Journal of Infrastructure, Policy and Development 2024, 8(6), 5191.
https://doi.org/10.24294/jipd.v8i6.5191

Article

Servitization and digital integration of manufacturing enterprises in China: Performance and strategic paths

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CITATION

Huang Q, Kumarasinghe PJ. (2024). Servitization and digital integration of manufacturing enterprises in China: Performance and strategic paths. Journal of Infrastructure, Policy and Development. 8(6): 5191. https://doi.org/10.24294/jipd.v8i6.5191

ARTICLE INFO

Received: 13 March 2024
Accepted: 7 April 2024
Available online: 4 June 2024

Abstract: The integration of digitalization and servitization has become a significant trend in transforming the manufacturing industry due to digital intelligence technology. This paper examines the impact of the integration of digitalization and servitization on the performance of manufacturing companies and how small-scale enterprises can promote digital transformation leading to servitization. The study involved surveying 331 manufacturing companies in China using a seven-point Likert scale questionnaire. Measurement scales were validated using confirmatory factor analysis and discriminant validity tests. Mediation analysis assessed digitalization's impact on servitization and firm performance. The study's findings emphasize the significant impact of digitalization and servitization on enterprises' performance. Digitalization plays a crucial role in mediating this relationship. The study highlights three critical dimensions of digital variables, including digital technology, digital labor, and digital relationship resources, essential in enabling effective servitization. Manufacturing enterprises generally prefer aligning their technology investments and organizational changes within the digitalization framework to implement servitization successfully. The study suggests two integration strategies, namely conservative and aggressive. The finding emphasizes that the convergence of digitalization and servitization leads to a new manufacturing production mode called digital servitization.

Keywords: manufacturing servitization; digitalization; digital servitization; digital transformation

1. Introduction

The manufacturing industry worldwide is transitioning towards servitization, offering services alongside products. This trend extends beyond large-scale industrial equipment and facility manufacturing for businesses or Business-to-Business (B2B). However, even consumer goods manufacturing for individuals or Manufacturer to Customer (M2C) is transforming providing services due to the internet. Servitization, the strategic shift from traditional product-centric business models to service-oriented approaches, has emerged as a key strategy for manufacturers to enhance competitiveness, generate additional revenue streams, and foster long-term customer relationships (Kumar and Sharma, 2024; Mastrogiacomo et al., 2019). The combination of servitization and digitalization offers significant opportunities for manufacturing firms to provide value-added services, stand out from competitors, and adjust to evolving customer preferences (Gebauer et al., 2021). Manufacturers can better meet customer needs and improve satisfaction by offering comprehensive solutions that include physical products and complementary services. Digitalization has become essential for manufacturing enterprises aiming to succeed in today's fast-paced market. Digitalization not only enables manufacturers to deliver services more

efficiently and effectively but also facilitates the development of new service-based business models and revenue streams (Baines et al., 2020). However, there are still challenges, such as a lack of capacity and motivation for servitization. Combining servitization and digitalization is a critical strategy for driving high-quality manufacturing development (Liu et al., 2022; Martín-Peña et al., 2019). This study explores the experiences, mechanisms, and solutions to integrating servitization and digitalization in the manufacturing industry of Zhejiang Province in China.

Theoretically, the study advances industrial digitalization research by offering a fresh perspective: a digitalization-centric examination of manufacturing servitization. On a practical level, the study investigates the combined impact of 'servitization and digitalization' on Zhejiang's manufacturing sector in China. The study aims to fill a research gap by examining how Chinese manufacturing enterprises can integrate servitization and digitalization to foster high-quality manufacturing development and achieve the goals of the digital economy. Despite the growing body of literature on servitization and digitalization individually, comprehensive research still needs to examine their intersection within the context of Chinese manufacturing firms. Specifically, previous studies have often focused on either servitization or digitalization in isolation, overlooking the synergistic effects of their combined implementation. By filling this gap, our study seeks to shed light on the complex dynamics between servitization and digitalization, providing valuable insights into their joint impact on organizational performance.

The objectives of this study are as follows:

1) To examine how well servitization and digitalization are integrated within Chinese manufacturing enterprises.
2) To assess the impact of digital servitization on the financial performance of manufacturing firms.
3) To identify the strategic approaches manufacturing enterprises adopt to leverage the synergies between servitization and digitalization.

Thus, this study consolidates the successful experiences of exemplary companies in Zhejiang, China, that have achieved deep integration between the manufacturing and service sectors. Such insights are instrumental in identifying optimal entry points and focal areas for formulating scientifically grounded industrial policies conducive to manufacturing's service-oriented evolution. Further, the study underscores the importance of incorporating managerial implications derived from research findings into strategic decision-making processes within manufacturing enterprises. These implications guide how to use digitalization and servitization to improve competitiveness and performance, bridging the gap between theory and practice for managers.

2. Literature review

The term 'servitization' was first introduced in 1988 by Vandermerve and Rada (1988). It refers to transforming the manufacturing industry from simply producing goods to offering services and products, also known as the 'Service Pack' transformation. There are two types of servitization—input servitization and output servitization. Input servitization involves using the output of the service industry as an

intermediate input in the manufacturing industry. In contrast, output servitization refers to the actual transformation of the manufacturing industry to provide services to customers. The introduction of digital servitization has brought about a convergence of perspectives from both digitalization and servitization paradigms, emphasizing the need for an integrated approach (Gebauer et al., 2021). Recent literature highlights the significance of understanding critical dimensions for implementing Industry 4.0 in Small and Medium-sized Enterprises (SMEs), emphasizing the importance of taxonomy studies in this context (Kumar and Sharma, 2022). Moreover, exploring research issues and potential future directions in Industry 4.0 adoption among SMEs provides valuable insights into the challenges and opportunities associated with this transformative process (Kumar and Sharma, 2023). The integration of digitalization and servitization often referred to as "digital servitization," has emerged as a significant trend in transforming the manufacturing industry. Gebauer et al. (2021) argue that digital servitization represents a convergence of two megatrends: digitalization and servitization. They highlight the role of digital technologies in expanding the service business of traditional product-oriented companies, thereby enabling effective servitization. This aligns with our study's focus on the intersection of servitization and digitalization within Chinese manufacturing enterprises.

Studies have also examined the interdependencies among solution dimensions for sustainable development in SMEs within the framework of Industry 4.0, underscoring the need for a holistic approach to address complex challenges (Kumar and Sharma, 2024). Additionally, the state-of-the-art review on smart manufacturing and Industry 4.0 elucidates these transformative technologies' current landscape and prospects, emphasizing the need for comprehensive understanding and strategic implementation (Kumar et al., 2023). This supports our objective of examining how well servitization and digitalization are integrated within Chinese manufacturing enterprises.

Table 1. Research on the servitization of manufacturing and scholars.

Topics	Details	Primary literature
Evolution of servitization	Evolution is divided into three categories based on the type of service provided-product extension service, functional service, and overall solution.	(Brax and Visintin, 2017; Davies, 2004; Kowalkowski et al., 2011; Vandermerwe and Rada, 1988)
Impact of environmental factors on transformation of servitization	Environmental factors are divided into two subcategories: internal and external. Internal factors include the complexity of product structure, human resources status, corporate culture, and organizational skills. External factors include network relationships, industry technology changes, and market dynamics.	(Alvarez et al., 2015; Ayala et al., 2017; Baines, 2015; Bastl et al., 2012; Benedettini et al., 2015; Demeter and Szász, 2013; Feng and Sivakumar, 2016; Gebauer et al., 2010; Laine et al., 2012; Lenka et al., 2017; Mennens et al., 2018; Saccani et al., 2014; Santamaría et al., 2012; Shah et al., 2020; Valtakoski, 2017)
Process changes and development of servitization	Process changes and development include determining the organizational structure based on the manufacturing servitization strategy, optimizing resources and building capabilities, and building a manufacturing service ecology with platform-based thinking.	(Alvarez et al., 2015; Baines et al., 2011, 2020; Bandinelli and Gamberi, 2012; Bastl et al., 2012; Brax, 2005; Cenamor et al., 2017; Kohtamäki et al., 2020; Lafuente et al., 2017; Lightfoot et al., 2013; Oliva and Kallenberg, 2003; Qi et al., 2020; Rabetino et al., 2017; Tan et al., 2019)
Performance impact of servitization	There are different views on the performance impact of servitization. Most believe it can improve manufacturing enterprises' sustainable growth and customer asset management. However, some believe there is a 'servitization dilemma,' and others suggest a more complex 'U' shape.	(Bustinza et al., 2015; Hu et al., 2021; Kastalli and Van Looy, 2013; Martín-Peña et al., 2019; Zhou et al., 2020)

Scholars have studied the various aspects of manufacturing servitization, including mode types, environmental factors, process changes, and performance impacts. **Table 1** shows the main content and representative research of the field.

2.1. Research on the digitalization of manufacturing

Research on digitalization in manufacturing traces back to the 1950s. It is broadly divided into two perspectives: technical and organizational society. The technical perspective focuses on applying digital technology in manufacturing processes, with research topics including networked manufacturing, intelligent manufacturing, and digital factories (Arica and Powell, 2021). However, challenges persist, with only 20% of companies benefiting from digital transformation. The failure of digitalization often stems from a fundamental misunderstanding of its nature, emphasizing the need for organizational and social systems alignment (Tanaka, 2007). Research from the organizational society perspective explores how organizations integrate digital technologies, such as information systems and workshop management, to drive change. Recent studies extend to the impact of digitalization on business model innovation, introducing concepts like the Industrial Internet and Industry 4.0 (Bouwman et al., 2019). Overall, manufacturing digitalization entails the deep integration of new information technology and advanced manufacturing technology across the entire life cycle of design, manufacturing, and service.

The literature review provides a broad overview of research on digitalization in manufacturing, spanning technical and organizational perspectives. It highlights the challenges and evolving trends in the field, laying the groundwork for the study's focus on integrating digital technologies and servitization in manufacturing enterprises.

2.2. Research on servitization and digitalization of manufacturing

Baines et al. (2020) suggest that digitalization is pivotal in the servitization of the manufacturing industry, enabling the embedding of digital technology into product-service systems. Manufacturing companies are transforming into servitization. They utilize data from complex equipment for predictive maintenance and other services. These services include real-time monitoring, performance optimization, equipment troubleshooting, remote assistance, lifecycle management, and customized solutions tailored to meet customer requirements (Kowalkowski et al., 2017; Luz Martín-Peña et al., 2018; Arica and Powell, 2021). Moreover, data monetization has become increasingly prevalent within manufacturing enterprises, resulting in the emergence of 'data reuse' as a substantial opportunity for advancing servitization efforts. Digitalization also enhances the success of servitization initiatives by expanding service networks, increasing resource mobility, and enabling innovative business models to address the 'service-oriented dilemma.' The integration of digitalization and servitization is viewed as cutting-edge practice in the manufacturing industry, with digital servitization potentially reshaping production modes in the digital age. However, further clarification on digitalization and servitization is needed (Rakic et al., 2023; Chen et al., 2023).

The current literature on manufacturing servitization needs an exploration of the

internal mechanisms governing key resources and capacity development, necessitating further research to elucidate how firms can effectively leverage digital technology to enhance outcomes. Bridging this gap is crucial for advancing our understanding of manufacturing servitization and providing actionable insights for practitioners.

This literature underscores the intricate relationship between servitization, digitalization, and business performance in the manufacturing sector, emphasizing the need to comprehend their intersection and impact on organizational outcomes. In light of this understanding, we have formulated three hypotheses aimed at elucidating the influence of servitization and digitalization on firm performance, specifically focusing on the mediating role of digitalization. Through empirical research, we endeavor to validate and refine our comprehension of these intricate dynamics, offering valuable insights for manufacturing enterprises navigating the evolving landscape of servitization and digital integration.

2.3. Exploring the interplay between servitization, digitalization, and enterprise performance

Servitization is an effective strategy for manufacturing enterprises to evolve and improve performance. Research suggests that servitization positively impacts firm performance through various pathways. Firstly, it addresses customer needs by offering integrated solutions and attracting more users (Jang et al., 2021; Kamalaldin et al., 2020). Secondly, it diversifies revenue sources and ensures sustained income, with service business units often yielding higher profit margins than product sales (Baines et al., 2013). Additionally, servitization fosters long-term customer relationships, shifting from one-time transactions to continuous service-based revenue streams, enhancing financial stability. Customized services can help companies differentiate themselves from competitors, reducing business volatility from a competitive standpoint (Jankovic-Zugic et al., 2023). Moreover, continuous service relationships enable manufacturers to innovate by gathering insights into customer needs (Bettiol et al., 2022). Thus, we proposed Hypothesis 1 to investigate the relationship between servitization and firm performance.

Hypothesis 1 (H_1) posits that servitization significantly influences firm performance.

Concurrently, digitalization is crucial in driving organizational transformation and enhancing business performance. It encompasses digital technology resources, digital labor resources, and digital relationship resources. Digital technology resources involve investments in interactive, process, and basic digital technologies, collectively impacting enterprise performance (Bettiol et al., 2022; Huang et al., 2023; Jang et al., 2021). Digital labor resources emphasize the importance of human-machine collaboration and efficient management practices (Dou et al., 2023). Additionally, digital relationship resources involve reimagining internal and external organizational relationships, fostering synergy between humans and machines, and creating ecosystems that transcend traditional boundaries (Morrison-Smith and Ruiz, 2020). We proposed Hypothesis 2 to examine the relationship between digitalization and business performance.

Hypothesis 2 (H_2) proposes that digitalization significantly affects firm

performance.

While servitization enhances performance, it may encounter challenges, such as resource conflicts and mismatches between supply and demand, leading to performance declines (Kowalkowski et al., 2017; Struwe and Slepniov, 2023). However, digitalization mitigates these challenges by enabling the design of state-of-the-art services, reducing service costs, and enhancing resource utilization efficiency (Luz Martín-Peña et al., 2018; Stanko and Allen, 2022). Additionally, digital platforms also enable greater value co-creation and user participation in the value-creation process (Abou-Foul et al., 2023; Kamalaldin et al., 2020; Vendrell-Herrero et al., 2022).

Hypothesis 3 (H_3) suggests that digitalization mediates the relationship between servitization and firm performance.

The framework, depicted in **Figure 1**, elucidates the complex interplay among servitization, digitalization, and business performance within manufacturing enterprises. It emphasizes the importance of understanding how these factors intersect and influence organizational outcomes.

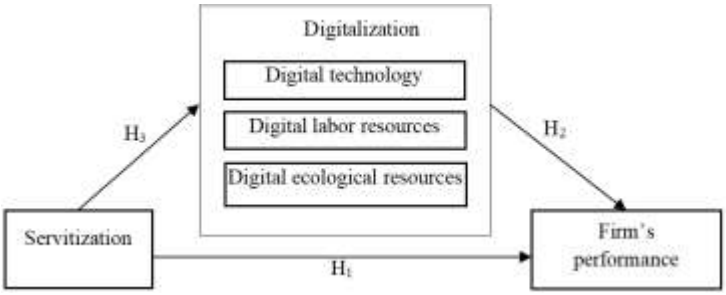

Figure 1. Conceptual model of the convergence effect of servitization and digitalization.

We identified digital technology, digital labor resources, and digital ecological resources as critical aspects for analyzing digitalization due to their key roles in shaping the manufacturing enterprise's digital landscape (Bouwman et al., 2019; Luz Martín-Peña et al., 2018; Ayala et al., 2017). Digital technology encompasses the technological infrastructure and tools organizations utilize, representing the foundation for digital transformations. Digital labor resources highlight the human capital aspect, focusing on the skills, capabilities, and workforce composition necessary for effective digitalization initiatives. Finally, digital ecological resources encompass the organizational structure, relationships, and external networks that facilitate the integration of digital technologies into broader ecosystems. By examining these three interconnected dimensions, we aim to comprehensively understand how digitalization impacts various facets of manufacturing enterprises, from technological investments to organizational dynamics and external collaborations.

This study offers a novel perspective by focusing on the intersection of servitization and digitalization within Chinese manufacturing enterprises. Our research fills a significant gap in the literature by providing unique insights into how these two transformative trends are integrated and leveraged within the context of Chinese manufacturing. By explicitly examining the interplay between servitization and digitalization, we contribute to advancing theoretical understanding in the field

and offer practical implications for manufacturing firms aiming to enhance their competitiveness and performance.

3. Methodology

In 2021, a survey of Chinese manufacturing companies assessed the influence of servitization and digital integration on enterprise performance. The survey focused on four key manufacturing sectors: machinery and equipment, computer and electronic products, electrical equipment, and telecommunications.

Scale development for digital level

The scale's development of the questionnaire was based on a synthesis of previous research findings (Huang et al., 2020). Additionally, semi-structured interviews were conducted with middle and senior executives to explore digital servitization strategies. These interviews helped identify the most appropriate indicators to describe the digital level, resulting in 21 variables initially. Subsequently, three academic experts with extensive experience in scale development evaluated the questionnaire's format, content, item selection, clarity, redundancy, and accuracy. After discussing the concept of the digital level and its dimensions, the experts assessed the appropriateness of each item to represent the corresponding dimension. The final scale comprised three dimensions: digital technology resources (3 items), digital labor resources (7 items), and digital relationship resources (8 items).

Before conducting the main survey, fifty pilot questionnaires were distributed in Hangzhou High-tech Development Zone, Xiasha Industrial Park, and Haichuang Park in China. The 7-point Likert scale was utilized for all measurements, meeting test requirements for one-dimensionality and reliability by Churchill's guidelines for refining the measurement process (Churchill, 1979). **Table 2** provides definitions for the study's variables and corresponding data sources.

In order to ensure the sample's quality, two indicators were used for sample selection: employee size and sales. Firstly, the sample size needed to exceed 100 employees to mitigate the impact of small businesses, which may have limited capacity to offer a diverse service portfolio. Secondly, to ensure ongoing business activities, companies with sales of less than 100 million yuan were excluded, as lower sales often correlate with more significant performance fluctuations. Based on these criteria, 400 manufacturing companies in China were selected. The research team received a total of 335 responses from enterprises through various methods, including visits and mailings. After excluding four incomplete questionnaires, 331 valid questionnaires were obtained.

Table 2. Variable definitions and data sources.

Variable name	Definition	Data source
Firm's performance	The growth rate of return on assets over the three years following the implementation of the service-oriented strategy, considering the lagged effect of existing digitalization and servitization activities on company performance	Survey questionnaire responses

Table 2. (*Continued*).

Variable name	Definition	Data source
Level of servitization	The proportion of service products in a company's sales	Survey questionnaire responses
Level of Digitalization	Assessment of digital technology resources, digital labor resources, and digital ecological resources within the company, comprising digital technology utilization, workforce metrics, and organizational ecology.	Survey questionnaire responses
Age of the business	Age of the manufacturing enterprise in years	Survey questionnaire responses
Size of the enterprise	Sales revenue of the manufacturing enterprise in million yuan	Survey questionnaire responses
Control variable 1	Number of employees	Survey questionnaire responses/Financial Statements
Control variable 2	Total assets	Survey questionnaire responses
Control variable 3	Cash flow	Survey questionnaire responses
Control variable 4	Number of patents	Survey questionnaire responses

4. Results and findings

We have conducted a Little's Missing Completely At Random (MCAR) test to assess non-response bias and ensure the representativeness of our research for the population under study. The results of Little's MCAR test indicate that our sample is representative of the target population, thereby enhancing the validity and reliability of our study. **Table 3** provides an overview of the variables examined, including mean, minimum, and maximum values, standard deviations, and correlations.

Table 3. Correlation matrix.

Variable	Performance	Level of servitization	Level of Digitalization	Age of the business	Size of the enterprise
Firm's performance	1	0.216**	0.378***	0.138***	0.397***
Level of servitization		1	0.123**	0.085	0.154***
Level of Digitalization			1	0.105**	0.153***
Age of the business				1	0.120**
Size of the enterprise					1
mean	17.325	7.689	3.628	37.277	79.869
Standard deviation	1.860	13.874	1.672	16.781	298.211

Note: Significance level $p < 0.001$; **significance level $p < 0.01$; *significance level $p < 0.05$.

4.1. Scale validation analysis

Confirmatory factor analysis was performed using Analysis of Moment

Structures (AMOS) 20.0 software to validate the dimensions of the digital measurement scale. The results in **Table 3** indicated that the factor loadings were above 0.6, confirming the robustness of each dimension. Cronbach's alpha coefficients were computed for the total digital level scale and its three-dimensional subscales using AMOS 20.0 software. The coefficient values indicated in **Table 4** show strong internal consistency and reliability.

Table 4. Confirmatory factor analysis results.

	Factor 1	Factor 2	Factor 3
Digital technology resources			
Our company has adopted basic digital management tools such as punch and clock, order management, etc.	0.64		
Our company adopts new systems such as online office, customer relationship management, MRP, etc.	0.69		
Our company has adopted an integrated online business system of production, sales, and after-sales.	0.86		
Digital labor resources			
The level of education of our personnel is getting higher and higher.		0.74	
The average age of our workforce is gradually decreasing.		0.77	
Many positions in our company have been reduced in staff.		0.81	
The size of our company remains stable.		0.72	
We often carry out training in digital management and production.		0.84	
Our job assessment has been adapted to the needs of digital work.		0.92	
Our recruitment focuses on learning and using digital tools.		0.88	
Digital ecological resources			
New positions and departments related to digital have been created in our company.			0.62
The management hierarchy of our company has been reduced.			0.73
There is more and more collaboration between our company departments.			0.86
Our internal business processes have been reorganized.			0.64
We have a closer relationship with our customers.			0.84
We have a more accurate understanding of our customers.			0.83
Most of the suppliers have a simple business relationship with our company.			0.85
Many of our suppliers are partners with our company.			0.86
Cronbach's α (Total scale 0.903)	0.851	0.902	0.894
Cumulative variance (%)	22.419	43.035	58.391

Discriminant validity test

Table 5 demonstrates that the square root of the average variance extracted (AVE) for each dimension of the digital level significantly surpasses the correlation coefficient between any two dimensions. This indicates excellent discriminant validity, as the AVE values for all three dimensions exceed the minimum criterion of 0.50. **Table 5** also presents the results of the discriminant validity test, which includes

Cronbach's α, the AVE, and the correlations between the dimensions of the digital level.

Table 5. Discriminant validity test.

	Cronbach's α	**AVE**	**Digital technology resources**	**Digital labor resources**	**Digital relationship resources**
Digital technology resources	0.851	0.712	0.844		
Digital labor resources	0.902	0.780	0.576	0.883	
Digital ecological resources	0.894	0.671	0.549	0.508	0.819

Note: The values on the diagonal represent the square root of the AVE.

The findings demonstrate a strong correlation between the three dimensions of the digital level: digital technology resources, digital labor resources, and digital ecological resources. This implies that as organizations adopt digitalization, their investments in digital technology also impact aspects related to the organizational structure, such as the composition and size of the workforce and the internal and external relationships. Greater investments in digital technology and deeper technology integration are associated with more significant organizational structure and relationship changes. On the other hand, organizations with minimal digital technology investments experience minor changes in their structure and relationships, mainly limited to basic instrumental technology.

4.2. Regression analysis

The analysis commenced with a correlation analysis to explore initial relationships between variables. Subsequently, we performed multiple regression analyses to investigate further and confirm these relationships. Through regression analysis, we evaluated the model and tested relevant hypotheses. We used ordinary least squares estimation, considering the normality of the error term distribution and each variable. Firm performance was the dependent variable in Models 1 and 2, with servitization as the independent variable in Model 1 and digitalization in Model 2. Model 3 integrated the mediating effect of digitalization. The study considers control variables such as company size, cash flow, total assets, and property rights protection to explore their impact on the relationship between digitalization efforts and organizational performance. The size of a company, often indicated by the number of employees, is a measure of its stability. Larger companies prioritize expanding their workforce to make the organization stronger overall. In addition, cash flow and total assets play important roles in the relationship between digitalization efforts and organizational performance. Companies with healthy cash flow and substantial assets are better positioned to use digitalization, which can lead to improved performance effectively. Furthermore, the number of patent rights provides strategic advantages by safeguarding intellectual property. This helps companies mitigate competition and retain customers, leading to higher performance. **Table 6** contains the results relating to regression analysis with the control variables and hypothesis testing.

Table 6. Regression analysis results of the control variables and for hypothesis testing.

Argument	Model 1 (H_1)	Model 2 (H_2)	Model 3 (H_3)
Level of servitization	0.089 (0.011)	-	0.041 (0.176)
Digitalization level	-	0.072 (0.034)	0.342 (0.000)
The age of the business	0.091(0.017)	0.171 (0.000)	0.152 (0.000)
The size of the enterprise	0.092 (0.001)	0.346 (0.000)	0.401 (0.000)
Number of employees	0.025 (0.005)	0.018 (0.012)	0.031 (0.007)
Total assets	0.003 (0.002)	0.005 (0.003)	0.004 (0.001)
Cash flow	0.007 (0.003)	0.009 (0.004)	0.006 (0.002)
Number of patents	0.012 (0.004)	0.015 (0.005)	0.011 (0.003)
R^2	0.079	0.389	0.569
F value	7.531 (0.000)	39.774 (0.000)	49.747 (0.000)

Note: Standard coefficients and significance levels are in parentheses. Sample size is 331.

The level of servitization and firm performance (H_1) were positively correlated, confirmed by multiple regression analysis in Model 1. Similarly, Model 2 indicated a positive correlation between the level of digitalization and firm performance (H_2). Hypothesis 3, involving the relationship between the level of servitization, digitalization, and firm performance, suggests potential interactions. Thus, the regression results of Models 1, 2, and 3 confirmed the necessary conditions for mediation.

We used Model 4 of PROCESS in Statistical Package for the Social Sciences (SPSS) to determine the significance of mediation. We calculated servitization's total, direct, and indirect effects on performance. We estimated the indirect effects and provided bootstrap standard errors and confidence intervals. If the confidence interval does not contain 0, there may be an intermediary effect. The results in **Table 7** were obtained by analyzing the three variables presented in **Figure 1**. We provided indirect effect estimates (b = 0.061) along with bootstrap standard errors and confidence intervals. We also calculated a fully standardized indirect effect or mediation index (0.0389). Since the confidence interval does not contain 0, there is an indirect effect. Therefore, digitalization fully mediates the relationship between servitization and a firm's performance.

Table 7. Mediation analysis results for overall, indirect, and direct effects.

Influence relationships	Level of influence	SE (HC3)	LLCI	ULCI	*P*
Overall Impact	0.0171	0.0054	0.0041	0.0253	0.0091
Immediate impact	0.0104	0.0075	0.0005	0.0178	0.0548
	Level of influence	**Boost SE (HC3)**	**Boost LLCI**	**Boost ULCI**	
Indirect impacts	0.0061	0.0017	0.0018	0.0094	
Full standard error	0.0389	0.0128	0.0134	0.0712	

Note: The confidence interval is 95%, and the number of guided samples is 5000.

5. Discussion

The findings show a strong correlation between the level of digital technology resources, digital labor resources, and digital ecological resources among enterprises. Specifically, organizations with high digital technology resources tend to have more extensive digital labor and digital ecological resources (Arica and Powell, 2021; Kamalaldin et al., 2020). Conversely, businesses with low levels of digital technology resources have lower levels of digital labor and digital ecological resources. These findings have two important consequences.

The first implication of this analysis is that for digitalization to help enterprises achieve effective servitization, in addition to digital technology investment, organizational adjustment is needed. Suppose an enterprise aims to provide disruptive and innovative services. In that case, it must invest in digital technology that penetrates the bottom layer of the organization but also makes significant adjustments to the internal organizational structure and the relationship between external organizations. For instance, if an enterprise provides an overall solution based on the Internet of Things, it must invest heavily in the Internet of Things system technology and reconstruct the organization, the business process, and the external ecological relationship (Huang et al., 2020). Furthermore, the observed correlation between digital technology resources and servitization underscores the need for a holistic approach to digital transformation within manufacturing enterprises. Beyond mere investment in technology, fostering a culture of digital innovation and agility across all levels of the organization is crucial (Chirumalla et al., 2023; Shen et al., 2023). This entails updating technological infrastructure, cultivating digital literacy among employees, and fostering collaboration between departments to maximize the value derived from digital initiatives.

The second implication is that to achieve effective digitalization or servitization, manufacturing enterprises often need to match the level of servitization with the level of digitalization. That is, a high level of servitization needs to match a high level of digitalization to achieve transformation success (Martín-Peña et al., 2019) Enterprises with low digital transformation orientation often rely on digital systems' essential extension services. Some enterprises are positioned as fundamental innovations in business models from the beginning, so the digital technology invested in digital initiatives must be basic digital technology, and the organizational structure and inter-organizational relationships also need to be subversively adjusted (Alvarez et al., 2015; Luz Martín-Peña et al., 2018).

Due to the difference in the strategic positioning of servitization and digital integration transformation, the development strategy of digital and service-oriented integration of manufacturing enterprises can be divided into conservative and aggressive. Manufacturing enterprises can choose conservative or aggressive transformation strategies according to their resource conditions and external environment. Enterprises with low digital transformation orientation may extend essential digital services. Their focus lies on incremental improvements rather than radical shifts. These enterprises can implement digital technologies gradually, starting with essential services and expanding over time. This conservative approach allows them to learn and adapt to new technologies with less risk (Baines et al., 2013;

Kowalkowski et al., 2017; Luz Martín-Peña et al., 2018). On the other hand, some companies position themselves as primary innovators from the start. They require fundamental digital technology investments and revolutionary adjustments to organizational structures and inter-organizational relationships. An aggressive strategy involves a rapid transformation towards digitalization and servitization. Enterprises adopting this strategy are willing to take higher risks for greater rewards, invest heavily in digital technologies and innovative services, and adjust their organizational structures and relationships (Arica and Powell, 2021; Huang et al., 2020; Kamalaldin et al., 2020). Choosing a conservative or aggressive strategy depends on the enterprise's resource conditions, external environment, and strategic objectives. Successfully implementing digitalization and servitization can enhance an enterprise's performance and competitiveness in the digital era (Baines et al., 2020; Kowalkowski et al., 2017; Luz Martín-Peña et al., 2018). However, effectively managing the transformation process helps to minimize potential risks and challenges. Balancing these approaches ensures a harmonious alignment between servitization and digitalization, fostering successful transformation. This strategic decision will significantly impact the enterprise's performance and competitiveness in the digital era.

The discussion about the link between digitalization and servitization in the manufacturing sector has been centered around two main schools of thought: 'service-oriented' and 'digital-led.' This paper presents empirical research that confirms the role of digitalization in facilitating servitization, which supports the 'service-oriented' perspective. According to this view, integrating digitalization and servitization constitutes a novel scenario for enterprises in the digital era, epitomizing a manifestation of service-oriented logic in contemporary manufacturing practices (Kowalkowski et al., 2017; Martín-Peña et al., 2019). Conversely, proponents of the 'digital dominance' theory assert that digital technology is both the driver and enabler of servitization. Digitalization not only mitigates the challenges and risks associated with servitization but also facilitates the realization of its benefits. The proliferation of digital technology has fundamentally reshaped products, services, processes, production systems, and business activities, expanding the scope of offerings and paving the way for new business models, including servitization services (Kohtamäki et al., 2020; Luz Martín-Peña et al., 2018; Martín-Peña et al., 2019). Both perspectives find research support, underscoring the evolutionary trajectory of the manufacturing industry in the digital era. Whether 'service-oriented' or 'digital-oriented,' these approaches represent distinct pathways towards a common goal: realizing a new production mode characterized by digital service-oriented practices. In response to intense market competition, manufacturing companies have sought to bolster their competitiveness through product-oriented customized services, maintenance services, and complete lifecycle management services (Arica and Powell, 2021). However, challenges such as loose property rights and incomplete service functions have impeded the efficacy of servitization, leading to what has been termed a 'service-oriented dilemma' (Dmitrijeva et al., 2022).

Enterprises facing obstacles in service provision, cost reduction, and business model optimization have turned to digital technologies. Digitalization has streamlined service provision, reduced costs, enhanced service value, and even reshaped business

models (Ayala et al., 2017; Bouwman et al., 2019). This convergence of servitization and digitalization has led to adopting integrated digital service-oriented practices (Kowalkowski et al., 2011; Martín-Peña et al., 2019). Some enterprises have also implemented digitalization initiatives to enhance production and sales processes, improving performance benefits. However, excessive investment in profound digitalization has resulted in what is known as the 'digital dilemma' (Gebauer et al., 2020).

The study findings have important implications for manufacturing companies transitioning to the digital era. These companies must align their digitalization efforts with their goals of providing services. This requires careful coordination of investments to maximize performance impact. At the same time, they need to manage their resources judiciously, balancing financial, human, and technological resources to support digital and service-oriented initiatives effectively. Organizational adaptation is also critical, necessitating restructuring internal processes and fostering collaboration to ensure smooth service delivery. Strategic positioning is crucial for enterprises, as they need to assess the competitive landscape and market trends to identify opportunities and establish strategic partnerships (Favoretto et al., 2022). Finally, fostering a continuous learning and adaptation culture is essential in rapidly evolving technological environments. This allows organizations to take advantage of emerging opportunities and stay ahead of the curve.

The combination of manufacturing servitization and digitalization represents a move towards integrated digital service-oriented practices. Some companies are working together to transform their practices from the beginning. Although approaches may differ, the ultimate aim is to integrate digital service-oriented practices, marking the emergence of a new manufacturing production mode.

6. Conclusion

This study explores the evolving landscape of the global manufacturing industry, specifically focusing on the intersection of servitization and digitalization in Chinese manufacturing companies. A comprehensive literature review identified key areas where digitalization and servitization intersect. The impact of servitization and digitalization on the performance of manufacturing enterprises was examined, leading to the formulation of research hypotheses. An empirical investigation was carried out using data from 331 Chinese manufacturing enterprises, exploring the influence of integrating digitalization and servitization on enterprise performance.

The findings highlight the significant impact of digital servitization on the financial performance of the manufacturing sector, surpassing the effects of standalone digitalization or servitization initiatives. The research suggests that manufacturing enterprises can adopt either conservative or aggressive strategic positions to integrate servitization and digitalization, emphasizing the importance of collaborative transformations to leverage digitalization for effective servitization. Moreover, the study points out the importance of fostering a culture of digital innovation and agility across all levels of the organization to maximize the value derived from digital initiatives. Manufacturing enterprises can enhance their performance and thrive in an increasingly digitalized business environment by implementing collaborative

transformations and leveraging digital technologies for effective servitization. The study suggests that integrating servitization and digitalization holds promise as an effective strategy to overcome the challenges posed by the 'digital dilemma' and 'servitization dilemma' in the manufacturing industry. By capitalizing on the interactions between these two transformative forces, manufacturing enterprises can navigate the complexities of the digital era while enhancing their competitive edge. The findings emphasize the critical role of integrating servitization and digitalization in shaping the future trajectory of the manufacturing industry. Manufacturing enterprises can enhance their performance and thrive in an increasingly digitalized business environment by embracing collaborative transformations, fostering digital innovation, and leveraging digital technologies for effective servitization. By capitalizing on the interactions between these two transformative forces, manufacturing enterprises can navigate the complexities of the digital era while enhancing their competitive edge. The findings emphasize the critical role of integrating servitization and digitalization in shaping the future trajectory of the manufacturing industry. Manufacturing enterprises can enhance their performance and thrive in an increasingly digitalized business environment by embracing collaborative transformations, fostering digital innovation, and leveraging digital technologies for effective servitization.

7. Limitations and future research

While this study offers valuable insights into the convergence of servitization and digitalization in the manufacturing industry, it is important to note some limitations. These include the sample size, cross-sectional design, reliance on self-reported data, concerns about measurement validity, contextual factors, and potential endogeneity, all of which may impact the findings' generalizability, reliability, and robustness. Future research could use more extensive and diverse samples to address these limitations, employ longitudinal designs, triangulate data from multiple sources, consider additional contextual factors, and address potential endogeneity issues. Furthermore, while our focus is primarily on assessing the impact of digitalization and servitization, it is important to acknowledge the possibility of reverse causality, where better enterprise performance may drive higher levels of digitalization and servitization. Future longitudinal studies can provide deeper insights into causal relationships. Additionally, unobserved variables may simultaneously influence independent and dependent variables, leading to biased estimates. Future research should explore instrumental variable techniques to mitigate this concern and strengthen the validity of findings. Moreover, this study must delve into the characteristic distinctions between Manufacturer-to-Business (M2B) and Manufacturer-to-Consumer (M2C) models within the manufacturing industry. This would further enhance our understanding of the intersection of servitization and digitalization in the manufacturing industry.

Author contributions: Conceptualization, QH and PJK; methodology, QH; software, QH; validation, QH and PJK; formal analysis, QH; investigation, PJK; resources, QH; data curation, QH; writing—original draft preparation, PJK; writing—review and

editing, QH; visualization, PJK; supervision, QH; project administration, QH; funding acquisition, QH. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Major Humanities and Social Sciences Research Projects in Zhejiang higher education institutions, grant number 2023QN010, and the APC was funded by the Open Project of the Belarus Research Center of Zhejiang Shuren University, grant number KF2023001.

Conflict of interest: The authors declare no conflict of interest.

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