Research article

Servitization level, digital transformation, and enterprise performance of sporting goods manufacturing enterprises in China

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A B S T R A C T

To identify the effect and mechanism of servitization level and digital transformation on the performance of listed sporting goods manufacturing enterprises in China, we construct an index to measure the degree of digital transformation using data from 31 sporting goods manufacturing firms listed on Shanghai and Shenzhen A-shares and the New Over-the-Counter Market in China. The study uses the proportion of service business income in enterprise operating income to quantify servitization level, by analyzing the semantic expression of national digital economy policy and collecting digital category keywords from enterprise annual reports using crawler technology. Thereafter, we analyze the impact of servitization extent and digital transformation on company outcomes as well as if digital evolution acts as a moderating factor between servitization and company outcomes. The findings indicate that the extent of servitization reduces the outcomes of publicly traded sporting commodities production companies, showing a servitization paradox occurrence. Digital transformation degree has a positive U-shaped impact on enterprise performance and a weak positive moderating effect on servitization level and enterprise performance.

1. Introduction

China is developing rapidly, and is currently in a late stage of industrialization and is facing severe challenges with economic transformation and development. In line with Made in China 2025, "vigorously cultivating service-centric manufacturing and productive service sectors" has ascended to a critical mission, setting up a route for the synchronized evolution of manufacturing and services. Moreover, the developmental target of transitioning from production-centric manufacturing to service-centric manufacturing has been determined [1]. The servitization of manufacturing will spearhead the transformation and update of China's manufacturing sector and augment the commodity worth of corporations [2]. However, in some cases, the degree of servitization will have a diametrically opposed effect on the performance of manufacturing enterprises, which is known as the servitization paradox [3]. In addition, in the process of manufacturing transformation and upgrading, digitalization is a path for enterprises to use digital technology and capabilities to drive business model innovation and business ecosystem reconstruction to achieve business innovation and growth [4]. Unfortunately, in actual business practice, a part of enterprises have confronted the dilemma in which, although they have invested heavily in digitization, they have achieved negligible results, and performance has not obtained the expected return, resulting in the digital paradox phenomenon [5].

The sports industry is a fundamental component of China's "five happiness industries." In 2021, the aggregate magnitude of China's

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sports sector industry is 3117.5 billion yuan, while the industry's contributes to the national economy at a continuous pace. The sporting goods production sector is a significant facet of China's sports industry, and the gross output and value-added of the national sporting goods and associated commodities production sector had reached 1357.2 billion yuan and 343.3 billion yuan, respectively, in 2021, accounting for 43.5 % and 28 % of the total volume of the sports industry [6]. In the field of traditional manufacturing, research on the impact of enterprise servitization and digital transformation on the performance of enterprises is more extensive, but the research conclusions differ [7–9]. There is a lack of research regarding the sporting goods manufacturing industry, and the only studies that have been conducted have argued that servitization and digital transformation have a positive effect on the high-quality development of sporting goods manufacturing enterprises from a theoretical perspective [10–12]. Amid a complex and changing market environment, the conclusions drawn from theoretical analyses alone are not highly persuasive and must be confirmed via rigorous quantitative research to investigate if the process of servitization and digital change enhances the efficacy of sports equipment manufacturing businesses. Does a servitization contradiction or a digital contradiction occurrence appear in China's sports equipment production sector? In addition, what role does the application of digital technology have in the process of service-oriented transformation of China's sporting goods manufacturing industry?

This study takes these research questions as a starting point to conduct an empirical analysis using unbalanced panel data of 31 listed companies in China's sporting goods manufacturing industry from 2000 to 2021 to provide a realistic reference for improving the performance and high-quality development of sporting goods manufacturing enterprises. The marginal contributions of this study are twofold. (1) At the theoretical level, this study analyzes the effects of enterprise servitization and digital transformation on enterprise performance using financial data disclosed in the annual reports of listed sporting goods manufacturing enterprises and explores the mechanism of enterprise digital transformation in the relationship between servitization and enterprise performance. (2) At the methodological level, this study extracts service-oriented business revenue data from "other business income" more accurately, calculates the degree of servitization of enterprises, and proposes a more comprehensive index to reflect the degree of digital transformation of sporting goods manufacturing enterprises using a machine learning text analysis method, presenting a solid foundation for accurate research results.

2. Literature review and theoretical hypotheses

2.1. Servitization of manufacturing industry and enterprise performance

Manufacturing servitization has been a popular research topic in recent years, which originated from the "service revolution" experienced by the manufacturing industry since 1980. Manufacturing servitization can be understood as (1) manufacturing enterprises transitioning from product manufacturing to service provision, and (2) continuous improvement of the degree of embedded service elements in the process of production and operation [13]. Research has produced different perspectives regarding the impact of manufacturing servitization on enterprise performance.

Globally, scholars have predominantly argued that a positive correlation exists between manufacturing servitization and firm performance [14,15]. Chinese scholars have also confirmed the positive relationship between manufacturing servitization and firm performance in China from perspectives of service innovation [16], servitizing evolution [17], manufacturing transformation and upgrading [18], and employment skill structure [19]. Other studies have found a nonlinear relationship between manufacturing servitization and enterprise performance, including positive U-shaped curve, an inverted U-shaped curve, and "saddle" relationships, as well as specific characteristics of life cycle stages. However, investing in servitization business also incurs certain risks; specifically, for enterprises with immature servitization strategies and management. Enterprises entering service areas that differ from the primary business must engage in business activities that require considerable investment costs, organizational management, and personnel training, resulting in service-oriented business revenue being inadequate to compensate for the investment cost, resulting in the emergence of a servitization dilemma [3]. A study of 558 German industrial firms found that the service innovation activities of manufacturing enterprises reduce overall profit, and servitization strategies will only promote enterprise performance in a specific context [20]. When the service provided by the enterprise has good complementary cooperation with the original products, it will have a positive impact for the enterprise [21]. Domestic research in China has found that if enterprises fail to accurately address the problems of service-oriented investment and internal resource allocation, significant decline in corporate profitability will occur [22]. Research concerning enterprise servitization strategy has determined that it has an immediate impact on enterprise market performance, but a negative impact on enterprise financial profitability [23].

Establishing a formal servitization research methodology, Chinese academics have thoroughly detailed the beneficial function of servitization in facilitating the transition and enhancement of China's sports equipment production sector [24,25]. They have put forward a growth blueprint for servitization strategy analysis in the sports equipment production industry [26], and confirmed the positive influence of servitization on sports equipment manufacturing businesses. Nevertheless, in comparison to research on conventional manufacturing sectors, those evaluating the servitization of China's sports equipment production industry are predominantly theoretical and lack solid empirical backing, thus creating uncertainty about the impact of servitization on China's sports equipment manufacturing businesses. Compared with traditional manufacturing enterprises, the sporting goods manufacturing industry faces a series of challenges, such as the dominant position of processing trade, unreasonable export structure, lack of well-known international brands, lack of innovation, lack of research and design, over-concentration of product sales channels, and lack of clear brand positioning [27]. This suggests that servitization must be implemented cautiously according to industry characteristics. Moreover, the market configuration of sports equipment production is still in an expansion phase, the count of public companies is at a definite drawback compared to other sectors, and the majority of the firms have gone public in a span of 1–5 years,

corresponding to the growth stage of the corporate life cycle. In the process of servitization, organizational inertia [28], corporate culture [29], manufacturing-driven microfoundation [30], cognitive barriers [31], and other factors may have a negative impact on corporate performance. Therefore, we propose the following hypothesis.

H1. Servitization does not have a positive impact on the performance of sporting goods manufacturing enterprises, and a servitization paradox may arise.

2.2. Digital transformation and enterprise performance

Digitization, which refers to increasing the availability of digital data by creating, transmitting, storing, and analyzing digital data, has the potential to "build, shape, and influence the contemporary world" [32]. The specific digitalization in an enterprise indicates the application of digital technology and the changes that digitization brings to the enterprise and the market. The combination of data, licensing, and analytical skills represents the digital capabilities of a company; however, the digital application of physical enterprises is a complex process that requires systematic optimization and the integration of various factors. Cutting-edge digital technology has strong advantages for advancing many aspects of the operation and management of manufacturing enterprises, but the impact mechanism of digital transformation on the performance of physical enterprises has not yet been determined [33]. Digital technology can meet the increasingly differentiated needs of consumers for products and services at a lower cost [34], and technical content will also accelerate innovation in production approaches and optimize management process [35]. Conversely, digital transformation is a complex and difficult process, including optimizing and integrating various technologies (big data, artificial intelligence, cloud computing, blockchain, the Internet of things, and other forms). In the early stage, enterprises must invest considerable human, material, and financial resources to organically integrate the original technological framework of the enterprise with new emerging technologies, and upfront as well as hidden costs are extremely high [36]. Digitalization may promote innovation of enterprise business models, but it will inevitably change the original business process, causing overall imbalance and an increase in the enterprise management costs [37]. In addition, digital transformation is closely related to the digital value proposition and transformation concept of enterprises. Based on market feedback, enterprises must constantly test and modify products, testing managers' cognitive capabilities and implementation strategies for digital transformation, and the final impact on enterprise performance is unknown [38]. Generally, in the initial stages of a manufacturing company's digitalization strategy implementation, digital technologies are most likely to inhibit enterprise business performance, which will only improve when the digital technology is mature and past the risk period [39].

Research investigating the impact of digitization on sporting goods manufacturing enterprises has primarily been limited to theoretical interpretation, and empirical research is relatively scarce. Related research has argued that the digital transformation of sports enterprises can reduce production, management, and marketing costs and improve resource allocation, capital, and labor production efficiency, resulting in economies of scale, scope economy, and long tail effects [40]. Moreover, digital technology can also reduce the production, management, and operating costs of sporting goods enterprises, build an information bridge between consumers and service platforms, improve marketing efficiency, and generate new business growth points such as customized services, accurate after-sales approaches, and buyback tracking [41]. However, China currently does not have a comprehensive governmental policy supporting digital technology for enterprises, coupled with inadequate supply of essential sports core technology [42]. Sporting goods manufacturing enterprises are also confronted with diversified practical challenges such as weak capability to resist information risks, unclear strategic planning, and a shortage of digital talent [43]. As a result, the effect of digital transformation on improving sporting goods manufacturing enterprise performance in the short term is not optimistic. Combined with the digital experience of other manufacturing enterprises, we propose the following hypothesis.

H2. The improvement of sporting goods manufacturing will be restrained in the early stage of digital transformation, and a promotional effect on performance will occur in the later stage as digital technology matures, presenting a positive U-shaped relationship.

2.3. Moderating effect of digital technology

When implementing enterprise servitization, digital transformation can navigate the instability of technological innovation and market changes through stable digital flow, improve the efficiency of resource allocation, and advance profitable service-oriented business [44]. The emergence of new value through digital technology, alongside traditional business principles, heralds significant transformation. These changes extend to the organizational structure and operational processes within the enterprise, and inducing adaptive changes in production, sales and after-sales environments [45] to achieve comprehensive upgrade of the executive power of each process, including the transformation of products and services [46]. Furthermore, the digital economy reduces the search, replication, transportation, traceability, and certification costs of enterprises and significantly improves supply chain coordination and the ability to manage and control production risks [47]. In the service-oriented production of enterprises, the use of digital technology enables real-time analysis of customer behavior and consumer demand. This allows for swift identification of potential changes in customer preferences and facilitates the flexible and efficient adjustment of service schemes [48], to meet customers' differentiated needs for products and services at a lower cost facilitating a virtuous circle of product and service coordination. Generally, digitization can effectively promote the accurate search, positioning, and customization abilities of enterprises in the process of servitization; provide accurate decision support; and reduce unnecessary human, material, and financial resource waste to promote the coordinated development of enterprise servitization awareness and capabilities and fully integrate the enterprise servitization concept. Based on the above analysis, we propose following hypothesis.

H3. The extent of digital change in businesses favorably modulates the correlation between service and business performance in the sports equipment production sector.

3. Research and design

3.1. Sample selection and data sources

This study takes the sporting goods manufacturing enterprises listed on the Shanghai Stock Exchange, the Shenzhen Stock Exchange, and the New Over-the-Counter Market as samples, applying the following selection criteria. (1) The public sports firms adhere to the pertinent statutes of the national sports industry statistical categorization. (2) The operational range of the public companies encompasses sports equipment production, their own trademark, and the sports equipment production business constitutes more than 50 % of the overall revenue [49]. (3) Public firms have no significant financial shortcomings in the annual report. (4) Listed companies have not been continuously ST, SST, S*ST, * ST, or PT in the past five years. (5) To guarantee the stability and uniformity of sample data, we choose businesses with three successive years of sample data. Financial metrics are primarily sourced from the Guotai'an database, Juchao Information Network, and corporate annual report data. Our final sample includes the information of 31 enterprises, with a total of 231 observations as the research object. Table 1 presents the basic information regarding our study sample.

3.2. Variable selection and data description

3.2.1. Enterprise performance
An enterprise is regarded as a legal person or other for profit socioeconomic organization, and the financial performance of the enterprise directly represents profitability [50]. In general, financial performance is the proxy for enterprise performance, depending on the variable. In traditional enterprise performance measurement, total return on assets (ROA) can reflect the profitability of enterprises more accurately than return on net assets (ROE) [51]. Hence, we employ ROA to assess the performance of sports equipment manufacturing businesses in the benchmark regression model. This is derived by calculating the net profits of the current year's pre-tax net profit and the current year's total assets.

3.2.2. Servitization level
Regarding the presently related analytical methods to calculate the servitization degree of manufacturing businesses, we utilize the ratio of service-oriented revenue to overall business revenue to compute the servitization degree of sports equipment manufacturing public enterprises. Nonetheless, some firms do not directly provide service revenue data and employ other business revenue as service revenue data [39,52]. Some studies have carried out analyses concerning the precision of the alternative method, and the outcomes corroborate the alternative method to be practical and trustworthy as a target and micro index to calculate business service revenue [53]. Moreover, the index of "other business revenue" is construed as "revenue from ancillary business other than the main business" in the Accounting General principles, which may also involve revenue of material sales as well as the intangible assets transferring. Therefore, the value after excluding these items from the business financial statements is assumed to be the service-oriented business revenue after securing the other business revenue, and the ratio of this value in the operating revenue of the business is assumed to represent the servitization degree of the business. For firms that did not disclose the details of other business revenue, we use other business revenue as the service-oriented revenue index.

Table 1
Basic information about the study sample.

Security Code	Company Dame	Data Period	Security Code	Company Dame	Data Period	Security Code	Company Dame	Data Period
002780	Sanfo Outdoor	2015–2021	603908	Comefly	2017–2021	833649	Beaume Outdoor	2015–2021
600679	Shanghai Phoenix	2000–2021	002899	Impulse	2017–2021	836210	Sumar Marine	2017–2021
300526	China Dive	2016–2021	300651	Jinling Sports	2017–2021	833151	Tongfang Health	2015–2021
002105	HL Corp	2007–2021	002870	Senssun	2017–2021	870749	Jianhua Zhongxing	2017–2021
603558	Jasan Group	2015–2021	603555	Guirenniao	2014–2018	833429	Competitor	2015–2021
002395	Double Elephant	2010–2021	831326	Sanlida	2014–2021	839446	Minghong Sports	2016–2021
002486	Challenge	2010–2021	873009	Sifang Swimming	2018–2021	832875	Fushide	2015–2021
300005	Toread	2010–2021	838464	Carving Ski	2016–2021	830877	Kanglai Sports	2014–2021
603129	Chunfeng Power	2017–2021	430759	Cronus	2014–2017	871594	Cnsg Holdings	2017–2021
002832	Biemlfdlkk	2016–2021	837226	Lianchuang Artificial Lawn	2017–2021	837720	Youli Sports	2016–2021
002489	Zhejiang Yongqiang	2010–2021						

Note: Noble Bird was *ST in 2019–2020 and ST in 2021; Cronus was suspended from trading by ST in 2018–2020.

3.2.3. Degree of digital transformation

The vocabulary used in annual reports of the enterprise can reflect strategic characteristics and future prospects. Therefore, mining the lexical expressions related to digitalization from the annual reports of listed sporting goods manufacturing enterprises can directly reflect the significance and implementation of digital applications. To determine the characteristic words of enterprise digital transformation, we referenced relevant classical literature on the theme of digital transformation [54,55] and authoritative policy documents such as the *Digital China Development Report (2021)* issued by China's State Internet Information Office and the *Government Work Report* in recent year to construct a thesaurus of 116 digital-related words. We subsequently remove the expressions of negative words before keywords and digital keywords that are not related to the sample company. Finally, we employed Python to search, match, and count word frequencies in the annual reports of the 31 listed sporting goods manufacturing enterprises based on our digital thesaurus, taking the frequency of digital keywords in the annual report as the index of the degree of digitization. This study uses the degree of digital transformation as a core explanatory variable and a regulatory variable.

3.2.4. Control variables

Referencing relevant research on the influence of enterprise servitization and digitalization on enterprise performance, we select enterprise scale [56], enterprise age [57], enterprise capital density [58], enterprise development prospects [59], enterprise growth ability [60], and enterprise management ability [61] as control variables. Among them, enterprise scale is expressed as the logarithm of the total assets, the enterprise age is expressed by the difference between the years of available data and the year the enterprise was established, enterprise capital density is expressed by the degree of capital density, enterprise development prospects is measured by earnings per share, enterprise growth ability is represented by the rate of operating income growth, and enterprise operating ability is measured by the asset–liability ratio. Detailed measurement methods are presented in Table 2.

3.3. Model construction

First, the total effect of the level of servitizing and the degree of digital transformation on enterprise performance is constructed separately, and equation (1) and model (2) are constructed. In addition, since the independent variables and dependent variables in this paper may contain linear or nonlinear relationships, such as the "U" type relationship, the quadratic terms of the level of servitizing and the degree of digital transformation are introduced to further test models (3) and (4):

$$ROA_{it} = \beta_1 + \beta_{11}SER_{it} + \beta_{13}VAR_{it} + \varepsilon_{it} \tag{1}$$

$$ROA_{it} = \beta_2 + \beta_{21}DIG_{it} + \beta_{23}VAR_{it} + \varepsilon_{it} \tag{2}$$

$$ROA_{it} = \beta_3 + \beta_{31}SER_{it} + \beta_{32}SER_{it}^2 + \beta_{33}VAR_{it} + \varepsilon_{it} \tag{3}$$

$$ROA_{it} = \beta_4 + \beta_{41}DIG_{it} + \beta_{42}DIG_{it}^2 + \beta_{43}VAR_{it} + \varepsilon_{it} \tag{4}$$

To examine if the extent of digital transformation moderates the servitization degree and performance of sports equipment manufacturing businesses, we develop the following model through incorporating the multiplication term of servitization and digital transformation based on the benchmark model.

$$ROA_{it} = \beta_3 + \beta_{31}SER_{it} + \beta_{32}DIG_{it} + \beta_{33}SER^*DIG_{it} + \beta_{34}VAR_{it} + \varepsilon_{it} \tag{5}$$

where *ROA* is the explained variable of enterprise performance, *SER* is the servitization level, *DIG* is the degree of digital transformation, and *VAR* represents the control variable, including company size (*SIZE*), enterprise age (*AGE*), capital intensity (*KLR*), earnings per share (*DLP*), growth rate of operating income (*OIGR*), and asset–liability ratio (*DEBT*). Among the three models, β_1, β_2, and β_3 are constant terms, β_{11}—β_{34} are the regression coefficients, and ε_{it} is a random error.

Table 2
Variable names and measurement.

Variables	Symbols	Definition and Measurement
Enterprise Performance	ROA	Return on total assets = net profit/average total assets
Servitization Level	SER	Service-oriented business revenue/enterprise sales
Degree of Digitization	DIG	Frequency of digital technology keywords in the annual report of the enterprise
Enterprise Scale	SIZE	Natural logarithm of the total assets of the enterprise
Enterprise Age	AGE	Years of available data minus the year of incorporation
Enterprise Capital Density	KLR	Capital intensity = natural logarithm (net fixed assets/number of employees)
Enterprise Development Prospect	DLP	Earnings per share = total profit/total equity
Enterprise Growth Ability	OIGR	Rate of operating income growth = increase in operating income/total operating income in the previous year
Enterprise Management Ability	DEBT	Asset–liability ratio = total liabilities/total assets

Table 3
Descriptive statistics and variable correlation coefficients.

Variables	Observed Value	Mean	S.D.	1	2	3	4	5	6	7	8	9	VIF
ROA(%)	231	3.179	8.539	1.000									–
SER(%)	231	2.033	3.582	−0.239***	1.000								1.21
DIG	231	17.143	21.288	0.053	0.067	1.000							1.06
SIZE	231	20.252	1.484	0.136	−0.046	−0.197**	1.000						1.56
AGE	231	15.199	6.076	−0.153*	0.028	0.054	0.122	1.000					1.04
KLR	231	11.474	1.161	−0.193**	0.100	0.241***	0.259***	0.044	1.000				1.39
DLP(%)	231	27.101	49.745	0.721***	0.067	−0.253***	0.026	−0.124	−0.326***	1.000			1.52
OIGR(%)	231	13.196	31.468	0.518***	0.072	−0.170***	0.112	−0.025	−0.067	0.450***	1.000		1.28
DEBT(%)	231	41.312	17.918	−0.177**	−0.184**	0.003	0.429***	0.062	−0.002	−0.149**	−0.058	1.000	1.37
Average *VIF*													1.30

Note: ***, **, and * represent significance levels of 1 %, 5 % and 10 %, respectively.

4. Empirical results and tests

4.1. Descriptive statistics and correlation analysis

Table 3 presents the brief descriptive statistics and correlation coefficients of each variable. From the data, the total ROA of sporting goods sample enterprises is only about 3.2 %, indicating low overall profit efficiency. The average proportion of service-oriented business revenue is only about 2 %, indicating a minimal level of current servitization. The average number of keywords related to digitization is 17.1, but a large gap between enterprises is evident, and the word frequency in some years of some enterprises is 0, indicating that digital technology has not been widely valued and the degree of application is uneven. Regarding correlation, we find a negative correlation between SER and result variables and no significant correlation between DIG and result variables, confirming the previous hypothesis to some extent, but these results require additional investigation. In addition, the variance expansion factor (VIF) of the explained variable, the explanatory variable (regulatory variable), and the control variables are far less than 10, indicating no multicollinearity problem, which ensures the accuracy of the later regression results.

4.2. Stationarity tests

To rule out possible pseudoregression, we next test the smoothness of each variable. Because this study selects unbalanced panel data, the IPS test [62] proposed by Im et al. is used to test whether there is a unit root in each variable, which considers the heterogeneity of the panel data, classifying the construction of the test statistic into DF-type or ADF-type test statistics, and demonstrates that the series of the IPS test converges to standard normal distribution, which is more aligned with empirical applications than the LLC test and has been widely used in the field of economics and finance [63]. As shown in Table 4, the test results reject the hypothesis that the variables have a unit root and all data are smooth.

4.3. Model selection

We employ F, LM, and Hausman tests to determine the appropriate econometric model for Equations (1)–(5), and Table 5 presents the results and corresponding p-values for the three tests. First, in the individual effects test, the p-values from the F-test are less than 0.001, indicating that all individual effects are significant overall (i.e., the fixed effects model is superior to a mixed-effects model). Second, the p-values from the LM test are all less than 0.001, indicating that the random effects are highly significant (i.e., the random effect model is better than a mixed effect model). Finally, the p-values from the Hausman test are less than 0.1, rejecting the original hypothesis of the appropriateness of using a random effects model. In summary, Equations (1)–(5), are analyzed using the fixed effect model(FEM).

4.4. Regression results and analysis

4.4.1. Impact of servitization on enterprise performance

Model (1) in Table 6 reveals that by controlling individual and year fixed effects in the ordinary least squares (OLS) model, the servitization level of China's sporting goods manufacturing enterprises exhibits a significant inhibitory effect on enterprise performance, indicating that when the servitization level of enterprises increases by 1 %, performance decreases by 0.4 %. Model (3) confirms that no U-shaped relationship exists between the servitization level and performance of sporting goods manufacturing enterprises. These analysis results confirm H1, indicating the presence of a servitization paradox.

The goal of all businesses is to maximize profit, and the service business can achieve considerable benefits through lower costs and accommodating a wider range of customers, which is considered to be a new path for enterprises to further open the market. Some scholars predict that in the future manufacturing enterprises will make more profits from the lower reaches of the industry, rather than from the product itself [64]. However, the dividend of servitization to the performance of sporting goods manufacturing enterprises has not yet appeared. Most manufacturers have more of a coping attitude toward servitization strategy, and the senior management teams generally lack sufficient understanding of servitization strategies [3]. In addition, China's sports service market is immature, and enterprises lack enthusiasm for the development of the sports service business [65], which is also one of the important reasons for

Table 4
Unit root test results.

Variables	Statistic	Conclusion
ROA	−1.934**	Stationary
SER	−3.158*	Stationary
DIG	−1.548**	Stationary
SIZE	−1.647***	Stationary
AGE	−4.05**	Stationary
KLR	−2.0233**	Stationary
DLP	−1.998***	Stationary
OIGR	−2.829***	Stationary
DEBT	−1.884**	Stationary

Table 5

Results of F, LM, and Hausman tests.

Inspection Methods	Equation (1)	Equation (2)	Equation (3)	Equation (4)	Equation (5)
F-test	3.240***	3.560***	3.570***	3.970***	3.170***
LM test	11.370***	15.120***	11.980***	18.800***	9.780***
Hausman test	8.120**	17.710**	19.730**	22.330***	14.820*

Table 6

Impact of servitization levels and digital transformation on corporate financial performance.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	FEM	2SLS	FEM	2SLS	FEM	2SLS	FEM	2SLS
SER	−0.004***	−0.005***	−0.002	−0.001				
	(0.000)	(0.000)	(0.003)	(0.003)				
SER^2			0.000	0.000				
			(0.000)	(0.000)				
DIG					−0.001	−0.001	−0.005***	−0.001***
					(0.001)	(0.001)	(0.001)	(0.000)
DIG^2							0.001***	0.001***
							(0.000)	(0.000)
SIZE	0.008**	0.007***	0.008**	0.006	0.015**	0.016**	0.016***	0.018***
	(0.005)	(0.001)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
AGE	−0.001	−0.001	−0.001	−0.001	−0.001*	−0.001*	−0.001	−0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
KLR	0.002	0.004	0.002	0.004	−0.002	−0.001	−0.003	−0.001
	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
DLP	0.067***	0.066***	0.067***	0.066***	0.070***	0.070***	0.0750***	0.080***
	(0.020)	(0.019)	(0.020)	(0.020)	(0.021)	(0.022)	(0.019)	(0.017)
OIGR	0.052***	0.050***	0.051***	0.048***	0.056***	0.054***	0.041**	0.028
	(0.014)	(0.013)	(0.015)	(0.014)	(0.017)	(0.016)	(0.016)	(0.186)
DEBT	−0.048*	−0.042	−0.047	−0.040	−0.061*	−0.063*	−0.055*	−0.051*
	(0.029)	(0.028)	(0.029)	(0.028)	(0.034)	(0.034)	(0.031)	(0.029)
Cons	−0.152	−0.137	−0.147	−0.121	−0.244**	−0.263**	−0.267*	−0.320***
	(0.103)	(0.104)	(0.104)	(0.105)	(0.113)	(0.109)	(0.114)	(0.116)
Year fixed	YES	YES	YES	YES	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES	YES	YES	YES	YES
Adj-R^2	0.615	0.618	0.616	0.609	0.537	0.526	0.611	0.560
Log-likelihood	376.296		381.269		372.926		379.476	
L.SER		0.456**		1.389***	15.239**			
		(0.179)		(0.315)	(6.689)			
$L.SER^2$				−0.053***	−0.432*			
				(0.018)	(0.244)			
L.DIG						0.835***	0.912***	9.085*
						(0.051)	(0.172)	(4.885)
$L.DIG^2$							−0.003*(0.002)	0.447**
								(0.178)
F statistic	15.77	15.77	20.66	15.82/12.38	8.36	47.74	11.09	45.49/15.01
Obs	231	231	231	231	231	231	231	231

Note: Robust standard deviation is shown in parentheses, the same below.

lackluster performance. Furthermore, enterprises must adjust the original enterprise structure and marketing mode in the process of integrating servitization strategy, which inherently increases operating costs. Competitive pressure from the market, strategic dispersion, organizational conflicts, technological innovation, and even communication and transportation infrastructure can be observed and captured through such strategies, as well as some hidden factors at the enterprise level. For example, the characteristics of the enterprise management team, including age, psychology, education, experience, and other factors may have an impact on the servitization decision-making and implementation of enterprises. In addition, excessive pursuit of the expanding service business while ignoring research and development (R&D) and marketing of core products challenges to the survival of enterprises. Imbalances of income and expenditure caused by a lack of competitiveness in the product core market are also difficult to compensate through service business income. In addition, investment in servitization increases the financial burden of enterprises. In addition, external pressures (i.e., government regulations, tax adjustment, and other considerations) may damage the market share and profits of enterprises. To recover lost territory, enterprises often regard servitization as a means to earn profit through market disruption. In other words, servitization is often the choice of underperforming enterprises [66].

4.4.2. Impact of digital transformation on enterprise performance

Model (5) in Table 5, controlling for individual and year fixed effects, reveals that the digitization level of sporting goods

manufacturing enterprises in China has a weak negative impact on enterprise performance, but the effect is not insignificant. Model (7) further examines whether a nonlinear relationship exists by adding the square term of digital level. *DIG* and *DIG²* pass the test at a 1 % significance level, and the coefficients are positive and negative, revealing a positive U-shaped curve and an inflection point at 21.89. This indicates that early investment in data technology R&D and operation funds to increase digital development for sporting goods manufacturing enterprises will result in a decline in enterprise performance. As enterprises digital technology application capabilities mature and digital transformation improves, enterprises performance will gradually improve, which confirms H2.

The rationale for this, from the perspective of internal environment, is that the matching degree of enterprise management capabilities and digital transformation strategy has an important impact on the benign relationship between digital transformation and enterprise performance. If management capabilities lag behind the digital change, then introducing and integrating new digital technology is difficult to couple with the original resources and innovation process of the enterprise. The high-risk and high-cost (double high) problem of digital transformation makes some small and medium-sized enterprises fall into an insurmountable labor pain [67]. Following a survey of Chinese companies in its "win–win together" report released in 2020, Accenture noted that a lack of cross-departmental collaboration within companies increased the cost of investing in digitization by 7.7 %. In the external environment, the digital transformation of enterprises not only tests their ability to control digital technology and analytical activities, but ensuring sufficiently matching platform supervision, technology procurement contracts, social licensing system, and other related links also affects the enterprise digital technology dividend. In particular, a mismatch in the initial stage of small and medium-sized sporting goods manufacturing enterprises' digital transformation and external collaborative factors may inhibit performance improvement. Further coordination of the internal and external digital environment and maturity in the application of digital technology may promote improved performance. Supportive government policy is as important as technology platform support, which can inject strong vitality into the digital transformation of enterprises. For example, the Jinjiang Municipal Government has made great efforts to support digital Internet platform development in recent years, such as Yipingjia, Shoe Chuangyun, swimsuit warehouse, and others, establishing cloud incubation centers with leading domestic digital enterprises and providing solid digital technical support for sporting goods manufacturing enterprises.

4.4.3. Moderating effect of digital transformation on servitization and enterprise performance

According to the model (1) in Table 6, the regression coefficient of servitization is − 0.004 at a 1 % significance level. At the same time, models (9) and (11) in Table 7 suggest that the interaction term of servitization level and digital transformation (*SER* × *DIG*) are significant, and the coefficient is positive, indicating that the degree of digital transformation has a weak positive moderating effect between servitization level and enterprise performance, validating H3. The rationale for this is that digital technology can effectively advance the accurate search, positioning, and customization ability of enterprises in the service process and provide informed decision support [68]. Digital transformation is also a new expansion and primary focus of technological innovation in the manufacturing industry, which can improve the entire production + service chain, advance innovation in production servitization manufacturing, and promote the personalized service demand mining and large-scale customized service realization of manufacturing enterprises [69].

4.5. Robustness analysis

4.5.1. Endogeneity

The benchmark regression model controls for unobservable year and enterprise fixed effects, which alleviates endogeneity

Table 7
Test results for moderating effects of digital transformation.

Variables	(9)	(10)		(11)	(12)		
	FEM	2SLS		FEM	2SLS		
SER	−0.004***	−0.006***		−0.003**	−0.024*		
	(0.001)	(0.001)		(0.001)	(0.013)		
DIG	−0.000	−0.000		0.000	0.001		
	(0.000)	(0.000)		(0.000)	(0.003)		
SER×DIG				0.001**	0.002**		
				(0.000)	(0.001)		
Control variables	YES	YES		YES	YES		
Year fixed	YES	YES		YES	YES		
Individual fixed	YES	YES		YES	YES		
Adj-R²	0.615	0.610		0.616	0.611		
Log-likelihood	377.025			377.068			
L.SER		0.447**	−0.275**		0.271*	−0.426***(0.136)	1.354**
		(0.176)	(0.111)		(0.144)		(0.995)
L.DIG		0.046*	0.846***		−0.122*	0.788***(0.053)	−0.179**(0.084)
		(0.027)	(0.049)		(0.065)		
L.SER×DIG					0.058***	0.049***	0.208*
					(0.02)	(0.013)	(0.119)
F statistic	13.73	13.43/44.05		15.02	14.15/46.88/11.62		
Obs	231	231		231	231		

problems caused by sample selection and omission of variables to some extent. However, the improvement of enterprise performance may also provide sufficient capital to expand service-oriented business, introduce more advanced digital technology platforms, train digital technology personnel, and other benefits, implying two-way causality. At the same time, the correlation between explanatory variables and missing variables cannot be ruled out. The presence of endogeneity was further confirmed by the Hausman test, which found p = 0.0569 < 0.1. Referencing Xu et al., we use lag in servitization and digital transformation as instrumental variables to conduct 2SLS regression [70]. The results are presented in models (2), (4), (6), and (8) in Table 6, revealing that the conclusions still hold after considering potential endogeneity. In the digital moderating effect test, the degree of service orientation is considered to be an endogenous variable based on the previous analysis; thus, the interaction term between servitization and digitization can also be considered to be related to the error term. The traditional approach to accommodating endogenous interaction items is to introduce the interaction items of the tool variable and the modulator as the new tool variable [71]. Since servitization and enterprise performance are linear, there is no need to test the moderating effect of digitization on the square term and servitization performance. The 2SLS test results are presented in models (10) and (12) in Table 7, and the regression results are essentially unchanged. In addition, we conduct weak instrumental variable tests in Tables 6 and 7 The F statistic of the significance of instrumental variables exceeded the critical point of 10, and the p-value was 0.000, indicating that the selection of instrumental variables is appropriate, and the 2SLS test results had high confidence.

4.5.2. Robustness test

We also employ the method of replacing explanatory variables [72] and removing extreme values [73] to verify robustness with two tests. (1) Referencing Li et al. [61] to measure the performance level of enterprises using ROE. (2) Shrinking all variables by 1 %. In Table 8, models (13)–(16) are the test results of replacing the explanatory variables, and models (17)–(20) are the test results of tail shrinkage.

5. Conclusions

Drawing on the financial data of China's sports equipment manufacturers listed on A-share and China's New Third Board, this study corroborates the impact mechanism of servitization and digital transformation concerning the performance of sports equipment manufacturing firms using unbalanced panel data from 2000 to 2021. The key findings are as follows: (1) The degree of servitization of China's sporting goods manufacturing companies has a significant negative impact on the performance of the enterprises, with no evident nonlinear relationship, indicating the presence of a servitization paradox, which remains valid after replacing the core variables in the measurement method and applying instrumental variables in the endogeneity test. This extends the explanatory scope of Deutscher et al. [20], Gebauer et al. [3], and Xiao [74] on the "servitization paradox" of manufacturing industry, validating that it extends from the traditional manufacturing industry to the sporting goods manufacturing industry. Notably, unlike related qualitative research [10,27], this study complements the findings of the service-oriented study of the sporting goods manufacturing industry in China with quantitative empirical research, and arrives at different conclusions. Although the servitization strategy has been successful in some areas of China's manufacturing industry, considering the objective phenomena of China's sporting goods manufacturing industry such as overall undeveloped scientific and technological innovation ability, low brand value, immature product service systems, and other challenges, developing servicing business must be carefully considered based on the characteristics of enterprises' products, corporate cultures, and customer groups. (2) The impact of digital transformation on the performance of China's sporting goods manufacturing enterprises shows a positive U-shaped trajectory, inhibiting performance improvement in the early stage, with a positive impact as digital transformation deepens. This conclusion remains valid after replacing the core variables and using instrumental variables for endogeneity testing, which verifies the findings of Li et al. [39] and expands the sample to this research industry, while supplementing the empirical perspectives of Bai et al. [41] and Lin et al. [43] on digital transformation in China's sports

Table 8
Robustness test results.

Variables	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
	Replacement of explanatory variables				Winsorize			
SER	−0.003**(0.001)	−0.018 (0.012)			−0.004*** (0.001)	−0.003 (0.003)		
SER^2		0.001 (0.001)				−0.000 (0.000)		
DIG			−0.001 (0.001)	−0.004**(0.002)			0.001 (0.001)	−0.005*** (0.001)
DIG^2				0.001** (0.000)				0.003*** (0.001)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
Year fixed	YES	YES	YES	YES	YES	YES	YES	YES
Individual fixed	YES	YES	YES	YES	YES	YES	YES	YES
Adj-R^2	0.556	0.609	0.611	0.612	0.559	0.673	0.477	0.528
Log-likelihood	52.783	52.839	52.286	52.387	418.243	423.672	414.247	417.724
F statistic	8.38	9.73	14.05	18.33	8.8	9.77	15.3	11.82
Obs	231	231	231	231	231	231	231	231

industry. We determine that enhancing digital technology in sports enterprises has a trajectory of initial suppression and then enhancement. Digital technology only benefits enterprises after full integration and maturity. (3) Digital transformation also has a weak positive moderating effect on servitization and firm performance; a finding that still holds after replacing the core variable measures and applying instrumental variables for endogeneity tests. This is consistent with the findings of a similar study by Liu et al. [75] on the sporting goods manufacturing industry in China, which concluded that digitalization drives service-oriented transformation. However, this study also confirms on this basis that this driving role has not yet been fully achieved, and the inhibitory effect of servitization on firm performance cannot yet be remedied by digital transformation. However, with the continuous improvement of enterprise digital technology, the role of digitalization in upgrading the service-oriented transformation of China's sporting goods manufacturing enterprises and improving enterprise performance will become increasingly obvious.

6. Limitations and future research

Relying on the financial data of China's sports equipment manufacturing companies listed on the A-share and New Third Board, the mechanism of the influence of servitization and digital transformation on the performance of sports equipment manufacturing companies is authenticated with unbalanced panel data between the years 2000 and 2021; however, this study still has the following three constraints. First, due to the fact that the conceptual range for sports equipment manufacturing businesses in China has not been precisely delineated, some selection omissions of listed businesses in the sample of this study may have taken place. In addition, as mandatory disclosure of corporate financial data is not required for unlisted companies in China, financial data of unlisted small and medium-sized sporting goods manufacturing companies are not available, which means that they could not be included in the research sample. Second, this study considers all listed sports equipment companies as a whole, and the impact of different service product types and digital transformation methods on the performance of sports equipment manufacturing companies in different geographies and of different sizes may be inconsistent. Third, in the process of servitization and digital transformation influencing the performance of sports equipment manufacturers, other factors may have mediating, moderating, or threshold effects, which may have different impacts on the research results. For example, in 2019–2022, due to the impact of China's new crown epidemic prevention policy, residents' outdoor sports activities have substantially declined, causing online service business for China's sporting goods manufacturing enterprises to expand and offline service business to shrink, and all these factors have an impact on enterprise performance.

Therefore, in future studies, we procure financial data of small and medium-sized sports equipment manufacturing businesses in different regions of China through questionnaires and field research to probe the impact of servitization and digitization on the performance of sporting goods manufacturing firms of different sizes to conduct an in-depth and precise analysis. We also further enrich the examination of the heterogeneous effects of servitization and digital transformation on sporting goods manufacturing firms with different geographic locations, life cycles, years of establishment, and ownership structure characteristics, while considering the impacts of unforeseen events, sports industry policies, and residents' sports consumption habits on China's sporting goods manufacturing firms. We also combine the research on traditional manufacturing and high-tech enterprises to explore other factors affecting the performance improvement of China's sporting goods manufacturers and more comprehensively examine the impact of service level and digital transformation on the high-quality development of enterprises.

Ethical approval and consent to participate.

The authors declare that they have no known competing financial interests or personal relationships that seem to affect the work reported in this article. We declare that we have no human participants, human data, or human tissues.

Additional information

No additional information is available for this paper.

Availability of data and materials

All data are disclosed by listed companies in their annual reports on the start of work and sourced from CNINFO (http://www.cninfo.com.cn/new/index).

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CRediT authorship contribution statement

Heng Li: Writing – original draft. **Lai bing Lu:** Conceptualization. **Shaoxiong Yang:** Data curation.

Declaration of competing interest

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Laibing Lu reports financial support was provided by National Office of Philosophy and Social Sciences. If there are other authors,

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Appendix A. Supplementary data

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