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Research on the Impact of Digital Economy on the High-Quality Development of Supply Chain in China's Automotive Manufacturing Industry

Zilong Xu[1,*], Hanwen Zhang[2], Yuheng Mao[3]

[1]Master's degree in Logistics and Engineering Management, Hubei University of Automotive Technology, Ganzhou, Jiangxi Province, China

[2]Master's degree in Logistics and Engineering Management, Hubei University of Automotive Technology, Heilongjiang Province, China

[3]Master's degree in Logistics and Engineering Management, Hubei University of Automotive Technology, Shanxi Province, China

[*]Corresponding author

Abstract

At present, the digital economy is developing rapidly worldwide, and the global economic system is undergoing profound changes. As an important pillar of traditional industries, the transformation and upgrading of the automotive manufacturing industry's supply chain have a profound impact on the reshaping of the global industrial chain. Although China's automotive manufacturing industry has significant advantages in terms of the length of the industrial chain and the degree of technological integration, its position in the global value chain still faces many challenges, such as insufficient international competitiveness of domestic brands, lagging core technological innovation capabilities, and the immaturity of the development of the new energy vehicle field. This study is based on the data of A-share automotive manufacturing enterprises from 2009 to 2022. It employs a two-way fixed effects model for empirical analysis, aiming to comprehensively evaluate the mechanism of the digital economy's impact on the automotive manufacturing supply chain in terms of efficiency improvement, cost optimization, technological innovation, and green sustainable development. At the same time, the differences in supply chain development of enterprises with different property rights and scales under the background of the digital economy were also explored. The aim is to provide solid academic support and practical suggestions for the high-quality development of supply chains in China's automotive manufacturing industry in the digital economy era, and thereby enhance the competitiveness and status of China's automotive manufacturing industry in the global industrial chain.

Keywords

Digital Economy, Automobile Industry, Supply Chain Efficiency, Entropy Weight Method

1. Introduction

The automotive manufacturing industry is a vital pillar of the national economy. It features a long industrial chain, high interconnection and strong driving force, and plays a stabilizing role as the "ballast stone" for the steady growth of the industrial economy [1]. The "Automobile Industry Growth Stabilization Work Plan (2023-2024)" jointly issued by the Ministry of Finance and six other departments also sets out corresponding development goals, and emphasizes that the automobile industry should continue to operate within a reasonable range and the quality and efficiency of the industry should be further enhanced. However, with the increasingly diverse market demands and the intensifying competition, the automotive manufacturing supply chain is confronted with numerous challenges and pressures [2]. These include the insufficient competitiveness of domestic brands, prominent shortcomings in the industrial chain, weak core technological innovation capabilities, and lagging development in the new energy vehicle sector. Meanwhile, the automotive industry is also facing new and significant development opportunities: Firstly, the global automotive industry is evolving towards mobile intelligent terminals, energy storage units and digital spaces. Business models, consumption patterns, manufacturing methods, and profit channels are undergoing significant changes continuously, and the industrial ecosystem and competition landscape are being reshaped. Secondly, new technologies such as 5G and intelligent driving are rapidly evolving, bringing new opportunities for the high-quality development of the automotive industry. Thirdly, cars are gradually transforming from transportation tools into mobile intelligent terminals, creating and stimulating new consumption demands. Fourthly, accelerating the construction of a new development pattern, enhancing the autonomy and controllability of the automotive manufacturing industry's supply chain, and creating a more favorable environment. Fifthly, achieving "carbon peak and carbon neutrality", promoting energy conservation and emission reduction and high-quality development is imperative. Energy-saving and new energy vehicles, as well as intelligent connected vehicles, have become the main directions of innovation and development for the automotive industry [3].

The global automotive industry is rapidly advancing towards intelligence and new energy. Consumer demands are changing rapidly, and competition among enterprises is becoming increasingly intense. With the widespread application of digital technology, the impact of the digital economy on the supply chain of China's automotive manufacturing industry cannot be ignored [4]. Digital technology has provided more intelligent and efficient means and tools for supply chain management [5]. Through the digital operation model, China’s automotive manufacturing industry can better handle the information flow, logistics and capital flow in each link of the supply chain, improve the transparency and collaboration ability of the supply chain, and reduce the cost and risks of the supply chain. The digital economy has provided new opportunities for the innovation of the supply chain in China's automotive manufacturing industry [6]. In the era of digital economy, China's automotive manufacturing industry can leverage new technologies and new models to innovate the supply chain, promoting the transformation of the supply chain from the traditional linear supply chain to a digital, intelligent, and networked supply chain. In the era of digital economy, studying the impact of digital economy on the high-quality development of the supply chain in China's automotive manufacturing industry holds significant theoretical and practical significance. By deeply analyzing the impact mechanism of digital economy on the supply chain of China's automotive manufacturing industry, it can provide references and inspirations for the supply chain management of China's automotive manufacturing industry, and promote China's automotive manufacturing industry to accelerate the realization of high-quality development [7].

2. Literature Review

With the vigorous development of the digital economy, its impact on the high-quality development of China's automotive manufacturing supply chain has increasingly become the focus of attention from both the academic community and the industry [8]. Through the review and analysis of existing literature, it is clearly seen that the digital economy has played a significant role in enhancing supply chain efficiency, reducing costs, strengthening collaborative capabilities, and promoting transformation and upgrading.

Jingmin Wang et al. (2020) found that the innovation ability of the leading enterprise in the supply chain has a positive impact on supply chain efficiency [9]. It can facilitate the transformation of supply chain efficiency through technological empowerment, product innovation, and service extension. Lu Jin (2020) found that factors such as resource integration, data analysis, information sharing, and logistics support are significantly correlated with the efficiency of cross-border e-commerce supply chains [10]. In particular, the ability of information integration and data analysis will determine the overall trend of cross-border e-commerce in the future. Tao Zhao (2020) explored the effects of the digital economy on promoting high-quality urban development and the underlying mechanisms, and analyzed that the digital economy can empower high-quality development by enhancing entrepreneurial activity [11]. Tianjian Li and Xuejun Zhao (2022) emphasized in their research that the security of the industrial chain and supply chain stems from the essential requirements of industrialization, and it holds significant strategic importance for economic security and national security [12]. Shushan Zhang and Cheng Gu (2023) and others found that enterprise digital transformation can significantly reduce the inventory turnover days of enterprises and improve supply chain efficiency [13]. Moreover, some scholars conducted relevant empirical studies, further verifying the positive impact of the digital economy on the high-quality development of the automotive manufacturing supply chain [14]. The results show that enterprise digital transformation can significantly reduce the inventory turnover days and enhance supply chain efficiency, supply chain digitalization can improve the risk-bearing capacity of enterprises and maintain the security and stability of the supply chain [15]. At the same time, the innovation ability, resource integration ability, data analysis ability, etc. of the leading enterprises in the supply chain also have a significant positive impact on supply chain efficiency. These studies not only reveal the specific mechanism of the digital economy in the supply chain, but also provide strong evidence support for the digital transformation of the automotive manufacturing industry [16].

3. Model Research Design

3.1 Specification of Model

The bidirectional fixed effect model of this paper is as follow:

$$\begin{aligned} InEFFI_{it} &= \beta_0 + \beta_1 DIG_{it} + \beta_2 InSIZE_{it} + \beta_3 InLEV_{it} + \beta_4 InROA_{it} + \beta_5 InCASH_{it} + \beta_6 InMANAGE_{it} \\ &+ \beta_7 InSALE_{it} + \beta_8 InSOE_{it} + \mu_i + \theta_i + \varepsilon_{it} \end{aligned} \tag{1}$$

$EFFI_{it}$ represents the high-quality development of the automotive manufacturing supply chain, which is the dependent variable in this study. On the right side are the various independent variables. Among them, DIG_{it} is the core explanatory variable indicating the development of the digital economy, while the rest are control variables, including enterprise size ($SIZE_{it}$), debt ratio (LEV_{it}), return on assets (ROA_{it}), operating cash flow ($CASH_{it}$), management expense ratio ($MANAGE_{it}$), sales growth rate ($SALE_{it}$), and ownership nature (SOE_{it}). is the individual fixed effect of the panel data enterprise, is the time fixed effect of the panel data, and is the random disturbance term.

3.2 Variable Selection and Data Explanation

3.2.1 Variable Selection

(1) explained variable. The dependent variable is the high-quality development of the automotive manufacturing supply chain. Supply chain efficiency is used as the proxy indicator. Supply chain efficiency emphasizes enhancing the communication frequency and trade volume between upstream and downstream enterprises, and is manifested as the smooth circulation of product and service turnover. Existing studies use non-finished product inventory as the indicator to represent supply chain efficiency. However, only using the stock level to represent supply chain efficiency will ignore the mobility of factors among supply chain node enterprises. Therefore, in this paper, based on the inventory stock level of enterprises, the inventory turnover days are further used to reflect supply chain efficiency. The calculation method is ln(365/inventory turnover rate).

(2) Core explanatory variable. The five key measurement indicators selected in this article are as follows: Internet penetration rate, scale of Internet practitioners, economic value generated by the Internet, base of mobile Internet users, and inclusive development of digital finance, as shown in Table 1.

Table 1. Digital economy indicator system

Primary indicator	Secondary indicator	Third-level indicators
The development of the digital economy	The penetration rate of the Internet	Internet users per 100 people
	The number of employees related to the Internet	The proportion of personnel in the computer services and software industry
	The relevant outputs of the Internet	Per capita total telecommunications volume
	The number of mobile Internet users	Number of mobile phone users per 100 people
	The inclusive development of digital finance	China Digital Financial Inclusion Index

(3) The variables that need to be controlled. To improve the estimation accuracy in the empirical process, this paper selects seven variables, namely enterprise scale, asset-liability ratio, return on assets, operating cash flow, management expense ratio, sales growth rate and property rights nature, for control.

3.2.2 Data Declaration

The data description is shown in Table 2 below.

Table 2. Variable description and measurement methods

Types of variables	Variable name	Judgment method	Representations of variable
The variable being explained	High-quality development of the automotive manufacturing supply chain	Drawing on the research approach of Zhang Shushan (2023), using supply chain efficiency as the proxy indicator, the calculation method is ln(365/ inventory turnover rate), and the larger the value, the lower the supply chain efficiency.	effi
Core explanatory variable	The development of digital economy	The digital economy index of the prefecture-level city where the enterprise is located was calculated by the entropy weight method, drawing on the research approach of Zhao Tao (2020)	dig
The variables that need to be controlled	Firm size	The logarithm of a company's total assets	size
	Asset-liability ratio	The ratio of total liabilities to total assets	lev
	Return on assets	The ratio of net profit to total assets	roa
	Operational cash flow	Ratio of net cash flow to total assets	cash
	Management expense ratio	Ratio of administrative expenses to total assets	manage
	Sales growth rate	The ratio of the increase in main business revenue in the current year to the main business revenue of the previous year	sale
	Nature of property right	State-owned takes 1, non-state-owned takes 0	soe

Note: Data source: Csmar database

4. Research Results and Analysis

4.1 Benchmark Model Analysis

4.1.1 Correlation Coefficient Matrix

Table 3. Results of Correlation Coefficient Analysis

Variable	effi	dig	size	lev	roa	cash	manage	sale	soe
effi	1								
dig	-0.054**	1							
size	-0.403***	0.090***	1						
lev	-0.290***	-0.064***	0.435***	1					
roa	-0.082***	-0.032	-0.192***	-0.410***	1				
cash	-0.135***	0.006	-0.067***	-0.228***	0.451***	1			
manage	0.313***	-0.046*	-0.302***	-0.107***	-0.191***	-0.202***	1		
sale	-0.051**	-0.028	0.049**	0.04	0.205***	0.02	-0.133***	1	
soe	-0.386***	-0.086***	0.352***	0.335***	-0.176***	-0.091***	-0.098***	-0.036	1

Note: * p<0.1, ** p<0.05, *** p<0.01

Based on the descriptive statistical analysis of the variables, the results of the correlation coefficient analysis are shown in Table 3 above. If the correlation coefficient between two variables is 1, it indicates an absolute positive correlation, meaning that the change of one variable completely determines the synchronous change of the other variable, a correlation coefficient of 0 indicates no correlation at all, meaning that the change of one variable will not have any impact on the other variable, and -1 symbolizes a complete negative correlation, where the increase of one variable is accompanied by the decrease of the other variable.

4.1.2 Multilinear Test

Table 4. Results of multiple linear tests

Variable	Variance inflation factor	1/VIF
roa	1.59	0.627649
lev	1.53	0.652781
size	1.46	0.68495
cash	1.3	0.771159
manage	1.22	0.817383
soe	1.22	0.821049
sale	1.08	0.923925
dig	1.04	0.961602
Mean VIF	1.31	

According to the conventional standards, when the VIF (Variance Inflation Factor) value exceeds 10, it is generally regarded as a clear indication of a multiple collinearity problem. As shown in Table 4, the results show that the VIF values of all variables are below the standard threshold of 10, which ensures the robustness of the model. Thus, it can be concluded that there is no significant multiple collinearity phenomenon among the variables in this research model.

4.1.3 Model Setting Verification

Table 5. Model Setting Test Results

Test method	Statistical index	Statistic	P	Inspection result
F-test	F(156, 1499)	21.82	0.0000	Reject mixed regression and choose fixed-effect models
LM-test	chibar2(01)	3826.70	0.0000	Reject the mixed regression and choose the random effects model
Hausman test	chi2(9)	37.22	0.0000	Reject random effects and choose fixed-effect models

To ensure the accuracy of the analysis, corresponding tests must be carried out on various sample data to determine the most suitable model for selection, the test results are shown in Table 5. Firstly, the F-test is implemented to determine whether a mixed regression model is suitable. The F-statistic value is 21.82, exceeding the critical threshold. Based on this, we strongly reject the original hypothesis (the hypothesis about mixed regression). Such characteristics indicate that the hybrid regression model is not applicable. The current task requires us to make a choice between considering random effects and fixed effects models. Secondly, in order to evaluate the applicability of different models, the LM test was implemented. Based on the results of the Chibar2 statistical test, a clear conclusion was drawn. The null hypothesis was strongly rejected, supporting the adoption of the mixed regression model. The research results indicated that the data characteristics were not suitable for analysis using the random effects model, but were appropriate for statistical analysis using the fixed effects model. Finally, the Hausman test was implemented to examine whether a fixed effect existed. After the test, it was confirmed that the fixed effect did exist. Thus, it was concluded that the two-way fixed effects model was proven to be the most suitable method in this study.

4.1.4 Model Regression Results

Table 6. Results of Model Regression Analysis

Variable	(1) effi	(2) effi	(3) effi	(4) effi	(5) effi	(6) effi	(7) effi	(8) effi
dig	-0.662***	-0.691***	-0.688***	-0.649***	-0.644***	-0.604***	-0.604***	-0.589***
	(-3.609)	(-3.814)	(-3.793)	(-3.603)	(-3.585)	(-3.404)	(-3.408)	(-3.325)
size		-0.105***	-0.101***	-0.085***	-0.092***	-0.057***	-0.054***	-0.050**
		(-6.027)	(-5.454)	(-4.548)	(-4.910)	(-2.909)	(-2.768)	(-2.572)
lev			-0.048	-0.128*	-0.133*	-0.179**	-0.147*	-0.182**
			(-0.644)	(-1.673)	(-1.746)	(-2.361)	(-1.925)	(-2.342)
roa				-0.918***	-0.773***	-0.484**	-0.382*	-0.405**
				(-4.804)	(-3.953)	(-2.433)	(-1.900)	(-2.013)
cash					-0.554***	-0.418**	-0.423**	-0.404**
					(-3.307)	(-2.500)	(-2.536)	(-2.423)
manage						1.381***	1.277***	1.274***
						(6.158)	(5.648)	(5.638)
sale							-0.075***	-0.073***
							(-3.041)	(-2.979)
soe								-0.180**
								(-2.181)
_cons	4.605***	6.853***	6.790***	6.559***	6.745***	5.859***	5.796***	5.792***
	(83.042)	(18.175)	(17.427)	(16.827)	(17.183)	(14.164)	(14.031)	(14.041)
Enterprise fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effect	yes	yes	yes	yes	yes	yes	yes	yes
N	1677	1677	1677	1677	1677	1677	1677	1677
R^2	0.754	0.760	0.760	0.763	0.765	0.770	0.772	0.772
F	2.389***	4.703***	4.433***	5.591***	5.923***	7.745***	7.860***	7.731***

Note: * p<0.1, ** p<0.05, *** p<0.01.

As shown in Table 6, an empirical test on the two-way fixed effect model revealed that the digital economy index (dig) was statistically significantly negatively correlated with the dependent variable of automotive supply chain efficiency (effi), and this correlation passed the 1% significance level. However, since the dependent variable effi is a negative indicator, under the condition that other factors remain unchanged, for every 1 percentage point increase in the level of the digital economy, the supply chain efficiency of automotive manufacturing enterprises is expected to increase by approximately 0.589%.

4.2 Heterogeneity Analysis

4.2.1 Heterogeneity of Property Rights

Table 7. Results of Heterogeneity Analysis of Property Rights

Variable	(9) effi	(10) effi	(11) effi	(12) effi
	Non state-owned enterprises		State-owned business	
dig	-0.837***	-0.716***	-0.444	-0.269
	(-3.789)	(-3.362)	(-1.379)	(-0.905)
size			-0.024	-0.215***
			(-0.941)	(-5.887)
lev			-0.122	0.199
			(-1.418)	(1.060)
roa			-0.051	-0.418
			(-0.229)	(-0.891)
cash			-0.432**	-0.408
			(-1.986)	(-1.573)
manage			1.881***	2.485***
			(7.276)	(4.436)
sale			-0.060**	-0.074*
			(-2.094)	(-1.713)
soe			0.000	0.000
			(.)	(.)
_cons	4.696***	5.152***	4.314***	8.818***
	(68.701)	(9.684)	(45.854)	(11.154)
Enterprise fixed effect	yes	yes	yes	yes
Year fixed effect	yes	yes	yes	yes
N	1151	1151	526	526
R^2	0.723	0.744	0.719	0.767
F	3.578***	7.278***	2.534***	7.241***

Note: The values in parentheses are t-statistics,* p<0.1, ** p<0.05, *** p<0.01.

As shown in Table 7, through the test of property rights nature and scale heterogeneity, it was found that in the sample of non-state-owned enterprises, the impact of the digital economy on the high-quality development of the supply chain of automotive manufacturing enterprises passed the 1% significance level. However, in the sample of state-owned enterprises, no significant effect was found. Therefore, the impact in non-state-owned enterprises was more significant, indicating that there is property rights heterogeneity in the impact of the digital economy on the high-quality development of the supply chain of automotive manufacturing enterprises.

4.2.2 Scale Heterogeneity

Table 8. Results of Scale Heterogeneity Analysis

Variable	(13) effi	(14) effi	(15) effi	(16) effi
	Non state-owned enterprises		State-owned business	
dig	-0.647***	-0.457*	-0.873***	-0.851***
	(-2.603)	(-1.856)	(-3.496)	(-3.636)
size			-0.027	0.028
			(-0.675)	(0.765)
lev			-0.334**	-0.087
			(-2.378)	(-0.929)
roa			-0.149	-0.714***
			(-0.472)	(-3.066)
cash			-0.511**	-0.261
			(-2.301)	(-1.204)
manage			2.008***	1.831***
			(5.069)	(6.668)
sale			-0.024	-0.119***
			(-0.785)	(-3.053)
soe			-0.198*	-0.228
			(-1.935)	(-0.625)
_cons	4.498***	5.281***	4.705***	4.165***
	(58.694)	(5.976)	(62.151)	(5.461)
Enterprise fixed effect	yes	yes	yes	yes
Year fixed effect	yes	yes	yes	yes
N	839	839	838	838
R^2	0.808	0.819	0.735	0.768
F	2.682***	4.311***	3.134***	7.465***

Note: The values in parentheses are t-statistics,* p<0.1, ** p<0.05, *** p<0.01.

Based on the median size of enterprises, the range is divided into high-scale group (above the median) and low-scale sample group (below the median). As shown in Table 8, through the test, it was found that in the low-scale sample group, the impact of the digital economy on the high-quality development of the supply chain of automotive manufacturing enterprises was relatively significant, passing the 1% significance level. However, in the high-scale group, it only passed the 10% significance level. Therefore, in low-scale manufacturing enterprises, the impact was more significant, indicating that there is also scale heterogeneity in the impact of the digital economy on the high-quality development of the supply chain of automotive manufacturing enterprises.

4.3 Robustness Test

Table 9. Results of Robustness tests

Variable	(17) effi	(18) effi	(19) effi	(20) effi	(21) effi	(22) effi
	Substitution variable method		Replacement measurement method		Change the tailing processing interval	
dig2	-0.720***	-0.581**				
	(-3.060)	(-2.533)				
dig3			-0.123***	-0.105***		
			(-4.103)	(-3.605)		
dig					-0.591***	-0.516***
					(-3.893)	(-3.553)
size		-0.087***		-0.049**		-0.040**
		(-3.564)		(-2.515)		(-2.412)
lev		-0.083		-0.185**		-0.157**
		(-0.788)		(-2.380)		(-2.256)
roa		0.210		-0.406**		-1.202***
		(0.804)		(-2.019)		(-5.098)
cash		-0.453**		-0.400**		-0.445***
		(-2.407)		(-2.402)		(-2.651)
manage		1.390***		1.271***		2.677***
		(5.133)		(5.628)		(7.622)
sale		-0.112***		-0.072***		-0.014
		(-4.036)		(-2.921)		(-0.423)
soe		-0.020		-0.178**		-0.171**
		(-0.206)		(-2.152)		(-2.468)
_cons	4.663***	6.460***	4.390***	5.579***	4.587***	5.502***
	(60.928)	(12.495)	(108.844)	(13.671)	(94.715)	(15.604)
Enterprise fixed effect	yes	yes	yes	yes	yes	yes
Year fixed effect	yes	yes	yes	yes	yes	yes
N	1246	1246	1677	1677	1677	1677
R^2	0.778	0.798	0.755	0.772	0.769	0.791
F	2.446***	7.680***	2.664***	7.833***	3.012***	10.089***

Note: The values in parentheses are t-statistics,* p<0.1, ** p<0.05, *** p<0.01.

As shown in Table 9, this paper mainly conducts robustness tests through three methods:

(1) Alternative Variable Method: The degree of enterprise digital transformation, denoted as dig2, was substituted for dig in the model and the two-way fixed effects model was re-applied for estimation. The test results revealed that dig2 passed the 1% significance level, and the outcome was significantly negative, which was consistent with the previous conclusion. Therefore, the results remain robust and reliable.

(2) Replacement of the measurement method for digital economy: The entropy method was modified to the factor analysis method to recalculate the level of digital economic development. After substituting the new measured variables into the model and conducting the test, it was found that the digital economy dig3 measured by the factor analysis method also passed the significance level of 1% and the sign of the regression coefficient remained unchanged. Therefore, the above empirical results are relatively robust and have passed the robustness test.

(3) Adjust the truncation processing range: For all continuous variables, change to perform truncation processing at the 5% level on both sides. After re-running the model, it was found that the conclusion remained unchanged, indicating that the empirical results are relatively robust.

5. Research Conclusions and Policy Recommendations

5.1 Research Conclusions

Taking the A-share automotive manufacturing companies from 2009 to 2022 as the research sample and the digital economy index of the prefecture-level cities where automotive manufacturing enterprises are located as the research data, and based on the perspective of enterprise inventory turnover, this study comprehensively reveals the impact effect and heterogeneity manifestation of digital economic development on the development of the automotive manufacturing supply chain. The research finds that digital economic development has promoted the development of the automotive manufacturing supply chain. After a series of robustness tests, the above conclusion still holds. The heterogeneity analysis results show that in the samples of non-state-owned enterprises and small-scale enterprises, the impact effect of digital economy on the development of the automotive manufacturing supply chain is more significant.

5.2 Policy Suggestion

Firstly, automotive manufacturing enterprises should increase their investment in digital technology and promote the construction of the digital economy. By introducing advanced digital tools and platforms, enterprises can optimize supply chain management processes, enhance supply chain efficiency, reduce costs, and strengthen competitiveness.

Secondly, enterprises should formulate personalized digital transformation strategies based on their own scale and characteristics. For small-scale enterprises, they can place more emphasis on the improvement of innovation capabilities and flexibility, for large-scale enterprises, they need to pay more attention to the optimization of organizational structure and process reengineering to overcome the obstacles of digital transformation. In addition, the government and various social sectors should also provide support and assistance to automotive manufacturing enterprises in their digital transformation. The government can introduce relevant policies to encourage enterprises to increase investment in digital technology, at the same time, industry associations, research institutions, etc. can also provide relevant training and guidance services to help enterprises better cope with the challenges of digital transformation. Finally, we should also continuously pay attention to the long-term impact of the digital economy on the high-quality development of the supply chain of automotive manufacturing enterprises, and adjust and optimize relevant strategies and suggestions according to actual circumstances.

In conclusion, the digital economy has a significant impact on the high-quality development of the supply chain of automotive manufacturing enterprises. Enterprises, governments, and all sectors of society should work together to promote the in-depth development of digital transformation, in order to achieve the sustained prosperity and high-quality development of the automotive manufacturing industry.

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