customer or according to Zhou et al. (2021) value is created together with the customer, are also very similar to SSCs, in which the focus is on the customer's value creation process. Likewise, Sousa & da Silveira (2017) related these concepts to each other and utilized the wording basic and advanced services. Since the designations "SSP" and "SSC" are more unambiguous than basic and advanced services, the classification into SSPs and SSCs will be used in the following. By employing the categorization displayed in Table 6, the breadth of the service portfolio or servitization extension is evaluated.

Table 6. Selected categorization of services for quantitative analysis

SSP	SSC
- Product distribution, documentation, and installation - Product-oriented service hotline - Preventive, predictive, and corrective maintenance including spare parts delivery - Product refurbishing - Product dismantling and recycling	- Training - Managing clients' functions (e.g., maintenance or product operation) - Consulting - Financing - Performing Research & Development for the customer

The term SSPs, as used in the following, describes services whose value creation consists of performing an action on the product and is based on the manufacturer's knowledge and capabilities regarding the product. The actions performed on the product range from delivering and installing it through maintaining and repairing it to refurbishment or disassembly. While some services, for example, delivery and disassembly of durable goods, are inherently transactional because they occur only at one point in time in the product lifecycle, the other services can be both transactional and relational. For instance, maintenance and repairs can be provided as on-demand services or as part of a service contract. A consideration of the effect of customer relationships, as performed for example by Eggert et al. (2014) and Kastalli & Looy (2013), is outside the scope of this research. Summarizing the results on the influence of SSPs on corporate performance, differing results become apparent.

Compared with SSCs, though, it can be stated that the influence on profitability is lower, if not negative. These results reflect the servitization paradox, in which companies at low to medium levels of servitization do not achieve expected returns. On the other hand, SSPs can be utilized to create an additional revenue stream besides product sales. However, due to their close relationship with the products, the success of these services seems to be strongly dependent on the success of the products themselves. An important implication for the topic examined is that SSPs play a role in building a set of customer service-related capabilities that in turn can be leveraged by SSCs.

The term SSC is used in the following to describe services that either support the customer in optimally utilizing the product, optimize and individualize the product for customers, or take over part of the operations of the product at the customer's site. Therefore, this category consists of services ranging from training and consulting through customer-centered research and development to managing functions at the customer's site, such as operating the product or maintenance management. Additionally, financing is grouped as SSC, as this service has a low relatedness to the product. Concerning the effect on company performance, SSCs are seen as typically more profitable services, although they initially require more investments into capabilities. In terms of the relationship to digitalization, both Kohtamäki et al. (2020) and Zhou et al. (2021) noted that a digitalized front end of the company, for example, sales and service provision, are complementary for SSCs. Drawing on the literature on IPS[2], integrated design and development of products and services also leads to lower costs and improved outcomes (Meier et al., 2010; Ulaga & Reinartz, 2011). Given the range of services in the SSC category, for example, research and development, the impact of digitalization of other elements in the business model, for example, value creation or value proposition, would be an appropriate typology for this study.

2.2. Typologies for Digitalization and its Operationalization

Similar to servitization, no uniform typology has been used for digitalization in previous studies. To cover a range as wide as possible for the implementation of digital solutions, existing typologies are described below.

2.2.1. Differentiation by Digital Technologies Employed

An approachable typology for digitalization is the differentiation according to the digital technologies used, as described by Paschou et al. (2020) in a literature review. An overview of the technologies, which shows a high degree of similarity with technologies mentioned in the Industry 4.0 context (compare, for example, Saucedo-Martínez et al. (2018)) is displayed in Table 7. Studies for this typology of digitalization and its relation to servitization have mostly been conducted with a focus on a single technology. Among the technologies most frequently studied in connection with servitization are IoT, big data analytics, cloud computing, and horizontal and vertical integration.

Table 7. Description of digital technologies; adapted from Paschou et al. (2020, p. 280)

Digital technology	Definition
Additive Manufacturing/3D-Printing	Manufacturing of products by layer-by-layer material deposition that allows the production of individualized and complex products and prototypes.
Advanced Manufacturing Solutions	Manufacturing systems that are both interconnected as well as suitable for collaboration with humans and controlled by software or artificial intelligence.
Artificial Intelligence	Simulation of human thought and behavior patterns by software. Also includes machine learning, which helps, for example, in recognizing patterns and making decisions based on them.
Big Data and Analytics	Methods for acquiring and processing large, unstructured data sets in order to derive and utilize patterns and insights from them.
Cloud Computing	Bundled, centrally managed computing resources that can be accessed remotely and configured and provisioned with limited effort.

Cyber Security	Security mechanisms to protect networked systems and processes, for example through user authentication and monitoring of vulnerabilities and changes.
Horizontal and Vertical System Integration	Networking of processes of different departments or organizations and physical items integrated therein by means of information systems.
(Industrial) Internet of Things	Interconnection of products and industrial systems for the interaction of the systems and the acquisition of data used for planning and forecasting as well as allowing the intelligent control of the systems.
Mixed Reality (Virtual and Augmented Reality)	Mostly visual systems that augment the actual surroundings with virtual objects in real-time.
Simulation of Connected Machines	Simulation of process flows through different departments, machines and plants to be able to test the efficiency of a solution in advance.

In a study on the use of the IoT in connection with servitization, Rymaszewska et al. (2017) described three cases in which the IoT is used differently. In all cases, usage and status data of the systems sold were recorded by sensors, and the products of the manufacturers surveyed were complex machines respectively. While in one case this information was used to offer a performance-based contract in which the customer pays for the use of the system, in the second case the provision of services was supported within the framework of service contracts, for instance by reacting earlier when a fault occurs, and in the third case the collected usage data was only made available to the customer for their own use. In the last case, only the value proposition was supported by the IoT, while in the second case the value creation, namely customer service, was also improved. In the first case, value capture was also integrated through a usage-based model, thus underscoring how the same technology can support different elements of the business model.

Opresnik & Taisch (2015) explored the relationship between Big Data and servitization and possible strategies for monetizing the use of Big Data analytics. They presented a model in which data is collected during the delivery of a product-related service and then exploited either through new service development or sales. They argued that big data analytics on the one hand allow manufacturers to build a new competitive advantage that is difficult to imitate and on the other hand, through the use of newly generated knowledge, can minimize the costs of providing services.

Regarding the vertical integration of customer and supplier processes, Baines & Lightfoot (2014) described several cases. As expected in the field of servitization, manufacturers integrate downstream activities of their customers, such as condition monitoring, maintenance, and repair of systems. Simultaneously, they often locate factories close to customers to be more responsive in providing services and utilize insights for manufacturing. However, upstream processes are also integrated, for instance when it comes to maintenance and optimization of purchased assemblies for a machine. This was found to be particularly true for high-priced sub-assemblies for which the original equipment manufacturer offers a narrower range of services and the manufacturer has to develop its own advanced services to meet its contractual obligations to its customers.

In these studies on individual digital technologies and their impact on servitization, it becomes clear that they rarely occur in isolation. Generating value from device data, as described by Rymaszewska et al. (2017), is closely related to the ability to acquire and analyze large amounts of data. To best generate value from this knowledge, manufacturers vertically integrate customer processes as described by Baines & Lightfoot (2014). As a conclusion from this brief overview and as noted by Paschou et al. (2020), the interplay of different digital technologies and their relation to servitization should be explored to get a holistic picture. Due to their fungibility, some digital technologies, such as cloud computing, artificial intelligence, and IoT, can be used for different elements in the business model. Therefore, the overview given by Paschou et al. (2020) serves as a basis but has to be enhanced with the application the technology is used for and further aggregated for quantitative research.

2.2.2. Back-End, Front-End, and Product Digitalization

Based on the solution business model approach by Storbacka (2011), which describes a model of necessary capabilities for solution providers, Coreynen et al. (2017) identified three options for digitalization to facilitate servitization as shown in Figure 7.

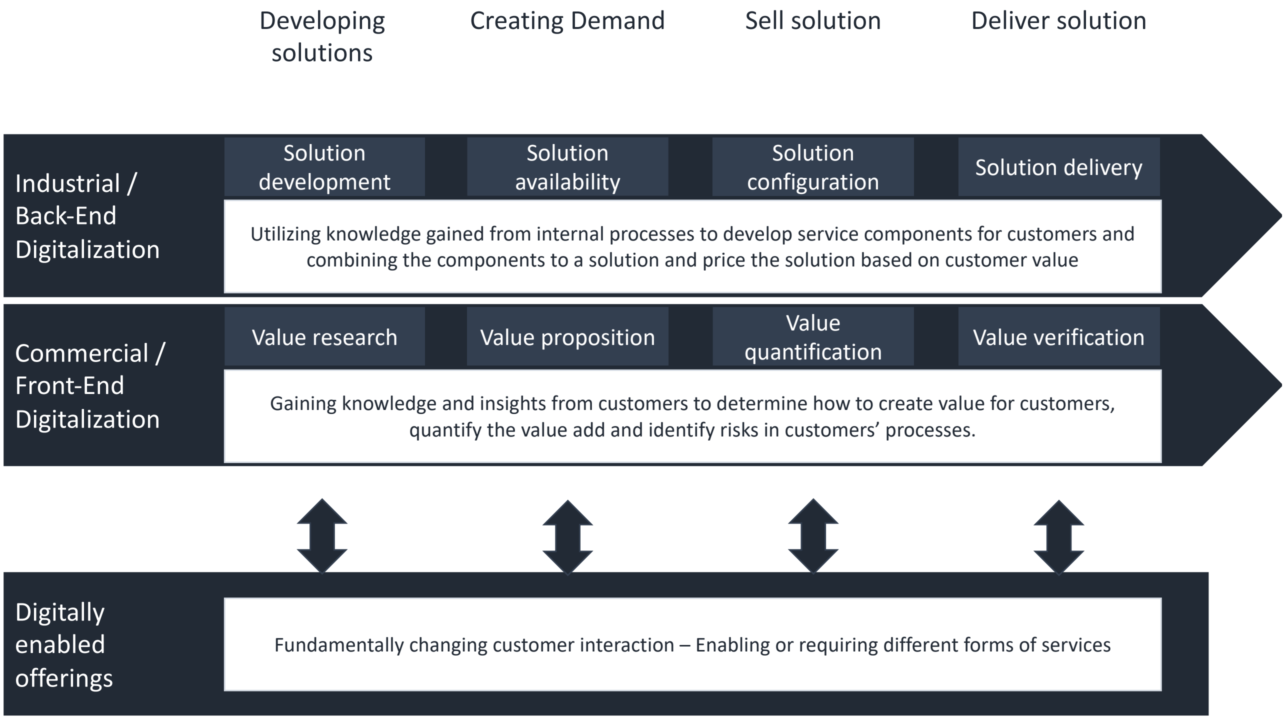

Figure 7. Digitalization pathways; figure based on Coreynen et al. (2017) and Storbacka (2011)

The first option is the digitalization of the back-end or industrial digitalization, which on the one hand reduces manufacturing costs and on the other hand enables knowledge creation. For servitization, this knowledge can be utilized to provide better training or improve customers' processes. Storbacka (2011) divided industrialization capabilities into four sets of capabilities, which are solution development, solution availability, solution configuration, and solution delivery. Solution development entails capabilities such as development to customer needs and standardized components in ERP (Enterprise Resource Planning) and PDM (Product Data Management System) that can be flexibly adapted to customer needs. Solution availability describes capabilities necessary to provide fitting solutions for different customers and segments, for example, different value propositions (input-based and output-based). To configure these solutions and set the pricing for these solutions, capabilities in solution configuration are needed. Finally, solution delivery describes capabilities such as the necessary information exchange to monitor the correct delivery of the solution. Coreynen et al. (2017) outlined cases that used industrial digitalization for offering new services. While some companies invested in production facilities to individualize products for example through 3D printing, others automated their production to increase production speed and lower costs.

The second option to boost servitization through digitalization is the usage of front-end or commercial digitalization. The goals of front-end digitalization are creating new ways of interacting with customers and gaining additional insights into customer processes and needs. Digitalization can be used to improve value research to incorporate customer needs into the solution development process, provide tools for the creation of customer-specific offerings, and measure customer value during the delivery process (Coreynen et al., 2017; Storbacka, 2011).

Besides the digitalization of production and customer interaction, the third option is to digitalize the product itself to enable a range of new ways of customer interaction and services (Coreynen et al., 2017). Smart products that add sensors and connectivity features to the physical product (Porter & Heppelmann, 2014) are the foundation for monitoring, optimization, and performance-based services. Furthermore, these smart products give insights into a product's condition and usage which in turn allows the manufacturer to better identify risks and to adapt services according to customers' needs.

Zhou et al. (2021) distinguished between the first two digitalization paths, internal and external digitalization, in their study of the interplay between servitization and digitalization. Their construct for internal digitalization is mostly centered around planning tools and cost-saving opportunities while external digitalization comprised collaboration tools and increased flexibility through digital technologies. They found that efficiency gains through internal digitalization are positively related to basic services while advanced services benefit from collaborative tools to enable value co-creation. Kohtamäki et al. (2020) employed a model based only on front-end digitalization used to support sales and service functions, customer analysis, and customer data integration. Since this typology has already been used in connection with servitization, it is suitable for the intended research objective. While Zhou et al. (2021) only use internal and external digitalization, especially through software tools for collaboration, it might be beneficial to use a broader interpretation of internal and external digitalization and also integrate the digitalization of products as described by Porter & Heppelmann (2014).

2.2.3. Digitalization of Manufacturing & Industry 4.0

While in the previously mentioned study by Zhou et al. (2021) the focus was on digitalization in the form of information and communication or collaboration tools, another common form of digitalization by manufacturers concerns their production environment. A familiar term in this context is Industry 4.0, which describes a range of concepts related to the fourth industrial revolution. In particular, cyber-physical systems controlled by new technologies such as IoT and AI are supporting the transformation of manufacturing companies' business models. Smart factories make it possible to react flexibly to individual customer needs and to customize products in a cost-efficient way. On the other hand, production costs, especially labor costs, can be reduced through greater automation (Buer, Strandhagen, et al., 2021). In addition to this digitalization of the production environment, Industry 4.0 also includes the vertical integration of business processes within companies and the horizontal integration of value creation networks. Furthermore, the products themselves are becoming smarter, for example through sensors and connectivity, and can thus be integrated into cyber-physical systems (Kagermann et al., 2013).

Buer, Strandhagen, et al. (2021) researched on the digitalization of companies of different sizes and with different production environments. Within the production environments, they distinguished between four types of production environments depending on volume, individualization, and product complexity. As displayed in Table 8, the level of digitalization was measured in terms of the digitalization of the shop floor, horizontal and vertical integration, and the organizational IT competence.

Within the typology by Coreynen et al. (2017) and Storbacka (2011), the digitalization of manufacturing operations fits primarily into the back-end or industrial digitalization. While this typology of digitalization of manufacturing operations provides additional aspects to integrate into a final model for digitalization, it mostly describes how value creation is supported.

Table 8. Digitalization of manufacturing operations, based on Buer, Strandhagen, et al. (2021)

Digitalization of the shop floor	Technologies for horizontal and vertical integration	Organizational IT competence
Real-time view of production Digitalization of production equipment (e.g., IoT) Sophistication of IT hardware Control system for manufacturing process	Digitalization of the value chain from development to production End-to-End IT-based planning system (sales, production, logistics) Digitalization value chain (suppliers, production, logistics, service, and customers) Level of IT integration with partners	Capability to create value from data Capabilities and resources related to Industry 4.0 Involvement, Support, and expertise of senior management regarding Industry 4.0 Capability of the IT organization Collaboration on Industry 4.0 with external partners

In a different approach to evaluating the impact of digital manufacturing and dynamic capabilities on organizational performance, Savastano et al. (2021) measured the use of digital innovation in the back-end and distinguished between the use of digital technologies in design and development and manufacturing. As a result, they established a positive relationship between digital manufacturing and organizational performance. Furthermore, digital manufacturing partially mediated the relationship between dynamic capabilities and organizational performance. Kroh et al. (2018) investigated the use of ICT in the innovation process and the relationship to servitization. They find that companies with a high level of servitization benefit from both internal and external ICT tools for innovation. Combining these results, it can be hypothesized that digital technologies for design and development processes improve a company's design-to-service capability and thereby lead to improved organizational performance.

Based on the aforementioned studies on the digitalization of manufacturing operations, a division into the digitalization of the production process and design and development processes makes sense. While the digitalization of production processes has a direct influence on company performance in the studies mentioned, the influence of design and development processes is more complex, mediated by other factors and therefore an interesting aspect in connection with digital servitization.

2.2.4. Enterprise Digitalization

In a study on the effect of digitalization and dynamic capabilities on company performance, Yu et al. (2021) identified four different categories for measuring digitalization. First, value chain digitalization describes how far activities along the value chain, like procurement, design, logistics, and customer services are supported through digital technologies. Second, business process digitalization encompasses solutions that connect and support different business activities. The third category of product-service digitalization contains products that have smart components and services based on digitally obtained knowledge. While the first three categories focus on the value proposition and value creation, the fourth category contains a set of technologies like IoT and cloud computing that have been explored or adopted by the company. The items contained in the categories are displayed in Table 9.

Table 9. Enterprise digitalization typology by Yu et al. (2021, pp. 7–8)

Category	Items
Value chain digitalization	- Digital procurement system - Intelligent equipment for production - Network-based software for research, development, and design of products - Digital technology for marketing - Digital logistics system - Intelligent customer service system
Business-process digitalization	- Digital solutions that connect activities including customers, suppliers, and employees - Data has a central role in decision making - Digital platform for implementation of innovative ideas
Product-service digitalization	- Utilization and exploitation of smart components - Emphasizes offerings that allow status and usage monitoring - Emphasizes offerings that include cloud connectivity to perform processing in the cloud - Emphasizes connectivity between products
Application of digital technology	- Exploration or adoption of o Internet of Things o Cloud computing o Big data o Data analysis technology

Interestingly, Yu et al. (2021) observed that the effect of enterprise digitalization on company performance has an inverted U-shape. This supports the notion of a digitalization paradox as identified by Gebauer et al. (2020), in which companies do not achieve the planned revenues through the employment of digital technologies when they invest on a larger scale. Moreover, it is consistent with the result of Kohtamäki et al. (2020) who also found an inverted U-shape for the relationship between digitalization and company performance but did not have a sufficiently significant result.

Compared to Coreynen et al. (2017), Yu et al. (2021) differentiated into the digitalization of the value chain and the digitalization of business processes instead of front-end and back-end digitalization. In the context of dynamic capabilities, the separate consideration of business process digitalization is a useful structure to determine the effect of digitalization on decision-making. However, as business process digitalization has overlaps with value chain digitalization, for example through the item digital solutions for connecting with suppliers and customers, the model of Coreynen et al. (2017) provides a slightly better differentiation for the intended research model.

2.2.5. Selection of a Model for Digitalization

Among the above-mentioned typologies for digitalization, the structures proposed by Storbacka (2011) and related to digital servitization by Coreynen et al. (2017) as well as the model by Yu et al. (2021) provide well-aggregated forms to measure digitalization, parts of which have previously been used for quantitative research. The typologies differ mainly in the distinction between back-end and front-end digitalization (Coreynen et al., 2017) and the differentiation between value-chain and business-process digitalization (Yu et al., 2021). Since the focus of this research is on manufacturing industries and the distinguishment of back-end digitalization provides a better frame to integrate findings related to Industry 4.0, which have been frequently linked to servitization (Paschou et al., 2020), the typology displayed in Table 10 is proposed. Based on the framework by Savastano et al., (2021), back-end digitalization is further subdivided into design and development as well as manufacturing operations.

Table 10. Typology for the measurement of digitalization

<table>
<tr><th>Back-End / Industrial Digitalization</th><th>Front-End / Commercial Digitalization</th><th>Digitally enabled offerings</th></tr>
<tr><td>Design & Development
Mixed reality (e.g., for product development)
Simulation of connected machines
Additive manufacturing / 3D printing (for prototyping)
Manufacturing
Advanced manufacturing solutions
Control system for manufacturing
Real-time production overview
Digitalization and integration of the value chain</td><td>Collaborative ICT tools
Digital vertical integration of customers
ICT tools to support sales and service functions
End-to-End planning systems</td><td>Smart components
Cloud connectivity
Connectivity between products
Status and usage monitoring</td></tr>
<tr><td colspan="3">General-purpose technologies
Artificial intelligence and big data (e.g., for production optimization, customer analysis, forecasting, and analysis of product usage/status)
Cloud computing
IoT (connection to own production equipment or connectivity of products sold to customers)</td></tr>
</table>

Most of the items mentioned in the reviewed typologies can be fitted into the distinguishment between back-end, front-end, and product digitalization. Still, some technologies, like Artificial Intelligence, cloud computing, and the IoT can be applied too broadly to categorize them without further information. Therefore, these are displayed as so-called general-purpose technologies, a category that relates to the category “application of digital technology” in the model by Yu et al. (2021).

The elements of the typology are as follows. In the design and development of products, technologies are listed that support the development process. Mixed reality systems help in the visualization and planning of products without the need to physically provide them, which, for example, favors greater interaction with customers and partners during development. The simulation of connected machines makes it possible to develop complex systems and thus simplifies the provision of individualized system solutions on the one hand. On the other hand, it accelerates the development process in general. Additive manufacturing, for example 3D printing, speeds up the construction of prototypes and can be used to test solutions quickly and cost-effectively. Overall, these technologies provide opportunities to develop products in the sense of a design-to-service approach and to offer individualization and development services.

In manufacturing, digital technologies are used either as part of automation or process integration solutions. The combination of these two areas of application leads to the formation of cyber-physical systems, which connect manufacturing systems with the control mechanisms for the value stream. Advanced manufacturing systems in the sense of Paschou et al. (2020) represent a broad field of networked and collaborative robots controlled by artificial intelligence. On the one hand, these can be used to achieve greater efficiency by automating manufacturing processes; on the other hand, the reprogrammability of these systems can be used to increase individualization. These manufacturing systems are linked to control systems that provide a real-time overview of the production and provide the ability to control production processes in real-time (Buer, Strandhagen, et al., 2021).

Although the data source used for this research (described in chapter 3.1) does not include information on front-end digitalization, the elements are described below to provide a complete typology. Collaborative ICT tools include, for example, communication tools such as video conferencing software, cloud platforms for collaborative document processing, or control of cross-company projects. Particularly in the case of standardized processes, customers are also vertically integrated digitally, for example by connecting enterprise resource planning or logistics systems. In project planning, end-to-end planning systems are also used for this purpose. Digital tools for sales and service functions include, for example, customer relationship management systems and service platforms that can also be used to interact with customers. Comparable elements were investigated by Kothamäki et al. (2020) in connection with servitization and they find that these digital tools have a positive effect on profitability at moderate investment levels. At higher investment levels the digitalization paradox becomes measurable and servitization can serve as a means to overcome this paradox.

The last element of the typology is product digitalization, which describes products enhanced by digital elements. A well-known publication on product digitalization comes from Porter & Heppelmann (2014) who described different elements that are combined into smart products. The product itself is equipped with sensors to collect data and software to collect data as well as to control the product components. Furthermore, it contains connectivity features to connect to either other products or a product cloud. The product cloud can take different forms, from a remote monitoring platform collecting data over an operating platform to control the product to a platform that enables autonomous operation and interaction with other smart products.

2.3. Typologies for Firm Performance and its Operationalization

The performance of companies and organizations belongs to the most frequently used dependent variables in management research. Despite the frequent use of this variable, there is ambiguity regarding the dimensions for measuring performance and the name of the constructs. Therefore, the following section describes several approaches for measuring the performance of companies and subsequently identifies suitable performance measures based on previous studies from the fields of digitalization, servitization, and digital servitization.

2.3.1. Performance Measurement in Strategy Research

Venkatraman & Ramanujam (1986) defined three levels at which firm performance can be measured, as shown in Figure 8. This classification is cited by many researchers when studying firm performance (Combs et al., 2005; Hamann et al., 2013; Richard et al., 2009). The narrowest level for measurement is financial performance, which is expressed, for example, in terms of company growth and profitability. Going beyond the purely financial performance of a company and adding measurements for operational performance, for example, market share, quality, process efficiency, or innovativeness, to the construct, leads to business performance. The most encompassing level is organizational effectiveness, which describes how effectively a company achieves a set of partially contradictory goals. The type of goals and their weighting depends on the values of the observer or stakeholder, which is why organizational effectiveness is mainly used in conceptual literature on strategic management but is not applicable for quantitative research.

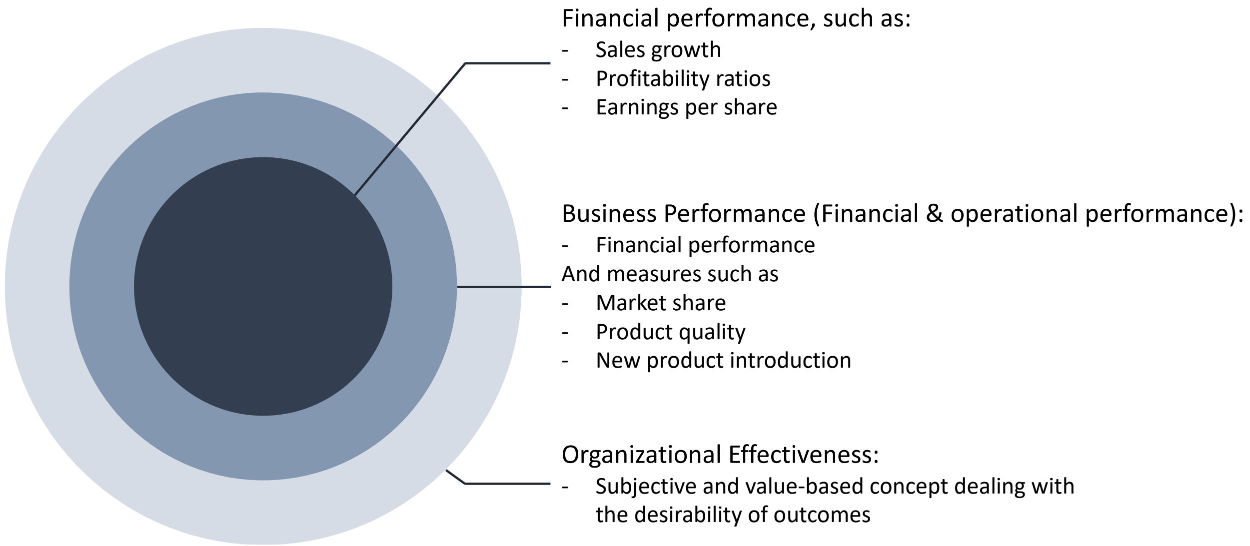

Figure 8. Scope of different firm performance concepts, based on Venkatraman & Ramanujam (1986)

Besides the classification by Venkatraman & Ramanujam (1986), the term *organizational performance* is frequently used in relation to the performance of firms. Organizational performance is defined as the *"economic outcomes resulting from the interplay among an organization's attributes, actions, and environment"* (Combs et al., 2005, p. 261) and is synonymously used with the terms financial performance or corporate economic performance (Hamann & Schiemann, 2021). Business performance, the middle dimension from Venkatraman & Ramanujam's (1986) model, is referred to as operational performance by Combs et al. (2005) emphasizing the non-financial indicators. Combs et al. (2005) argued that operational performance should be regarded as distinct from organizational performance and Hamann et al. (2013) added that operational performance may lead to organizational performance through achieving operational targets. The measurement of organizational performance is an ongoing discussion in the field of management research. Richard et al. (2009) found that within 213 papers on management they reviewed, 207 different measures for organizational performance were used. This leads to difficulties in comparing results of publications on otherwise similar fields and is also a topic in servitization research (Brax et al., 2021).

Concerning the measures to be employed to evaluate organizational performance, there is an ongoing discussion on the dimensionality of this construct. Based on a large set of longitudinal data, Hamann & Schiemann (2021) develop a multidimensional construct to measure organizational performance and argue that organizational performance consists of four dimensions. The first dimension is profitability, which describes the ability of a company to generate profits through the use of production factors and is evaluated, for example, through return on sales. Secondly, liquidity describes the ability to generate sufficient cash flow to pay obligations. For comparable measurement, cash flow is also measured as a ratio, for instance, cash flow return on sales. Third, growth, which describes the increase in the size of the company, for example the number of employees, sales or assets, over a certain period of time. Finally, the stock market performance of a company, for instance, the value generated for shareholders, is also assessed as a dimension of organizational performance. Ratios are also used for this, for example, Tobin's q. Combs et al. (2005) develop a model that consists of three dimensions and does not include the liquidity dimension of Hamann & Schiemann (2021). All remaining dimensions are described similarly.

Assuming that not all the firms considered are listed on the stock exchange and therefore shareholder returns cannot be captured, growth and profitability ratios are preferable as the focus of this research. Both Combs et al. (2005) and Hamann & Schiemann (2021) note that the performance dimensions are not interchangeable and should always be considered separately, as each dimension is influenced differently. In terms of designation, the performance measurement envisioned is a measurement of organizational performance in the nomenclature of strategic management research.

2.3.2. Performance Measurement in Servitization Research

Instead of using the designation *organizational performance* as used by Combs et al. (2005), most studies on servitization name the construct *company financial performance* as defined by Venkatraman & Ramanujam (1986) when only financial aspects are assessed or *firm performance* in case also non-financial aspects like customer loyalty are included. Firm performance as a target variable is measured differently throughout papers on servitization and digital servitization. As displayed in Table 11, the company performance is in most cases evaluated through a construct based on different factors. These factors differ significantly in terms of the dimension of business performance measured, the scale used (Likert scale or financial results), and the type of survey (Assessed by the company or market data).

Table 11. Overview of employed measures for organizational performance in quantitative servitization research

Author	Measures
Abou-foul et al. (2021)	All items on a Likert seven-point scale reported by the company Revenues - Revenue / Employee - Revenues / Fixed Assets Profitability - Return on sales - Return on investment - General profitability of the firm Market valuation - Market capitalization
Zhou et al. (2021)	All items on a Likert five-point scale reported by the company - Sales volume growth - Profit margin growth - Market share growth - Over-competitive position - Customer loyalty
Yu et al. (2021)	All items on a Likert seven-point scale reported by the company - Revenue grows faster than for competitors - Profit grows faster than for competitors - Return on Investment grows faster than for competitors - Market share grows
Kohtamäki et al. (2020)	- Return on Asset Growth over two years
Martín-Peña et al. (2020)	- Total sales
Sousa & da Silveira (2017)	All items on a Likert five-point scale reported by the company - Total sales - Return on Sales
Eggert et al. (2014)	Data collection at three points in time to evaluate changes and growth - Total revenue - Profitability on a five-point Likert scale

Kastalli & Looy (2013)	- Profit margin - Product sales - Service sales
Kothamäki et al. (2013)	Data collection at three points in time to evaluate changes and growth - Total revenue
Eggert et al. (2011)	Data collection at five points in time (t1-t5) to evaluate changes and growth - Profitability on a five-point Likert scale (at t3, t4, t5) With operational performance factor - Product innovation activities (t1-t3) And industry adaptation - Economic situation of the industry (t2-t5)
Fang et al. (2008)	- Tobin's q (Market value/book value)

Interestingly, studies using financial ratios (Eggert et al., 2014; Kastalli & Looy, 2013; Sousa & da Silveira, 2017) utilized the individual measures to identify effects on single performance measures. Both Sousa & da Silveira (2017) and Eggert et al. (2014) distinguished between effects on total sales and profitability. They noted, for example, that while certain services may lead to revenue growth, they initially have a negative impact on profitability. Studies that used subjective measures, for example a self-reported assessment of performance compared to other companies in a similar industry, usually form a construct that combines all measures. These studies lack some desirable granularity in terms of performance measurement, especially when it comes to effects such as the servitization and digitalization paradox.

To differentiate between effects on company performance, three indicators will be used within this research. Company profitability is measured in terms of return on sales, company growth is measured as the increase in annual turnover, and efficiency is calculated as revenues per employee. Through this differentiation, it is possible to identify effects that for instance lead to increased revenues but decrease profitability or vice versa.

2.4. Research Model and Hypotheses

To set up a research model and to identify the effect of digitalization on firms' financial performance as well as the mediating role of servitization, earlier studies have been reviewed in the previous part of chapter 2 and typologies for services, digitalization and financial performance have been defined. While general effects of digital servitization on firm performance have been researched in quantitative studies, a more granular view is only established for the individual fields of digitalization and servitization but not for the interplay of these. To contribute to closing this research gap, the research model in Figure 9 is proposed.

In terms of servitization, this model distinguishes between SSPs and SSCs. Digitalization is divided into three constructs, digitalization of the product, digitalization of manufacturing and digitalization of design & development processes. Due to limitations of the data set from the European Manufacturing Survey (EMS) questionnaire, front-end digitalization is not included. In this context, Kohtamäki et al. (2020) identified a moderating effect of advanced services on the impact of front-end digitalization on business performance, which is why this study can be used as an indication for the effects of this gap in the EMS data. Financial performance is measured through three indicators, return on sales, revenue growth and revenue per employee.

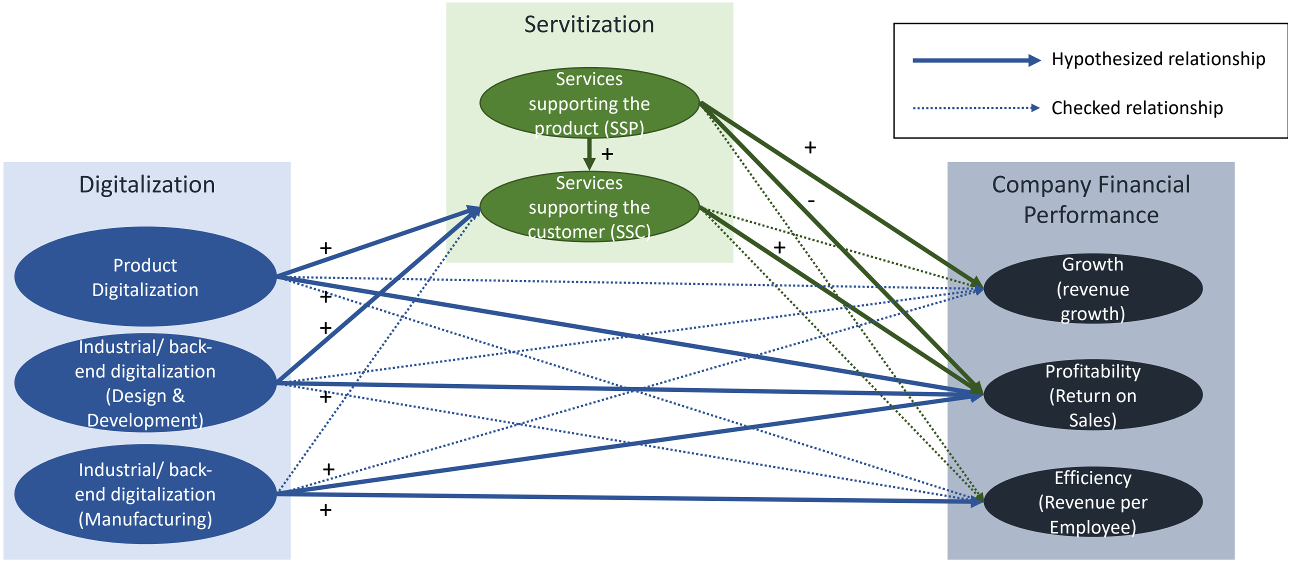

Figure 9. Proposed detailed research model

Drawing on the studies previously analyzed, the following hypotheses are formulated and subsequently substantiated based on previous studies:

1a. Services supporting the manufacturer's product (SSPs) have a negative effect on the profitability of a company. This is based on the assumption that the introduction of these services does not bring a sustainable competitive advantage, as these services are easy to imitate. Furthermore, product manufacturers might accept low margins for services to promote products (Sousa & da Silveira, 2017).

1b. SSPs have a positive effect on services supporting the customer's process (SSCs). By delivering SSPs the manufacturer, on the one hand, acquires the necessary knowledge to develop SSCs and on the other hand builds up closer customer relationships (Antioco et al., 2008; Oliva & Kallenberg, 2003; Sousa & da Silveira, 2017; Zhou et al., 2021).

1c. SSPs have a positive impact on revenue growth. They offer a possibility to grow the company by further utilizing capabilities related to manufacturing and establishing a further revenue stream (Antioco et al., 2008).

1d. SSPs have an indirect positive impact on profitability which is mediated through SSCs. By building service capabilities, intensifying customer relationships, and transforming the organization to deliver services in the course of providing SSPs, companies gain a competitive advantage that is leveraged by harder-to-imitate and more profitable SSCs (Eggert et al., 2014; Sousa & da Silveira, 2017).

2. SSCs have a positive effect on profitability. They require specific skills and knowledge of customer processes, are therefore more difficult to imitate, and create customer lock-in effects, ultimately resulting in higher achievable margins than SSPs (Sousa & da Silveira, 2017).

3a. Digitalization of manufacturing has a positive effect on efficiency in terms of revenue per employee. The digitalization of production processes in the back-end of manufacturing companies increases the efficiency with which these companies produce products. Automated processes replace manual labor. Therefore, this form of back-end digitalization leads to increased revenues per employee (Björkdahl, 2020; Buer, Semini, et al., 2021).

3b. Digitalization of manufacturing has a positive effect on profitability. This is based on the idea that the digitalization of production processes in the back-end of manufacturing companies reduces production costs and therefore increases profit margins (Buer, Semini, et al., 2021; Savastano et al., 2021).

4a. Digitalization of design and development has a positive effect on profitability. This is based on the assumption that the digitalization of design and development processes in the back-end of companies increases the customer value of a product, thus leading to higher profitability (Kroh et al., 2018).

4b. Digitalization of design and development has a positive effect on SSCs and thereby a positive indirect effect on profitability. The digitalization of design and development processes in the back-end of companies increases the ability of a company to combine products with services. Through an increased design-to-service capability, manufacturing companies improve the value they can create through services (Kroh et al., 2018; Reinartz & Ulaga, 2014; Ulaga & Reinartz, 2011).

5a. Digitalization of manufactured products has a positive effect on profitability. This is based on the assumption that this form of digitalization increases the value of products to customers, leads to product differentiation, and thereby allows higher profit margins (Porter & Heppelmann, 2014).

5b. The effect of the digitalization of manufactured products on profitability is mediated by SSCs. These services utilize digital features of the products and therefore increase the value created for the customer (Abou-foul et al., 2021; Rymaszewska et al., 2017).

3. Methodological Solutions for Quantitative Analysis of the Interplay between Servitization and Digitalization

To examine the research model described in Section 2.4, the methodology is explained below. First, the data acquisition from the European Manufacturer Survey is described. Subsequently, a focus on specific industries is defined, which is suitable based on both the queried services and digital technologies within the EMS as well as previous studies. Finally, the procedure for analyzing the data is explained.

3.1. Data Acquisition

This thesis is based on data from a survey of manufacturing companies conducted as part of the European Manufacturing Survey (EMS) 2018. EMS is an international network of research institutions coordinated by the Fraunhofer Institute for Systems and Innovation Research (ISI) that collect data on manufacturing companies in their respective countries. By aggregating data from different European countries for the proposed research, a larger data set can be achieved to identify even small effects. The data set entails secondary data that is not publicly available. The sample (N=798) contains data collected in Lithuania (Vilkas et al., 2021), Slovakia (Šebo et al., 2019), Austria (Zahradnik et al., 2019), Croatia, and Slovenia (Palčič & Prester, 2020) as part of the EMS in 2018-2019.

Since the data set stems from a general survey of European manufacturers and is not specifically tailored to the proposed research question, the proposed research model and typologies can only be assessed according to the available data. While this data is sufficient for applying the selected typology for servitization, within digitalization no items are available on commercial or front-end digitalization. Therefore, this dimension of digitalization cannot be analyzed based on the data set. Concerning the measurement of company financial performance, the EMS provides information on profitability in terms of return on sales and size in terms of the number of employees and revenues measured at two points in time (2015 and 2017).

3.2. Industry Focus

Taking the NACE code as a basis for the classification of enterprises, manufacturing enterprises are described by NACE divisions 10 to 33. Within this broad classification of enterprises, there are significant differences between products that need to be taken into account when measuring servitization. Among the lower of the NACE Division numbers are enterprises producing, for example, food products (Division 10), beverages (Division 11), or paper products (Division 17). All these products are non-durable and non-technical products. In the context of the classification of services selected as the basis for the analysis, which assumes the provision of product-related services such as maintenance, repairs, and monitoring, non-technical, non-durable products are difficult to include. Furthermore, the digitalization of the product is not feasible or only to a very limited degree. Allmendinger & Lombreglia (2005) gave a good overview of considerations for product digitalization and a guideline on which products are candidates for incorporating smart components. They advised excluding products that are not mechanical or electromechanical and products that are either very simple, have a short lifespan, or are used for a very long duration. While the first points seem logical, the last point needs to be viewed more carefully. Products with a long useful life could also benefit from digitalization, but the benefit must be in proportion to maintaining and updating digital technologies. For this research, these companies producing non-durable or non-technical goods are to be excluded from the statistical analysis to not dilute the results.

It should be noted that the NACE code only describes the industry in which the enterprise or business unit creates the most value (Commission of the European Communities (Statistical Office/Eurostat), 2008). This is assessed based on output, for example, sales, or based on input, for example, working time input. In addition to this main activity, a company may pursue other activities that are not covered by the classification. Therefore, as part of the descriptive analysis, it is necessary to verify whether the assumption that some services are only applicable to companies in certain industries is correct.

While most studies on servitization and digital servitization name manufacturing companies as their focus, participants mostly come from manufacturers of technical products (Jovanovic et al., 2019; Kowalkowski et al., 2015; Tronvoll et al., 2020). This issue is also shown by previous research, like Martín-Peña et al. (2020), who displayed no significant relationship between digitalization and servitization for non-technical products while this relationship is significant for technical products. Similarly, Guerrieri & Meliciani (2005) found that knowledge-intensive financial, communication, and business services are more often provided by manufacturers of for example professional goods and electric appliances. Sousa & da Silveira (2017), aiming at a research model for evaluating the effect of capabilities on servitization, solved this issue by focusing on ISIC Rev. 4 codes 25 to 30. For these economic activities and this high level of aggregation the NACE and ISIC Code correspond and provide a suitable delimitation for this research.

3.3. Data Analysis

Data analysis is performed in two steps. Initially, descriptive statistics are used to provide insights into the data distribution for countries and industries. Furthermore, assumptions on the applicability of services and use of digital technologies for industry groups are checked and outliers for the measurements of firm performance are identified. To assess whether both servitization and digitalization are more prevalent in the NACE groups 25 to 30, an independent samples t-test is performed for the individual indicators. This part of the analysis is performed using SPSS (IBM Corp., 2020). The items from the EMS questionnaire are subsequently categorized according to the selected typologies for servitization and digitalization.

For the regression analysis, Partial Least Squares Structural Equation Modelling (PLS-SEM) (Hair et al., 2017) is used. This method has several advantages over other methods such as covariance-based structural equation modeling (CB-SEM). Since the hypothesized relationship between the constructs in the previously displayed research model mostly originate from qualitative case studies or less granular models, a method that is suitable for exploratory research like PLS-SEM is beneficial. Since secondary data is used and survey questions were not specifically designed for the proposed research question, PLS-SEM is the more robust method for this analysis compared to CB-SEM. In this case, covariance-based approaches are unlikely to result in a sufficient model fit. PLS-SEM is more likely to yield a fitting result (Hair et al., 2019). While the constructs for servitization and digitalization consist of multiple items, the measurement of performance, in this case, is performed based on quotas, for which a single-item construct in PLS-SEM is appropriate (Hair et al., 2017). In CB-SEM, the use of single-item constructs would be restricted. PLS-SEM furthermore allows for working with nonnormal data and smaller data sets (Hair et al., 2011). Assuming that the effect sizes on the performance indicators in terms of R^2 are small, for example around 0.1, and with five constructs pointing at each of the performance indicators in the structural equation model, at least a sample size of 169 should be reached to achieve a result significant at the $p < 0.05$ level (Hair et al., 2017).

Following the proposed structure for applying PLS-SEM by Hair et al. (2017) the initial step, defining the structural model including the hypotheses is set up in chapter 2.4. Considering that in this research secondary data is used to measure the constructs, the specification of the measurement model and the examination of the data are done simultaneously in the next chapter. Based on this, the complete path model is built. Subsequently, the measurement model is examined first, and then the results of the structural model. A brief overview of the evaluation steps is shown in Table 12 and the process is explained subsequently.

Table 12. Measurements for evaluation of the PLS-SEM model

Measurement Model	Indicator loadings	Outer loading ≥ 0.7, or 0.4 < Outer loading < 0.7 for content reliability
	Internal consistency reliability	Composite Reliability ≥ 0.7
	Convergent Validity	AVE ≥ 0.5
	Discriminant Validity	HTMT ≤ 0.9
Structural Model	Multicollinearity	VIF ≤ 3
	Explanatory power	R^2 & p-value
	Direct and Indirect Effect Analysis	Total effects, direct and Indirect path coefficients & p-value

Initially, the outer loadings of the indicators are inspected. Since the EMS questionnaire does not follow a scale specifically designed to measure servitization or digitalization, it has to be expected that items with low loadings have to be removed to achieve a reliable measurement model. While in general loadings should exceed a value of 0.7, values between 0.4 and 0.7 can be acceptable under certain conditions. Following Hair et al. (2017), indicators with a loading below 0.7 are test-deleted to examine whether the reliability of the construct increases. If this is the case, the indicator is removed; otherwise and especially if the indicator contributes to content reliability, the indicator is retained.

The second step in assessing the quality of the model is the inspection of internal consistency reliability. Since PLS-SEM weights the indicators according to their reliability and does not assume the same reliability across all indicators, measuring Cronbach's alpha leads to an underestimation of the constructs' reliability. Therefore, in accordance with Hair et al. (2019), Composite Reliability is evaluated. This reliability indicator, similar to Cronbach's alpha, has a scale of 0-1 and is considered acceptable in exploratory research if it exceeds 0.6, and should exceed 0.7 in explanatory research to be satisfactory.

Thirdly, convergent reliability is tested based on AVE (Average Variance Extracted), which measures how much of the indicators' variance is explained by the constructs. This criterion is acceptable if the value lies above 0.5 (Hair et al., 2019), meaning that more than half of the variance of the indicators is explained through the constructs.

Finally, the discriminant validity of the constructs is assessed. Discriminant validity describes the degree to which constructs differ from each other to avoid two constructs measuring the same phenomena. A typical measure of this is the Fornell-Larcker criterion, which relies on comparing the square root of the AVE with the correlation between constructs, thus testing whether a construct shares more with another construct than with its indicators. Since this criterion has been criticized for its low detection rate of lack of discriminant validity, the HTMT (Heterotrait-Monotrait) ratio criterion has been developed as a method for assessing discriminant validity in variance-based structural equation modeling (Henseler et al., 2015). This criterion compares the average correlation of indicators between the two constructs with the geometric mean of the average correlation of indicators within two constructs. If the correlation of indicators between the two constructs is equal to or higher than the correlation within the construct, a lack of discriminant validity is indicated. Therefore this criterion should be below 1. Henseler et al. (2015) tested three different applications, a threshold of 0.85, a threshold of 0.9, and a test if the 90% confidence interval of the HTMT ratio is below 1. Since the HTMT criterion is considerably stricter than the Fornell-Larcker criterion (Ab Hamid et al., 2017), a threshold of 0.9 provides a good balance between sensitivity and specificity for discriminant validity. Hence, a threshold of 0.9 is used in the following.

Within the structural model, multicollinearity is tested to identify predictor constructs that predict each other or trend collinearly. Since multicollinearity leads to the problem that the effect on a dependent variable cannot be correctly assigned to one of the predictor constructs, the structural model needs to be checked for this (Mason & Perreault, 1991). SmartPLS outputs the variance inflation factor (VIF), which indicates how strongly the variance of the dependent variable increases as a result of the collinearity of the independent variables. The VIF value ideally lies below 3 to indicate that there is no problem with multicollinearity.

After testing the structural model for multicollinearity, the explanatory power of the model in terms of R^2 is assessed. Since this research deals with potential influence factors on financial performance, which is affected by a multitude of factors, the resulting values are expected to be rather low. Subsequently, the individual paths, as well as the direct and indirect effects, are analyzed.

Finally, the results from the investigation are compared with the hypotheses and previous research results and conclusions are drawn.

4. Research Findings and Discussion

In the following, the dataset from the EMS is analyzed using the previously selected constructs for digitalization, servitization, and financial performance. Initially, the dataset is described using SPSS and subsequently, the structural equation model is set up and assessed using SmartPLS.

4.1. Descriptive Statistics

To provide insight into the data set, the first part of the descriptive analysis is to discuss the composition of the data set in terms of company size and industry sector. Subsequently, the services and digital technologies queried in the EMS are analyzed, also in terms of prevalence in the selected industry sector of NACE divisions 25-30. Finally, the indicators for company performance are described and outliers are identified to define the cases to be subsequently analyzed in SmartPLS.

4.1.1. Country and Industry Focus

The dataset from the 2018 EMS contains data from 798 European manufacturing companies. As displayed in Table 13, the largest group by country is from Austria, accounting for 31.7%, while the smallest group is companies from Croatia, accounting for 13.2% of the dataset.

Table 13. Number of datasets within the EMS by country

Country name	Frequency	Percent
Lithuania	199	24.9%
Slovenia	127	15.9%
Croatia	105	13.2%
Slovakia	114	14.3%
Austria	253	31.7%
Total	798	100%

Table 14 shows the size of the surveyed companies within the EMS in terms of the number of employees and annual turnover.

Table 14. Company size of respondents within the EMS by the number of employees and annual revenues

	Single-Site		Multi-site		Information regarding number of sites missing	
Number of employees in 2017	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
Up to 24 employees	63	7.9%	18	2.3%	3	0.4%
25 - 49 employees	200	25.1%	50	6.3%	4	0.5%
50 - 249 employees	197	24.7%	130	16.3%	6	0.8%
250 - 999 employees	27	3.4%	73	9.1%	1	0.1%
1000 and more employees	5	0.6%	17	2.1%	0	0.0%
Missing values	2	0.3%	2	0.3%	0	0.0%
Annual revenue in 2017	**Frequency**	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
Below 2M € annual revenue	103	12.9%	22	2.8%	1	0.1%
2M € to below 5M € annual revenue	116	14.5%	22	2.8%	2	0.3%
5M € to below 10M € annual revenue	76	9.5%	39	4.9%	2	0.3%
10M € to below 50M € annual revenue	96	12.0%	91	11.4%	7	0.9%
50M € and above annual revenue	23	2.9%	68	8.5%	0	0.0%
Missing values	80	10.0%	48	6.0%	2	0.3%
Total	494	61.9%	290	36.3%	14	1.8%

In the questionnaire, respondents are explicitly asked to refer to the manufacturing site where they are located and not to the entire company. 37% of respondents indicated that their manufacturing site is part of a multi-site company. The production sites of companies with multiple locations are larger on average. The mean revenue of multi-site companies in 2017 was €60.25 million compared to €17.06 million for single-site companies. Also, the mean number of employees is 315 compared to 104 in companies with one location.

Taking the number of employees as a basis for assessment, 57.6% of the single-site companies have less than 250 employees and are thus classified as small- and medium-sized enterprises (SMEs) as defined by the European Union (European Commission Directorate-General for Internal Market Industry Entrepreneurship and SMEs, 2020). As to be expected, multi-site companies typically have a higher number of employees and higher revenues. Furthermore, this evaluation indicates that both the number of employees and annual revenues are highly right-skewed. To use the number of employees and annual turnover for further evaluation, the logarithmic function of both should be used, which is in line with previous research (Eggert et al., 2014; Sousa & da Silveira, 2017). Evaluating the dataset based on the main industry the companies perform in, provides the distribution displayed in Table 15.

Table 15. Distribution of respondents by industry based on NACE code

NACE Division	NACE Name	Frequency	Percent
n/a	Missing values	2	0.3%
10	Manufacture of food products	65	8.1%
11	Manufacture of beverages	20	2.5%
13	Manufacture of textiles	20	2.5%
14	Manufacture of wearing apparel	34	4.3%
15	Manufacture of leather and related products	11	1.4%
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	64	8%
17	Manufacture of paper and paper products	11	1.4%
18	Printing and reproduction of recorded media	12	1.5%
20	Manufacture of chemicals and chemical products	20	2.5%
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	5	0.6%
22	Manufacture of rubber and plastic products	53	6.6%
23	Manufacture of other non-metallic mineral products	43	5.4%
24	Manufacture of basic metals	18	2.3%
25	Manufacture of fabricated metal products, except machinery and equipment	137	17.2%
26	Manufacture of computer, electronic and optical products	38	4.8%
27	Manufacture of electrical equipment	39	4.9%
28	Manufacture of machine yard equipment n.e.c.	94	11.8%
29	Manufacture of motor vehicles, trailers, and semi-trailers	31	3.9%
30	Manufacture of other transport equipment	5	0.6%
31	Manufacture of furniture	48	6%
32	Other manufacturing	24	3%
33	Repair and installation of machinery and equipment	4	0.5%
Total		**798**	

The smallest industry groups represented in the survey are pharmaceutical manufacturers (NACE division 21) with 5 respondents, manufacturers of other transport equipment (NACE division 30), and companies specializing in installation and repair services (NACE division 33). Within the targeted industries in the NACE divisions 25 to 30, manufacturers of fabricated metal products, except machinery equipment (NACE division 25) are the largest group with 137 respondents. Among the selected NACE divisions, this group presumably offers the lowest potential for product digitalization (compare, for instance, Allmendinger & Lombreglia (2005)) since some subgroups of the NACE division 25 are only concerned with producing and treating metal structures. Since the data is aggregated at the division level, no distinction between the more detailed NACE groups and classes can be made. Therefore, NACE division 25 is retained in the targeted data set.

4.1.2. Types of Services Offered

In the EMS, services are queried to determine whether a manufacturer currently offers them. All services are dichotomous variables that indicate whether the service is offered or not (0 – service not offered; 1 – service offered). The questions are divided into three groups, product-related services, digital services, and service business models. To verify the assumption that certain services are only applicable to some industries, all services queried in the EMS are presented below against the NACE classification. For the verification, an independent samples t-test is performed to see if the services have a different distribution for firms that manufacture technical products. The result is shown in Table 16.

Table 16. Independent sample t-test for the service offerings of companies inside and outside of NACE code 25-30

(equal variances not assumed, ** p<.01 (two-tailed), * p<0.05 (two-tailed))

Service group	Service	NACE Group	N	Mean	Std. Deviation	Mean Difference
Product-related services	Installation, start-up	Not 25-30	396	0,22	0,416	-0,23**
		25-30	337	0,45	0,498	
	Maintenance and repair	Not 25-30	402	0,27	0,446	-0,28**
		25-30	339	0,55	0,498	
	Training	Not 25-30	402	0,29	0,456	-0,16**
		25-30	336	0,45	0,498	
	Remote support for clients (e.g. User Helpdesk, web platform)	Not 25-30	407	0,32	0,468	-0,14**
		25-30	337	0,46	0,499	
	Design, consulting, project planning (incl. R&D for customers)	Not 25-30	401	0,45	0,498	-0,21**
		25-30	337	0,66	0,476	
	Software development (e.g. software customization)	Not 25-30	381	0,07	0,248	-0,14**
		25-30	337	0,21	0,408	
	Revamping or modernization (incl. enhancement of functions, software extensions, etc.)	Not 25-30	384	0,14	0,343	-0,22**
		25-30	337	0,36	0,48	
	Take-back services (e.g. recycling, disposal, taking back)	Not 25-30	408	0,27	0,443	0,04
		25-30	338	0,23	0,42	
Digital solutions	Web-based offers for product utilization (online training, -documentation, error description)	Not 25-30	399	0,21	0,408	-0,04
		25-30	337	0,25	0,431	
	Web-based services for customized product configuration or product design	Not 25-30	394	0,12	0,325	-0,04
		25-30	335	0,16	0,368	

Service group	Service	NACE Group	N	Mean	Std. Deviation	Mean Difference
	Digital (remote) monitoring of operating status (e.g. condition monitoring)	Not 25-30	390	0,07	0,263	-0,13**
		25-30	335	0,2	0,401	
	Mobile devices for diagnosis, repair or consultancy (e.g. digital camera, smartphone, tablets, etc.)	Not 25-30	389	0,11	0,314	-0,07*
		25-30	337	0,18	0,381	
	Data-based services based on big data analysis	Not 25-30	387	0,04	0,199	-0,05*
		25-30	325	0,09	0,286	
Business models	Renting products, machinery, or equipment	Not 25-30	429	0,07	0,255	-0,05*
		25-30	332	0,12	0,326	
	Full-service contracts with a defined scope to maintain your products	Not 25-30	423	0,16	0,363	-0,14**
		25-30	329	0,3	0,458	
	Operation of your own products at customer site / for the customer	Not 25-30	421	0,11	0,309	-0,04
		25-30	328	0,15	0,357	
	Taking over the management of maintenance activities for the customer	Not 25-30	427	0,04	0,206	-0,09**
		25-30	327	0,13	0,342	
	Contracting offers (supply of operating resources)	Not 25-30	426	0,03	0,172	-0,01
		25-30	330	0,04	0,187	

As can be seen from the table, services are offered considerably less frequently by firms outside NACE group 25 to 30. For almost all services, the mean value is higher in the NACE group 25-30, and for 13 out of 18 services the difference is statistically significant at least at the $p < 0.05$ level. Furthermore, more sophisticated services from the *digital solution* and *service business model* groups are offered less frequently than services related to the product.

According to the distinction between SSP and SSC defined in chapter 2.1.6, the items surveyed in the EMS are categorized. As discussed in chapter 2.1.3, the capability to perform digital remote monitoring is not included in the services distinction but in the digitalization of the product. The categorization used is displayed in Table 17.

Table 17. Categorization of services surveyed in the EMS into the SSP/SSC typology

SSP	• Installation, start-up • Maintenance and repair • Revamping or modernization (incl. enhancement of functions, software extensions, etc.) • Take-back services (e.g. recycling, disposal, taking back) • Web-based offers for product utilization (online training, -documentation, error description) • Mobile devices for diagnosis, repair, or consultancy (e.g. digital camera, smartphone, tablets, etc.) • Renting products, machinery, or equipment • Full-service contracts with a defined scope to maintain your products
SSC	• Training • Remote support for clients (e.g. User Helpdesk, web platform) • Design, consulting, project planning (incl. R&D for customers) • Software development (e.g. software customization) • Web-based services for customized product configuration or product design • Data-based services based on big data analysis • Operation of your own products at customer site / for the customer • Taking over the management of maintenance activities for the customer • Contracting offers (supply of operating resources)

4.1.3. Types of Digital Technologies Employed

Within the EMS, digitalization is queried in two sections. On the one hand, the use of digital technologies as a product component is queried, and on the other hand, technologies related to production are evaluated. With regard to product digitalization, similar to the services, it is surveyed whether a certain technology is used or not. In a comparison between more technical products (NACE divisions 25 to 30) and other products, a clear difference can be seen in this area regarding the use of digital technologies in Table 18. All product digitalization elements are used significantly, at least at the $p < 0.05$ level, more often in technical products. Especially connectivity and sensors are more prevalent in these technical goods while interactive interfaces are still used rarely and tags for identification show a smaller but still significant difference.

Concerning back-end digitalization, for some elements, the EMS questionnaire not only queries the dichotomous (yes/no) information concerning the usage but also queries the extent to which the potential of the technologies is exploited. Therefore, questions in the area of production control, technologies for automation and robotics, and additive manufacturing technologies also contain a three-point scale indicating the exploited potential (low/medium/high). Viewing the descriptive statistics for this scale initially shows 63.5% missing values. By combining the dichotomous information on the usage of a certain digital technology and the extent to which the potential of this technology is used, a four-point scale (0-technology not used, 1 – low exploitation of potential, 2 – medium exploitation of potential, 3 – high exploitation of potential) is created. This scale increases the number of missing values from 6.2% to 7.6% but leads to a more detailed scale on the exploitation of the potential of digital technologies. Within the back-end digitalization, 9 out of 15 elements are more prevalent in the NACE divisions 25 to 30 at a significance level of at least $p < 0.05$. Taking a closer look at the different elements, technologies that can be used for more complex products, like digital prototyping, product lifecycle management, robotics, and additive manufacturing are more often used within the NACE divisions 25 to 30. Therefore, this distribution is as expected and the results support the focus on NACE divisions 25 to 30 for further analysis.

Table 18. Independent sample t-test for the digital technologies employed by companies inside and outside of NACE division 25-30.

(equal variances not assumed, ** p<.01 (two-tailed), * p<.05 (two-tailed))

Technology group	Digital Technology	NACE Divisions	N	Mean	Std. Deviation	Mean Difference
Technologies for production control (scale 0 – 3)	Mobile/wireless devices for programming and controlling facilities and machinery (e.g. tablets)	Not 25-30	427	0,721	1,0789	0,105
		25-30	323	0,616	0,9787	
	Digital solutions to provide drawings, work schedules, or work instructions directly on the shop floor	Not 25-30	423	0,818	1,1754	-0,430**
		25-30	318	1,248	1,2476	
	Software for production planning and scheduling (e.g. ERP system)	Not 25-30	422	1,308	1,3275	-0,441**
		25-30	315	1,749	1,2908	
	Digital Exchange of product/process data with suppliers/ customers (Electronic Data Interchange (EDI))	Not 25-30	412	0,871	1,1464	-0,084
		25-30	316	0,956	1,1971	
	Near real-time production control system (e.g. Systems of centralized operating and machine data acquisition, Manufacturing Execution System (MES))	Not 25-30	423	0,773	1,1501	0,028
		25-30	326	0,745	1,1474	
	Systems for automation and management of internal logistics (e.g. Warehouse management systems, RFID)	Not 25-30	431	0,571	1,0361	0,019
		25-30	321	0,551	1,0022	
	Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management	Not 25-30	285	0,298	0,7774	-0,147*
		25-30	285	0,446	0,9352	
	Virtual Reality or simulation for product design or product development (e.g. Finite element method (FEM), Digital Prototyping, computer models)	Not 25-30	431	0,39	0,882	-0,339**
		25-30	325	0,729	1,1388	
Technologies for automation and robotics (scale 0-3)	Industrial robots for manufacturing processes (e.g. welding, painting, cutting)	Not 25-30	440	0,416	0,9363	-0,385**
		25-30	321	0,801	1,1528	
	Industrial robots for handling processes (e.g. depositing, assembling, sorting, packing processes, automated guided vehicle (AGV))	Not 25-30	431	0,469	0,9781	-0,074
		25-30	326	0,543	1,0151	
Additive Manufacturing technologies (scale 0-3)	3D printing technologies for prototyping (prototypes, demonstration models, 0 series)	Not 25-30	430	0,142	0,4932	-0,303**
		25-30	328	0,445	0,9137	
	3D printing technologies for manufacturing of products, components and forms, tools, etc.)	Not 25-30	432	0,134	0,5057	-0,101*
		25-30	328	0,235	0,6794	
Flexible industrial robotic solutions (scale 0/1)	mobile industrial robots	Not 25-30	410	0,03	0,175	-0,01
		25-30	314	0,04	0,2	
	collaborating industrial robots (e.g. hand guided riveting robot)	Not 25-30	410	0,03	0,169	-0,07**
		25-30	314	0,1	0,299	
	autonomous industrial robots	Not 25-30	410	0,1	0,294	-0,07**
		25-30	314	0,17	0,372	
Digital elements in main product (scale 0/1)	Interactive interfaces with the operator (trimming, voice commands, data glasses, Virtual Reality/Augmented Reality (VR/AR))	Not 25-30	412	0,05	0,21	-0,04*
		25-30	338	0,09	0,293	
	Internet/network connection for automated data exchange (in real time)	Not 25-30	413	0,15	0,353	-0,21**
		25-30	337	0,36	0,48	
	Sensor technology, control elements for additional digital product functions	Not 25-30	410	0,1	0,304	-0,28**
		25-30	339	0,38	0,485	
	Identification tags (e.g. RFID, QR or bar codes)	Not 25-30	417	0,34	0,475	-0,1**
		25-30	336	0,44	0,497	

Concerning the typology used for this research, the elements from the questionnaire are grouped into the classification for digitalization developed in chapter 2.2.5 as shown in Table 19.

Table 19. Categorization of digital technologies surveyed in the EMS

Digitalization of Manufacturing	• Mobile/wireless devices for programming and controlling facilities and machinery (e.g. tablets) • Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor • Software for production planning and scheduling (e.g. ERP system) • Digital Exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI) • Near real-time production control system (e.g. systems of centralized operating and machine data acquisition, MES) • Systems for automation and management of internal logistics (e.g. warehouse management systems, RFID) • Industrial robots for manufacturing processes (e.g. welding, painting, cutting) • Industrial robots for handling processes (e.g. depositing, assembling, sorting, packing processes, AGV) • 3D printing technologies for manufacturing of products, components and forms, tools, etc.) • mobile industrial robots • collaborating industrial robots (e.g. hand guided riveting robot) • Autonomous industrial robots
Digitalization of Design & Development	• Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management • Virtual Reality or simulation for product design or product development (e.g. FEM, Digital Prototyping, computer models) • 3D printing technologies for prototyping (prototypes, demonstration models, 0 series)
Product Digitalization	• Interactive interfaces with the operator (trimming, voice commands, data glasses, VR/AR) • Internet/network connection for automated data exchange (in real time) • Sensor technology, control elements for additional digital product functions • Identification tags (e.g. RFID, QR or bar codes) • Digital (remote) monitoring of operating status (e.g. condition monitoring)

4.1.4. Indicators for Firm Performance

Within the EMS, manufacturers are asked to provide information on the annual turnover in the years 2015 and 2017, the number of employees in 2015 and 2017, and the profitability in terms of return on sales on a five-point scale (negative, 0 - 2%, > 2 - 5%, > 5 - 10%, > 10%). Based on this information it is possible to measure growth between 2015 and 2017 in terms of the number of employees and annual turnover. Furthermore, revenues per employee can be calculated as a measure of efficiency. Since turnovers and the number of employees are skewed, in the following the ln function of both is used to normalize the data. This transformation significantly reduces skewness.

Looking at the other performance indicators, clear outliers can be identified in terms of company growth (both in terms of revenue and the number of employees) and in terms of revenue per employee. While companies achieved a median revenue increase of 13.9% over two years, the highest value is a 1045-fold increase and the lowest value is an 80% reduction in revenue. The median for the increase in the number of employees was 6.7% while the lowest value represents a 91% reduction and the highest value represents a tenfold increase. The difference between the median and mean value for these performance indicators shows that there is a substantial influence of outliers which would influence the result of the PLS algorithm (Hair et al., 2017).

Table 20. Performance indicators before outlier analysis (n = 798)

		Return on sales 2017 (mil €)	**Revenue growth**	**Turnover in 2017 (ln function)**	**Number of employees in 2017 (ln function)**	**Growth in number of employees**	**Revenue per Employee in 2017 (mil € / employee)**
N	Valid	608	627	668	794	718	665
	Missing	190	171	130	4	80	133
Mean		3,2747	2,1701	2,0801	4,3821	0,147	0,1589
Median		3	0,1389	1,9879	4,1109	0,0667	0,1053
Std. Deviation		1,20756	42,19017	1,59717	1,10301	0,51113	0,23977
Skewness		-0,275	24,31	0,304	0,89	11,505	7,44
Kurtosis		-0,82	600,439	-0,033	0,377	174,454	80,564
Minimum		1	-0,8	-2,3	1,79	-0,91	0
Maximum		5	1045,51	7,31	8,4	9	3,57
Percentiles	25	2	0,022	0,9555	3,4965	0	0,0567
	50	3	0,1389	1,9879	4,1109	0,0667	0,1053
	75	4	0,2857	3,1088	5,118	0,177	0,1722

To reduce the impact of these extreme values, the resulting skew, and altered mean, outliers are removed by z-scoring. Therefore, z-scores are calculated for each indicator and cases with z-scores below -3 and above 3 (Aggarwal, 2017) are excluded. Thereby, 28 out of 798 cases are excluded and both skewness and kurtosis of performance indicators are reduced. Afterward, the indicators are filtered for the NACE divisions 25 to 30. By identifying outliers first and filtering subsequently, the number of excluded cases is lower. Otherwise, companies with comparably high but still comprehensible revenues per employee would have been excluded. Due to the robustness of the PLS algorithm to non-normal distribution (Cassel et al., 1999; Hair et al., 2019), the distribution of the proposed dependent variables, return on sales, revenue growth, and revenue per employee seem appropriate.

Table 21. Performance indicators after outlier analysis and filtering for NACE division 25 to 30 (n = 335)

		Return on sales 2017	**Revenue growth between 2015 and 2017**	**Revenue per Employee in 2017 in millions**
N	Valid	281	293	305
	Missing	54	42	30
Mean		3,3025	0,2091	0,1304
Median		3	0,1538	0,1029
Std. Deviation		1,19416	0,37482	0,1105
Skewness		-0,285	3,274	3,079
Kurtosis		-0,802	18,119	14,163
Minimum		1	-0,8	0,01
Maximum		5	2,75	0,87
Percentiles	25	2	0,0499	0,0636
	50	3	0,1538	0,1029
	75	4	0,303	0,1552

The resulting number of cases, n = 335, exceeds the estimation for the minimum number of cases required to identify effects of the size $R^2 = 0.1$ within a 95% confidence interval as described in chapter 3.3.

Table 22. Comparison of the effective sample with the initial sample

Indicator	Value (grouped)	Sample filtered for NACE divisions 25 to 30 and excluding outliers		Initial sample	
		N = 335		N =798	
Indicator	**Value (grouped)**	Cases	% of total	Cases	% of total
Number of Employees in 2017	Up to 24 employees	33	9,9%	84	10,5%
	25 - 49 employees	104	31,0%	254	31,8%
	50 - 249 employees	143	42,7%	333	41,7%
	250 - 999 employees	45	13,4%	101	12,7%
	1000 and more employees	9	2,7%	22	2,8%
	Missing values	1	0,3%	4	0,5%
Annual revenue in 2017	Below 2M € annual revenue	44	13,1%	126	15,8%
	2M € to below 5M € annual revenue	74	22,1%	140	17,5%
	5M € to below 10M € annual revenue	45	13,4%	117	14,7%
	10M € to below 50M € annual revenue	109	32,5%	194	24,3%
	50M € and above annual revenue	34	10,1%	91	11,4%
	Missing values	29	8,7%	130	16,3%
Age of the factory	< 5 years	10	3,0%	25	3,1%
	5 to below 10 years	18	5,4%	55	6,9%
	10 to below 20 years	79	23,6%	164	20,6%
	20 to below 50 years	148	44,2%	336	42,1%
	50 and above years	56	16,7%	159	19,9%
	Missing values	24	7,2%	59	7,4%
Country	Lithuania	44	13,1%	199	24,9%
	Slovenia	81	24,2%	127	15,9%
	Croatia	54	16,1%	105	13,2%
	Slovakia	56	16,7%	114	14,3%
	Austria	100	29,9%	253	31,7%
Multi-Site	No	210	62,7%	494	61,9%
	Yes	120	35,8%	290	36,3%
	Missing values	5	1,5%	14	1,8%

Regarding the composition of the effective sample, Table 22 displays the characteristics of the selected manufacturing companies in comparison to the initial sample. In terms of company size and age, filtering only slightly changes the composition of the sample. The most notable change occurs with respect to the country in which the company is located. Of the Lithuanian companies, only 44 out of 199 are in the selected industries, while in Slovenia 81 out of 127 are in the effective sample. Comparing this change with the contribution of the selected manufacturing industries (NACE division 25-30) to the total value added of the manufacturing industries of the respective countries (Eurostat, 2022), this shift is understandable.

4.2. Measurement Model

The structural equation model as displayed in Figure 10 is set up in SmartPLS (Ringle et al., 2015). According to the categorization of surveyed items into the typologies for digitalization and servitization, the constructs are built. The measurement model is analyzed using the PLS algorithm in SmartPLS. To account for missing values in some items, especially performance indicators, pairwise deletion is used to retain the highest amount of information.

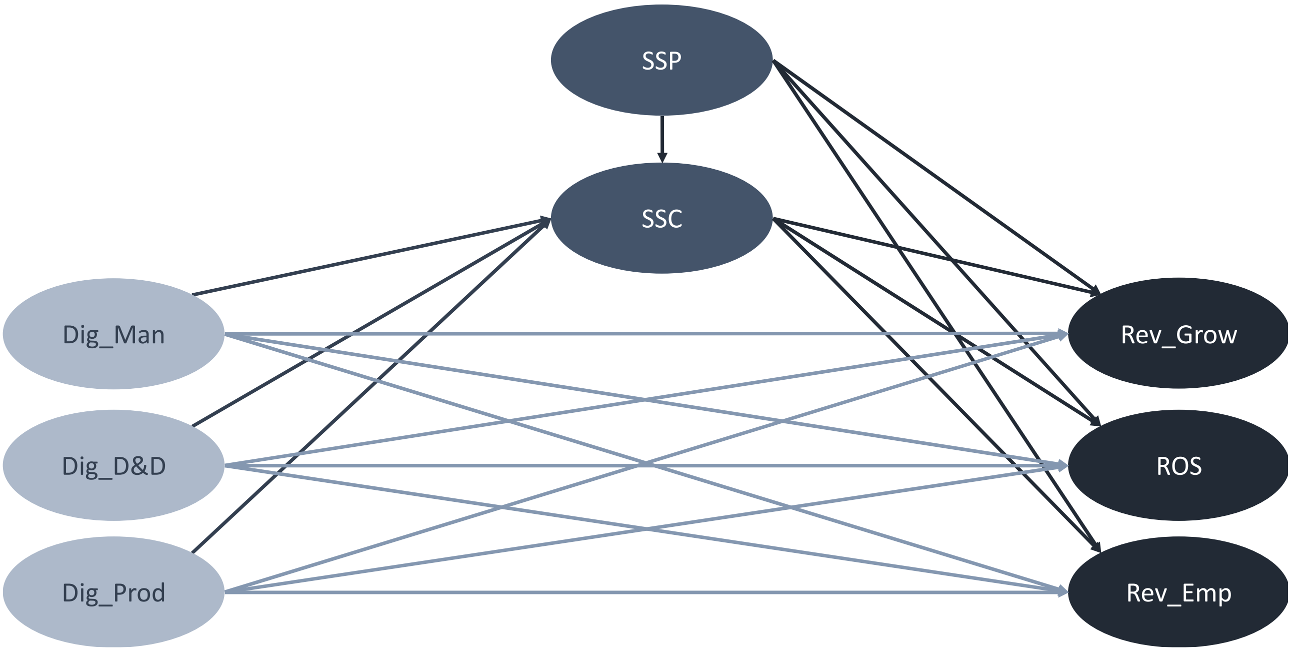

Figure 10. Structural model

(SSP: Services Supporting the Manufacturer's Product, SSC: Services Supporting the Customers' Process; Dig_Man: Digitalization of Manufacturing; Dig_D&D: Digitalization of Design & Development; Dig_Prod: Product Digitalization; Rev_Grow: Revenue Growth; ROS: Return on Sales; Rev_Emp: Revenues per Employee)

Since financial performance is measured through single indicator constructs, the following assessment does not apply to the constructs Revenue Growth (Rev_Grow), ROS (Return on Sales), and Rev_Emp (Revenue per Employee). Due to the use of secondary data and mostly dichotomous items, the initial loadings and construct reliability resulting from the PLS algorithm are not satisfactory. Therefore, the items assigned to the constructs are successively reduced by the items with the lowest loadings, taking content validity into account.

In Table 23 the resulting measurement model with the measures for internal consistency reliability and convergent validity are displayed. For content reliability reasons, the SSC *Taking over the management of maintenance activities for the customer* and the item *Product-Lifecycle-Management System (PLM)* in the Dig_D&D construct are kept despite their lower loadings. Since taking over functions of the customer is a key element in SSCs, maintenance management activities remain in the construct. Concerning the Dig_D&D construct, the slightly lower loading seems logical since the other two indicators are technologies that directly support the development process while PLM solutions rather act as an integrator of the development process into the manufacturing environment.

Table 23. Measurement model estimates

Construct	Item	Loading	AVE	Composite Reliability
Services Supporting the manufacturer's product (SSP)			0.659	0.853
	Installation, start-up	0.842		
	Maintenance and repair	0.824		
	Full-service contracts with a defined scope to maintain your products	0.766		
Services supporting the customers' process (SSC)			0.515	0.808
	Training	0.780		
	Remote support for clients(e.g. User Helpdesk, web platform)	0.727		
	Software development (e.g. software customization)	0.763		
	Taking over the management of maintenance activities for the customer	0.600		
Product Digitalization (Dig_Prod)			0.608	0.823
	Internet/network connection for automated data exchange (in real time)	0.739		
	Sensor technology, control elements for additional digital product functions	0.805		
	Digital (remote) monitoring of operating status (e.g. condition monitoring)	0.799		
Digitalization of Manufacturing (Dig_Man)			0.538	0.777
	Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor	0.705		
	Systems for automation and management of internal logistics (e.g. Warehouse management systems, RFID)	0.702		
	Software for production planning and scheduling (e.g. ERP system)	0.804		
Digitalization of Design & Development (Dig_D&D)			0.69	0.797
	Product-Lifecycle-Management-Systems (PLM) or Product/Process Data Management	0.682		
	3D printing technologies for prototyping (prototypes, demonstration models, 0 series)	0.761		
	Virtual Reality or simulation for product design or product development (e.g. FEM, Digital Prototyping, computer models)	0.844		

The integrative nature of PLM solutions is also part of the reason for a high but still acceptable HTMT ratio for the constructs Dig_D&D and Dig_Man as shown in Table 24. Among the other constructs, SSC and Dig_Prod also have a fairly high HTMT ratio, while still being below the threshold. Therefore, the measurement model is satisfactory and it is possible to proceed with the analysis of the structural model.

Table 24. HTMT ratio analysis

	Dig_D&D	Dig_Man	Dig_Prod	ROS	Rev_Emp	Rev_Grow	SSC	SSP
Dig_D&D								
Dig_Man	**0.90**							
Dig_Prod	0.37	0.41						
ROS	0.20	0.16	0.05					
Rev_Emp	0.07	0.30	0.07	0.13				
Rev_Grow	0.03	0.14	0.01	0.14	0.02			
SSC	0.48	0.38	**0.86**	0.14	0.11	0.04		
SSP	0.23	0.21	0.68	0.11	0.07	0.05	0.82	

4.3. Structural Model

Following the analysis of the measurement model, the structural model is examined in terms of multicollinearity, coefficient of determination (R^2), and the level and significance of the direct and indirect path coefficients as well as the total effects.

Multicollinearity is measured based on the inner VIF values obtained through the PLS algorithm. As shown in Table 25, the maximum value is 2 and is thus lower than the threshold of 3. Therefore, there are no multicollinearity problems in the structural model.

Table 25. Inner VIF values

	ROS	Rev_Emp	Rev_Grow	SSC
Dig_D&D	1.391	1.391	1.391	1.355
Dig_Man	1.369	1.369	1.369	1.368
Dig_Prod	1.715	1.715	1.715	1.410
SSC	2.001	2.001	2.001	
SSP	1.587	1.587	1.587	1.314

For further steps of the analysis, the bootstrapping algorithm of SmartPLS is used. Similar to the PLS algorithm, pairwise deletion for missing values is used to retain the highest amount of data. To minimize possible bias from sampling, 10,000 bootstraps are used. Bootstrapping is performed with the Bias-Corrected and Accelerated Bootstrap method. Table 26 displays the result of the R^2 calculation which indicates weak explanatory power for the performance indicators ROS and Rev_Emp. The explanatory power for revenue growth is not statistically significant. Due to the multitude of influence factors on financial performance, the size of R^2 is in the expected range. The explanatory power for SSCs is substantial, indicating that the exogenous constructs linked to SSCs describe a good degree of the variance in the offering of SSCs.

Table 26. R^2 analysis

	R^2	P Values (two-tailed)
ROS	0.078	0.030
Rev_Emp	0.068	0.035
Rev_Grow	0.022	0.353
SSC	0.500	0.000

Likewise, based on the bootstrapping algorithm, the path coefficients, as well as their significance, are calculated. The results displayed in Table 27 are obtained from the calculation and are analyzed in the following in comparison with the hypotheses proposed in chapter 2.4.

Table 27. Path coefficients and p-values for the structural model
(† p < .1 (two-tailed); * p < 0.05 (two-tailed); ** p < 0.01 (two-tailed))

	Path coefficient	Standard Deviation (STDEV)	P Values
Dig_D&D⇒ ROS	0.135†	0.078	0.084
Dig_D&D⇒ Rev_Emp	-0.107	0.071	0.136
Dig_D&D⇒ Rev_Grow	0.051	0.062	0.415
Dig_D&D⇒ SSC	0.134*	0.063	0.034
Dig_Man ⇒ ROS	0.047	0.076	0.535
Dig_Man ⇒ Rev_Emp	0.269**	0.069	0.000
Dig_Man ⇒ Rev_Grow	-0.084	0.085	0.322
Dig_Man ⇒ SSC	0.025	0.053	0.636
Dig_Prod ⇒ ROS	-0.107	0.080	0.178
Dig_Prod ⇒ Rev_Emp	-0.017	0.082	0.832
Dig_Prod ⇒ Rev_Grow	-0.131*	0.062	0.033
Dig_Prod ⇒ SSC	0.391**	0.054	0.000
SSC ⇒ ROS	0.243**	0.088	0.006
SSC ⇒ Rev_Emp	0.118	0.088	0.181
SSC ⇒ Rev_Grow	0.009	0.080	0.906
SSP ⇒ ROS	-0.213**	0.072	0.003
SSP ⇒ Rev_Emp	-0.092	0.066	0.162
SSP ⇒ Rev_Grow	0.106	0.091	0.244
SSP ⇒ SSC	0.371**	0.055	0.000

Besides the direct effects, also the indirect effects are calculated to obtain information on mediating effects. The result shown in Table 28 displays two significant indirect effects. Both the effects of Dig_Prod and SSP on profitability are mediated through SSCs. This is particularly interesting since SSPs have a negative direct effect on profitability and Dig_Prod, though not statistically significant, also seems to have a rather negative impact.

Table 28. Specific indirect effects and p-values for the structural model
(* p < 0.05 (two-tailed); ** p < 0.01 (two-tailed))

Path	Path coefficient	Standard Deviation (STDEV)	P Values
Dig_Man ⇒ SSC ⇒ Rev_Grow	0.000	0.005	0.9600
Dig_Man ⇒ SSC ⇒ Rev_Emp	0.003	0.008	0.7214
Dig_Man ⇒ SSC ⇒ ROS	0.006	0.013	0.6448
Dig_D&D ⇒ SSC ⇒ Rev_Grow	0.001	0.012	0.9175
Dig_D&D ⇒ SSC ⇒ Rev_Emp	0.016	0.016	0.3107
Dig_D&D ⇒ SSC ⇒ ROS	0.033	0.021	0.1184

Path			Path coefficient	Standard Deviation (STDEV)	P Values
Dig_Prod	⇒ SSC	⇒ Rev_Grow	0.004	0.031	0.9071
Dig_Prod	⇒ SSC	⇒ Rev_Emp	0.046	0.036	0.1999
Dig_Prod	⇒ SSC	⇒ ROS	0.095*	0.037	0.0109
SSP	⇒ SSC	⇒ Rev_Grow	0.003	0.030	0.9076
SSP	⇒ SSC	⇒ Rev_Emp	0.044	0.034	0.1986
SSP	⇒ SSC	⇒ ROS	0.090**	0.035	0.0096

Both the direct and indirect effects from the previous tables result in the total effects displayed in Table 29. Through both the direct and indirect effects, the total effect of Dig_D&D processes has a positive impact on profitability which is significant at the $p < 0.05$ level. Concerning SSPs, the negative direct impact on profitability and the positive indirect effect through SSCs lead to a total effect that is still negative but only significant at the $p < 0.1$ level. Similarly, the non-significant negative direct effect of Dig_Prod on profitability and the indirect positive effect lead to a total effect that is close to zero.

Table 29. Total effects and p-values for the structural model
(† p < .1 (two-tailed); * p < 0.05 (two-tailed); ** p < 0.01 (two-tailed))

	Total effect	Standard Deviation (STDEV)	P Values
Dig_D&D⇒ ROS	0.168*	0.079	0.035
Dig_D&D⇒ Rev_Emp	-0.091	0.070	0.192
Dig_D&D⇒ Rev_Grow	0.052	0.063	0.414
Dig_D&D⇒ SSC	0.134*	0.063	0.034
Dig_Man ⇒ ROS	0.053	0.076	0.486
Dig_Man ⇒ Rev_Emp	0.272**	0.069	0.000
Dig_Man ⇒ Rev_Grow	-0.084	0.085	0.322
Dig_Man ⇒ SSC	0.025	0.053	0.636
Dig_Prod ⇒ ROS	-0.012	0.072	0.864
Dig_Prod ⇒ Rev_Emp	0.029	0.065	0.661
Dig_Prod ⇒ Rev_Grow	-0.128*	0.062	0.039
Dig_Prod ⇒ SSC	0.391**	0.054	0.000
SSC ⇒ ROS	0.243**	0.088	0.006
SSC ⇒ Rev_Emp	0.118	0.088	0.181
SSC ⇒ Rev_Grow	0.009	0.080	0.906
SSP ⇒ ROS	-0.123†	0.068	0.071
SSP ⇒ Rev_Emp	-0.048	0.063	0.444
SSP ⇒ Rev_Grow	0.110	0.077	0.153
SSP ⇒ SSC	0.371**	0.055	0.000

Based on the direct, indirect, and total effects, the support for the hypotheses can be evaluated. Out of 10 hypothesized effects, five are supported at least at the $p < 0.05$ level while one further effect has only weak support at the $p < 0.1$ level. The results are summarized in Table 30.

Table 30. Comparison of results with hypothesized effects

Hypothesis No	Hypothesized effect		Result
1a	SSP↑	⇒ ROS↓	Hypothesis supported
1b	SSP↑	⇒ SSC ↑	Hypothesis supported
1c	SSP↑	⇒ Rev_Grow ↑	Hypothesis not supported
1d	SSP↑	⇒ SSC ↑ ⇒ ROS ↑	Hypothesis supported
2	SSC↑	⇒ ROS ↑	Hypothesis supported
3a	Dig_Man↑	⇒ Rev_Emp ↑	Hypothesis supported
3b	Dig_Man↑	⇒ ROS ↑	Hypothesis not supported
4a	Dig_D&D↑	⇒ ROS ↑	Hypothesis weakly supported ($p < .1$)
4b	Dig_D&D↑	⇒ SSC↑ ⇒ ROS ↑	Hypothesis not supported
5a	Dig_Prod ↑	⇒ ROS ↑	Hypothesis not supported
5b	Dig_Prod ↑	⇒ SSC↑ ⇒ ROS ↑	Hypothesis supported

Comparing the results of the PLS-SEM analysis with previous studies shows multiple similarities. The first hypothesis, which states that SSPs have a negative effect on profitability, was confirmed, making the result consistent with the findings from Sousa & Da Silveira (2017). Furthermore, SSPs are positively associated with SSCs, supporting the idea that companies build up service capabilities through SSPs and utilize them through SSCs. Through the mediation by SSCs, SSPs also have an indirect positive effect on profitability, which supports hypothesis 1d. Further effects of SSPs on performance indicators are not statistically significant, although they show comprehensible path coefficients. A positive effect on revenue growth as stated in hypothesis 1c is not found to be statistically significant and the non-significant negative path coefficient to revenues per employee could relate to the labor intensity of SSPs.

Concerning SSCs, a significant positive impact on profitability is found, which supports hypothesis 2. This effect, together with both the direct and mediated effect of SSPs is displayed in Figure 11. Further effects of SSCs on performance indicators show path coefficients that are not statistically significant. In contrast to SSPs, the effect of SSCs on revenues per employee has a positive yet not significant path coefficient. Relating this to the negative path coefficient found for SSPs, a difference in labor intensity seems logical. At the same time, the path coefficient from SSCs toward revenue growth is close to zero as shown in Figure 12.

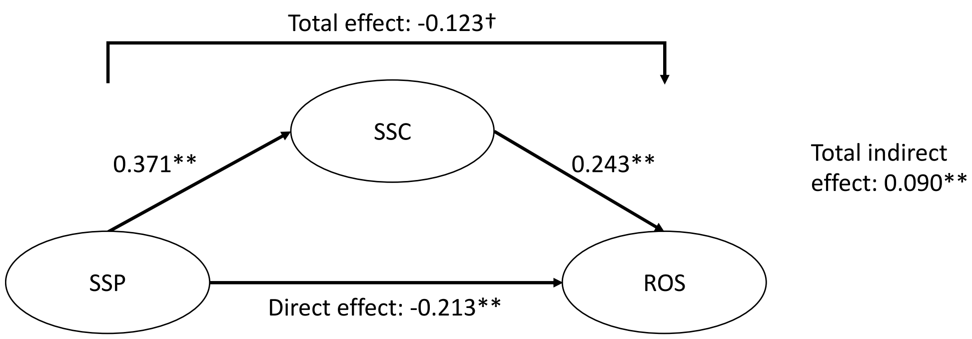

Figure 11. Effects of SSPs on ROS

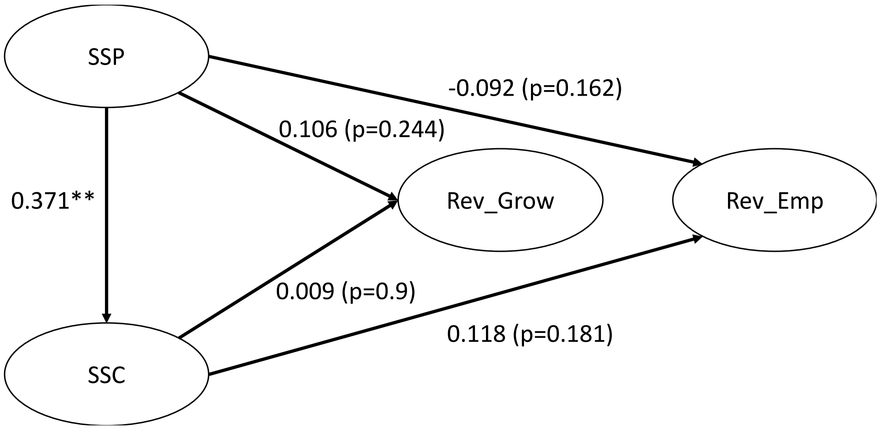

Figure 12. Effects of SSPs and SSCs on Rev_Grow and Rev_Emp

The use of digital technologies in manufacturing has a positive effect on efficiency in terms of revenues per employee and thereby supports hypothesis 3a. Nevertheless, no significant positive relation to profitability can be observed and hypothesis 3b is not supported. Further effects, for instance on company growth or the provision of services, cannot be identified either. Figure 13 shows the described total effects.

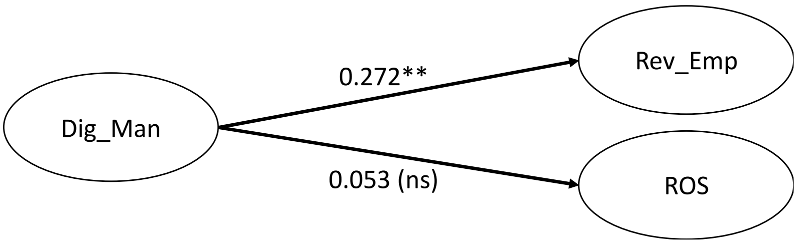

Figure 13. Total effects of Dig_Man on Rev_Emp and ROS

The use of digital technologies in design and development has a significant positive relationship with the delivery of SSCs. In terms of profitability, the direct path coefficient is also positive, but only significant at the $p < .1$ level. Thus, hypothesis 4a can be supported with limitations. Hypothesis 4b cannot be supported because although SSCs are positively influenced, the indirect effect on profitability mediated by SSCs is not significant as shown in Figure 14. No other statistically significant effects outside the hypotheses can be identified for the digitalization of design and development.

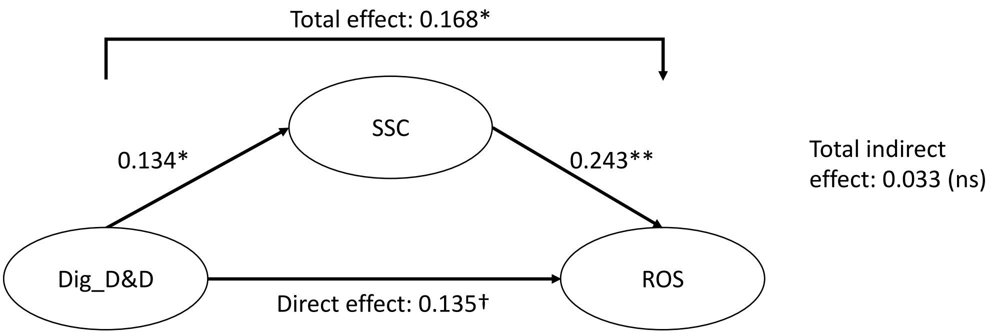

Figure 14. Effects of Dig_D&D on ROS

According to hypothesis 5b, the digitalization of the product has a significant positive effect on SSCs. This is also accompanied by a significantly positive indirect effect on profitability. The direct effect on profitability has a negative path coefficient that is not statistically significant, which means that hypothesis 5a cannot be supported. The effects are displayed in Figure 15. Outside the hypothesized effects, there is a statistically significant negative effect on revenue growth.

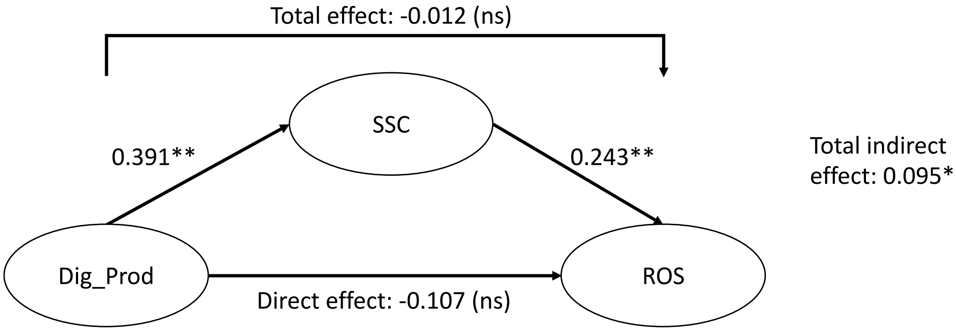

Figure 15. Effects of Dig_Prod on ROS

4.4. Discussion and Recommendations

Regarding the services investigated, the analyses carried out show comparable results to previous studies. SSPs, which tend to require fewer additional capabilities alongside existing production capabilities, can be difficult to transform into a defensible competitive advantage, which is evident from a negative impact on profitability as identified according to hypothesis 1a. Similar to the results found by Eggert et al. (2014) and Sousa & Da Silveira (2017), a broader SSP portfolio increases the breadth of the SSC portfolio. The SSCs in turn have a positive effect on company profitability, which corresponds with previous studies (Kohtamäki et al., 2020; Sousa & da Silveira, 2017; Zhou et al., 2021). The most interesting effect, viewing only the services, is that SSPs have a negative direct effect on profitability but a positive indirect effect which is mediated through SSCs. This effect can be related to the servitization paradox as mentioned by Gebauer (2005) and Brax (2005). Previous studies have shown how manufacturing companies build new capabilities and closer customer relationships through the introduction of SSPs. Companies can leverage these to build a competitive advantage and market through more profitable SSCs. Brax et al. (2021) therefore also referred to the servitization paradox as a transformation paradox, as companies make necessary investments in building capabilities and resources through SSPs. By differentiating performance indicators, the effect can be shown more precisely. Profitability in particular is affected by the servitization paradox, while companies are still able to grow revenues with SSPs, although this effect could not be shown to be statistically significant.

Concerning the hypotheses on digitalization, the statistical support is slightly weaker. As expected, digital technologies in manufacturing increase revenue per employee, as fewer employees are needed for the same work steps and tasks are performed more effectively. However, the hypothesis that this is also accompanied by an increase in profitability cannot be proven. One possible explanation for this could be that digitalization of manufacturing has been implemented to a certain degree by most manufacturers and therefore contributes to remaining competitive but does not generate a competitive advantage. This is also supported by the fact that the mean values for the items of the digitalization of manufacturing construct are high compared to other items as displayed in Table 18. Regarding digital servitization, as expected, no interaction was found between the digitalization of manufacturing and services.

At the same time, however, SSCs are positively influenced by the digitalization of design and development processes, which is consistent with the influence of design-to-service capabilities as described by Ulaga & Reinartz (2011) or integrated design capabilities according to Meier et al. (2010). Although the influence on the SSC portfolio is positive and significant, the indirect, mediated effect on profitability is not significant. Instead, the direct effect on profitability can be demonstrated, suggesting that the digitalization of design and development processes has an impact on profitability through further mechanisms, presumably through superior products.

For the digitalization of the product, the evaluation shows a rather negative direct effect on company performance. Both the path coefficients towards profitability and revenue growth are negative, with only the effect on revenue growth being statistically significant. This suggests that the product itself does not create substantial added value from the addition of digital components, connectivity, control, and monitoring. Instead, the digitalization of the product has a strong correlation with the provision of SSCs, which in turn lead to a positive mediated effect on profitability. Therefore, for digitally enabled products, it can be inferred that SSCs can be used to capture value from products equipped with digital technologies. The results support the suggestion of Chen et al. (2021) that manufacturers with experience in delivering advanced services can better derive value from product digitalization by providing smart solutions. Furthermore, these identified effects showcase the digitalization paradox. Investing in digital technologies to enhance the product leads to lower revenues (Gebauer et al., 2020). Interestingly, the performance impact differs from the impact of the servitization paradox. While in servitization, the main impact is on profitability, digitalization has a weaker impact on both profitability and revenue growth. While SSPs seem to generate an additional revenue stream, digitalized products might substitute previous offerings. Through SSCs as a way of capturing value from the possibilities the digital technologies offer, profitability can be increased again.

4.4.1. Recommendations

The recommendations for companies engaging in servitization and digitalization that can be derived from the results are twofold. Viewing only services, the effect of the servitization paradox becomes visible. Similar to case studies (Brax, 2005) describing challenges manufacturers face while increasing their service offerings, this quantitative analysis shows the negative profitability impact of SSPs, which most often are the first services introduced by manufacturers. Therefore, manufacturers need to carefully align their servitization strategy with their financial performance expectations. To differentiate from the competition and thus also increase profitability, the development of new service-related capabilities and the use of these capabilities in SSCs is necessary. Brax et al. (2021) find that tactically driven servitization, which leads to the offering of services but is not a commitment to transform the company into a service provider, leads to relatively low financial performance. Therefore, a company should decide whether it is ready to transform itself into a service provider or offer services through specialized partners and focus on leveraging manufacturing-related capabilities.

Viewing the context of digitalization, it becomes apparent that companies might encounter a digitalization paradox as described by Gebauer et al. (2020). Especially product digitalization does not seem to benefit company financial performance directly. Instead, the results suggest that its positive effect on profitability is mediated through SSCs. In this case, the digitalization paradox seems to differ from the servitization paradox in the way it affects company performance. While the servitization paradox mostly influences profitability, the digitalization paradox seems to materialize in companies not achieving revenue growth while also not improving profitability. Still, utilizing insights into the product usage and the ability to adapt the product functionality through software gives the manufacturer access to a valuable, rare, and hard to imitate resource. To leverage this resource and capture value from product digitalization, sophisticated services that turn this into a sustainable competitive advantage through organization can play a key role. Drawing on the insights on the relationship between advanced services and front-end digitalization from Kohtamäki et al. (2020), the same effect seems to be true for moderate or high levels of front-end digitalization.

Combining both the insights on servitization and digitalization, it can be deduced that manufacturers engaging in the digitalization of their products should have a service organization in place that has sufficient capabilities to capture value from the opportunities that digitalization in the form of smart products offers. Since servitization takes a more evolutionary path than digitalization, setting up the necessary organizational structures for delivering services needs to be done early on. Furthermore, companies need to be aware of the investments that are necessary for the transformation that accompanies both servitization and digitalization. Due to the profitability implications of the necessary transformation for servitization and the substantial investments into digitalization, a company should have access to sufficient financial resources.

4.4.2. Constraints and Directions for Further Research

While the results give granular insights from manufacturing companies across different European countries, this study has certain limitations. Since especially servitization is an evolutionary process, it would be beneficial to perform a longitudinal study to evaluate how the implementation of new services and new digital technologies interact and how the impact on financial performance unfolds over time. For instance, with a focus on servitization, a latent growth curve modeling approach has been used by Eggert et al. (2014).

Furthermore, this study is focused on an industry with rather technical products instead of across all manufacturing industries. This is related to the available secondary information from the EMS and the types of services included in the questionnaire. To expand this research across more industries, the service constructs should be adapted and also evaluate the applicability of certain services for certain industries – for example, maintenance and repair are hardly applicable for non-technical food and beverage products. Additionally, this study is based on the breadth of the service portfolio but does not take into account the actual share of revenue generated through the services and the profitability of only the service business, which could give more insights into how well the companies leverage their service capabilities.

In terms of digitalization, this study provides a more granular model than used in most previous research. To fully utilize this granularity, it would be beneficial to enhance the EMS data set by information on front-end digitalization, such as the use of CRM systems, communication technology, and service platforms, as done by Kohtamäki et al. (2020).

An interesting finding and possible avenue for further research is the difference in performance implications between the servitization and digitalization paradox. Through viewing these paradoxes while considering the multi-dimensionality of company financial performance, the results suggest that servitization rather impacts profitability and makes it necessary for the organization to adapt to delivering services rather than pure products while digitalization of the products leads to the need to find new methods to generate revenues and capture value from the adapted value proposition. Therefore, research on the similarities, differences, and interplay of both paradoxes could lead to further guidance for companies engaging in servitization and digitalization.

Conclusion

1. **In the course of the systematic literature analysis, diverse typologies were identified for both servitization and digitalization to examine the interrelationships with various phenomena. However, in the intersection of these areas, digital servitization, only generalized typologies have been used or individual aspects have been investigated. At the same time, previous studies show contradictory results with regard to the impact on company performance, which is partly due to different measurements of company performance.**

To summarize the role of servitization in the relationship between digitalization and firms' financial performance, both qualitative and quantitative studies on the relationship between servitization and digitalization were analyzed.

Research on servitization frequently shows an evolutionary development of services within manufacturing companies. Initially, companies offer services that are closely related to the product and production capabilities, for example, repair and maintenance services. From that point, companies eventually move towards the provision of more sophisticated services. Thereby, the underlying classification of services differs between different research streams. Furthermore, researchers find a servitization paradox, in which companies do not achieve expected returns for their investment into services after initial servitization efforts were successful.

Concerning digitalization, most researchers do not differentiate between different levels of sophistication, but between either the digitalization of different elements of the business model or different digital technologies employed. Similar to servitization, companies might face a digitalization paradox, in which the company does not achieve expected returns for major investments in digitalization after initial efforts have proven successful. In contrast to servitization, the organizational change initiated through digitalization is quicker and more radical.

Concerning the impact of servitization on the effect of digitalization on financial performance, previous quantitative studies view servitization either as a moderator or a mediator. Similarly, qualitative research describes cases in which companies develop new services to make use of digital technologies. Quantitative studies investigating the relationship between digitalization and servitization mostly view servitization and digitalization as a general construct without subdividing these further. Often, they consider only a certain category of services or digitalization.

Since studies on servitization find that manufacturing companies build additional capabilities through service delivery that are used in sophisticated services, and studies on digitalization conclude that complementary capabilities are needed to create value from digital technologies, the role of servitization in the relationship of digitalization and financial performance can be seen as a mediator.

2. **The designed research model integrates constructs from research on the individual fields of digitalization as well as servitization and different dimensions of company financial performance. Therefore, the developed model allows both a more precise view of the phenomenon of digital servitization and a differentiated consideration of effects on company financial performance.**

To create a holistic model for the quantitative assessment of the digitalization of companies, this thesis compared and integrated different approaches to digitalization. The research publications analyzed include papers dealing with digitalization in the context of Industry 4.0, solution business models, technologies supporting servitization, and dynamic capabilities. Since the most prevalent definition for digitalization in research publications concerning digital servitization highlights the transformation of elements of the business model, the framework of solution business models is used and enhanced through further typologies. The resulting constructs for digitalization distinguish between digitalization in the back-end of the company, digitalization in the front-end of the company, and product digitalization. Within the back-end, a further subdivision differentiates between digitalization supporting product development and digitalization supporting manufacturing.

A common theme in most publications on servitization is a division between services that are easier to deliver and more advanced services. This differentiation is, for instance, based on the necessary capability, the relatedness to the product, or the value proposition of the service. Within most quantitative studies, services are either grouped into services supporting the product and services supporting the customer's process or basic and advanced services. Since the later typology is used differently by different researchers, the naming of the first one is seen as more unambiguous and therefore is used within this thesis. In several previous studies, these typologies have been referred to as approximately synonymous, which makes the results transferable.

In terms of measuring performance, there is a difference between studies that assess performance using financial ratios and studies that assess performance using a single construct based on, for example, self-assessment items on a Likert scale. The use of financial ratios allows the identification of influences on different dimensions of corporate financial performance. This is advantageous, for example, if an influencing factor has a positive effect on revenues but a negative effect on profitability.

3. **A quantitative research methodology using PLS-SEM allows analyzing secondary data from a multinational survey on European manufacturing companies and investigating single-item performance constructs.**

The rationale of the methodology that allows testing the role of servitization in the relationship between digitization and financial performance was based on the available data as well as the previously selected constructs. Since the available dataset from the EMS is secondary data, not specifically tailored to fit the scales developed for the measurement of servitization and digitalization, and the dependent variables are single-item constructs, PLS-SEM is a more suitable methodological approach than CB-SEM.

A further finding concerning the methodological approach for the measurement of digitalization and servitization is the lack of applicability of certain scale items for different industries. Since technical services and digital elements in products are mostly applicable to technical goods, this thesis focuses on technical goods by limiting the cases to companies from the industry groups described by NACE divisions 25 to 30. For further quantitative research, this means that scales should be created that take into account the different services and digital elements that are usable in different industries to extend the meaningfulness of the results to a broader range of companies.

4. **The study shows that in order to successfully capture value from the digitalization of their products, manufacturing companies need to have experience in service provision. Servitization and digitalization both pose challenges to companies. SSPs tend to have lower profitability and product digitalization does not directly lead to revenue growth. Simultaneously, SSPs as well as product digitalization have a positive mediated effect on profitability through SSCs. Thus, the study results imply that the development of SSCs can serve to overcome both the digitalization and servitization paradox, leading to the recommendation that companies should align their digitalization and servitization strategy.**

To identify the role of servitization in the relationship of digitalization and financial performance of manufacturing companies, a dataset from 335 European manufacturing companies from the industries described by NACE divisions 25 to 30 was analyzed based on the previously described constructs and using SmartPLS for the PLS-SEM analysis. Viewing the individual effects of servitization and digitalization, results from previous studies, such as the servitization paradox, the effect of SSPs on SSCs, as well as the positive impact of digitalized manufacturing on efficiency, could be replicated.

In terms of the complete structural model, the obtained results highlight the interrelation between servitization and the digitalization of certain elements of the business model. While the digitalization of manufacturing has no relationship to SSCs, the digitalization of design and development processes positively influences the offering of SSCs. This effect can be related to design-to-service capabilities that are, for example, supported through collaborative tools for development. While also the effect of SSCs on profitability is positive, a mediating effect of SSCs on the effect of digitalization of design and development on profitability could not be established.

The most interesting relationship found within this research is the mediating effect of SSCs on the effect of product digitalization on profitability. While the direct effect of product digitalization on profitability is negative yet non-significant, the effect mediated through SSCs is positive. In combination with a negative direct effect of product digitalization on revenue growth, this leads to the conclusion that companies face the digitalization paradox while digitalizing products and can overcome this paradox by offering SSCs to utilize the potential created through digital technologies in their products. Since the capabilities to deliver SSCs also need to be developed, for instance, through providing SSPs, the pathways a company takes for digitalization and servitization need to be aligned to build up the necessary service capabilities to utilize the resources created through digital technologies. Specifically, this translates into the recommendation that companies should first build basic service capabilities and closer customer relationships through SSPs before digitalizing products. Through SSCs, the added value created by the digitalization of products can then be leveraged.

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