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Empowering Enterprises' New Quality Productive Forces Through Digital Supply Chains: Mechanisms and Policy Implications

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Abstract: As a core component of digital transformation, the digital supply chain serves as a critical driving force behind the qualitative leap in enterprise productivity. Based on panel data from China's A-share main board listed companies in Shanghai and Shenzhen from 2015 to 2022, this study builds on existing research to conduct an in-depth analysis of the impact and mechanisms through which digital supply chains influence enterprises' new quality productive forces. The results reveal that: (1) Digital supply chains significantly and positively enhance enterprises' new quality productive forces, a finding that holds robust across various tests; (2) Digital supply chains foster the development of new quality productive forces by reducing supplier concentration; (3) The power structure of corporate management plays an important moderating role, with board size exerting a negative moderating effect, while equity dispersion has a positive moderating effect; (4) These effects exhibit notable heterogeneity across ownership types, firm sizes, and regions. The findings of this study not only enrich the theoretical understanding of digital supply chains and new quality productive forces, but also offer practical pathways for policymakers and enterprise managers in China to seize the opportunities of digital transformation.

Keywords: Digital Supply Chain, New Quality Productive Forces, Supply Chain Resilience, Managerial Power Structure

1. Introduction

The widespread integration of the digital economy is reshaping the competitive landscape of enterprises by fostering the development of new quality productive forces. Digital technologies enhance supply chain transparency and optimize management processes, thereby improving operational efficiency and responsiveness [1]. Moreover, supply chains facilitate the accelerated transformation of innovation outcomes, contributing to improvements in total factor productivity driven by new quality productive forces. However, traditional supply chain models are often plagued by inefficiencies, high transaction costs, long delivery cycles, and poor information flow, which hinder the maintenance of competitive advantages. As a result, enterprises urgently need to undergo digital transformation to build more resilient supply chain systems. Research into the relationship between digital supply chains and new quality productive forces not only addresses these challenges but also promotes industrial upgrading and sustainable development.

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Although previous studies have examined the impact of digital supply chains from both macro and micro perspectives, they often suffer from limited analytical dimensions and fail to comprehensively reflect policy effects. Therefore, this paper adopts an interdisciplinary perspective that integrates innovation-driven theory, supply chain collaboration theory, and management decision-making theory. Based on panel data from A-share main board listed companies in Shanghai and Shenzhen from 2015 to 2022, this study employs a dual fixed-effects panel regression model to investigate the relationship between digital supply chains and enterprises' new quality productive forces, along with the underlying mechanisms. The marginal contributions of this paper are as follows: First, it expands the research on the economic consequences of digital supply chains by breaking through traditional analytical constraints and extending the focus to the field of new quality productive forces. It reveals the mediating role of supply chain resilience and broadens the application boundaries of contingency theory. Second, it supplements existing research by exploring the specific mechanisms through which digital supply chains influence new quality productive forces. Through heterogeneity analysis, the paper uncovers the differentiated enhancement effects of digital supply chains on new quality productive forces across various ownership structures, industry characteristics, and regional contexts, and proposes a portfolio of policy recommendations to support the in-depth application of digital supply chains.

The remainder of this paper is organized as follows: theoretical analysis and research hypotheses; research design and descriptive statistics; empirical analysis; mechanism testing and heterogeneity analysis; conclusion and policy recommendations.

2. Theoretical analysis and research hypotheses

2.1. Digital supply chains promote the development of new quality productive forces

Technological innovation serves as the core engine for unleashing new quality productive forces. The digital supply chain systematically reconstructs the operational model of traditional supply chains [2], enabling end-to-end data integration through technologies such as the Internet of Things and blockchain. This effectively reduces information costs and alleviates information asymmetry [3]. From the perspective of organizational transformation, decentralized networks built on digital platforms facilitate the evolution of supply chains from linear structures to ecosystems characterized by collaborative innovation. Digital twin technology enables virtual verification, thereby reducing the cost of developing complex products. In summary, the following hypothesis is proposed:

H1: Digital supply chains promote the improvement of new quality productive forces.

2.2. Digital supply chains promote new quality productive forces by enhancing supply chain resilience

The development of digital supply chains helps reduce supplier concentration. Technologies such as big data and the Internet of Things enable firms to acquire more comprehensive and accurate information about suppliers, making it easier to identify high-quality, high-risk, or competitive suppliers. This reduces dependence on a small number of suppliers and lowers supplier concentration. Furthermore, reduced supplier concentration enhances supply chain resilience. In the face of market demand fluctuations or emergencies, firms can more swiftly adjust procurement strategies, optimize resource allocation, and ensure stable supply chain operations [4]. Finally, enhanced supply chain resilience supports the development of new quality productive forces. Greater resilience facilitates better integration of various resources across the supply chain, allowing for precise allocation and efficient utilization—thus providing a solid material foundation for advancing new quality productive forces. In summary, the following hypothesis is proposed:

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H2: Digital supply chains promote the development of new quality productive forces by enhancing supply chain resilience.

2.3. Managerial power moderates the impact of digital supply chains on new quality productive forces

The effectiveness of digital supply chains is influenced by managerial decision-making centralization, the degree of checks and balances, and the alignment of interests. Current research presents conflicting views on the moderating role of managerial power. On the positive side, high decision-making centralization accelerates decision speed [2] ; a moderate degree of checks and balances aids risk control [5] ; firms with dispersed ownership and a moderate proportion of internal directors tend to make more prudent decisions; and a high level of managerial shareholding encourages long-term investment and fosters the development of new quality productive forces. On the negative side, excessive decision-making centralization can result in unbalanced development; insufficient checks and balances may lead to resource waste; and low or no managerial shareholding may cause a focus on short-term interests, hindering sustainable growth. In summary, the following hypothesis is proposed:

H3: Managerial power moderates the impact of digital supply chains on new quality productive forces.

3. Research design and descriptive statistics

3.1. Sample selection and data sources

Considering data availability, this study selects A-share listed companies on the Shanghai Main Board and Shenzhen Main Board from 2015 to 2022 as the initial sample. Following the approach of Jian Guanqun and Bai Feifan [6], the sample is processed as follows: (1) ST and *ST stocks are excluded; (2) companies in the financial industry are excluded; (3) firms with negative net assets are excluded; (4) companies that are suspended from listing or have been delisted are excluded. To mitigate the influence of extreme values on the analysis results, the top and bottom 1% of the sample is winsorized. The final sample comprises 13,972 firm-year observations. Data are primarily obtained from the CSMAR and WIND databases, with some regional data sourced from statistical yearbooks.

3.2. Model construction and variable definitions

To test the proposed hypotheses, the following model is constructed:

$$lnNQP_{it} = \alpha_0 + \alpha_1 DSC_{it} + \alpha_2 Controls_{it} + \mu_i + \sigma_i + \varepsilon_{it} \#(1)$$

Where i denotes the firm, t denotes the year, μ_i and σ_i represent firm and year fixed effects respectively, and ε_{it} is the error term. The dependent variable lnNQP_{it} represents firm i's new quality productive forces in year t; the independent variable DSC_{it} represents the level of digital supply chain finance for firm i in year t; $\mathrm{Controls}_{it}$ denotes the set of control variables.

3.2.1. Independent variable

Digital Supply Chain (DSC). Based on Zhang Lina et al. [7] and Zhang Huiping [8], and considering that digital supply chains use digital technologies to upgrade traditional supply chains toward digitalization, intelligence, and collaboration, five indicators are selected: artificial intelligence technology, blockchain technology, cloud computing, big data, and digital technology applications. The word frequency count (plus one) of these terms is taken and log-transformed to construct the DSC variable.

DOI: 10.54254/2754-1169/2025.AB24196

3.2.2. Dependent variable

Firm New Quality Productive Forces (lnNQP). Drawing on the study by Song Jia et al. [9], this paper constructs an index system of new quality productive forces based on four dimensions: living labour, materialized labour, hard technology, and soft technology. Each tier of indicators is assigned a specific weight, and the weighted sum is then log-transformed to obtain the firm's new quality productivity index (lnNQP). The detailed indicator system is shown in Table 1.

Table 1. Dependent variable: Firm New Quality Productive Forces (lnNQP)

Primary Indicator	Secondary Indicator	Tertiary Indicator	Indicator Description	Weight
Firm New Quality Productivity	Living Labour	Proportion of R&D Salaries	(R&D expenditure on salaries and wages) / (Operating income)	28
		Proportion of R&D Staff	(Number of R&D staff) / (Total number of employees)	4
		Proportion of Highly Educated Staff	(Number of bachelor's degree holders or above) / (Total number of employees)	3
	Materialized Labour (Objects of Labour)	Fixed Asset Ratio	(Fixed assets) / (Total assets)	2
		Manufacturing Cost Ratio	(Total cash outflows from operating activities + depreciation of fixed assets + amortization of intangible assets + impairment losses – Cash paid for goods and services + wages paid to employees) / Total cash outflows from operating activities + depreciation + amortization + impairment losses	1
	Hard Technology	R&D Depreciation and Amortization Ratio	(R&D depreciation and amortization) / (Operating income)	27
		R&D Lease Expense Ratio	(R&D lease expenditure) / (Operating income)	2
		Direct R&D Investment Ratio	(Direct R&D investment) / (Operating income)	28
		Intangible Asset Ratio	(Intangible assets) / (Total assets)	3
	Soft Technology	Total Asset Turnover	(Operating income) / (Average total assets)	1
		Inverse of Equity Multiplier	(Owner's equity) / (Total assets)	1

3.2.3. Control variables

Based on prior studies [6][10][11], five control variables are selected: firm ownership type (ENID, SOE = 1, private = 0), firm age (BYear, current year minus year of establishment), leverage ratio (Lev = total liabilities / total assets × 100%), return on equity (ROE = net profit / average shareholders' equity), and industry code (incode).

DOI: 10.54254/2754-1169/2025.AB24196

3.2.4. Mediating variable

Supply Chain Resilience (Spc). Following Gao Xuepeng and Zhao Rongrong [12], supplier concentration is used as a reverse indicator of supply chain resilience.

3.2.5. Moderating variable

Managerial Power (power). Based on Zheng Shanshan [13], managerial power is measured using a set of indicators: whether the CEO and Chairman roles are held by the same person, board size, proportion of internal directors, ownership dispersion, and management ownership. The specific definitions of variables are listed in Table 2.

Table 2. Variable definition table

Variable Type	Variable Name	Symbol	Definition
Dependent Variable	Firm New Quality Productivity	lnNQP	Includes four dimensions: living labour, materialized labour, hard technology, and soft technology
Independent Variable	Digital Supply Chain	DSC	Logarithm of word frequency (plus one) for AI, blockchain, cloud computing, big data, and digital tech use
Control Variable	Ownership Type	ENID	SOE = 1, private = 0
	Industry Attribute	incode	Based on the industrial classification standards issued by the National Bureau of Statistics
	Firm Age	BYear	Number of years since the firm's establishment
	Leverage Ratio	Lev	(Total liabilities / Total assets) × 100%
	Return on Equity	ROE	Net profit / Average shareholders' equity
Mediating Variable	Supply Chain Resilience	Spc	Supplier concentration (reverse indicator)
Moderating Variable	Managerial Power	power1	Whether CEO and Chairman are the same person (Yes = 1, No = 0)
		power2	Board size = total number of directors in the year
		power3	Proportion of internal directors = number of internal directors / total number of directors
		power4	Ownership dispersion = shareholding of 2nd–10th largest shareholders / shareholding of largest shareholder
		power5	Proportion of management shareholding

3.3. Descriptive statistics

Table 3 presents the descriptive statistics. The dependent variable ranges from a minimum of 0.148 to a maximum of 1.969, with a mean of 1.027 and a standard deviation of 0.341, indicating that the distribution of firms' new quality productivity is relatively concentrated, though it shows a certain degree of volatility. The independent variable ranges from 0.000 to 5.328, with a mean of 0.960 and a standard deviation of 1.061, suggesting that during the sample period, there is considerable variation

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in the adoption and development of digital supply chains across firms, with substantial fluctuation. This highlights the relevance and feasibility of the present study.

Table 3. Descriptive statistics

	Variable	Observations	Mean	Std. Dev.	Min	Max
Dependent Variable	lnNQP	13972	1.027	0.341	0.148	1.969
Independent Variable	DSC	13972	0.960	1.061	0.000	5.328
Control Variables	ENID	13972	0.370	0.483	0.000	1.000
	incode	13972	31.841	11.910	3.000	61.000
	BYear	13972	20.846	5.632	9.000	37.000
	Lev	13972	0.434	0.190	0.071	0.884
	ROE	13972	0.067	0.118	-0.503	0.350
Mediating Variables	SA	13972	1.832	0.880	0.231	4.909
	Spc	13972	33.036	19.084	5.280	89.920
Moderating Variables	power1	13,778	0.266	0.442	0.000	1.000
	power2	13,778	8.509	1.622	4.000	17.000
	power3	13,778	62.491	5.469	20.000	85.710
	power4	13,778	0.908	0.753	0.015	6.412
	power5	13,778	11.923	18.755	0.000	89.990

4. Empirical analysis

4.1. Baseline regression results

Table 4 reports the regression results of Model (2) using the sample data. In column (1), the coefficient of digital supply chain is 0.040 and is significantly positive at the 1% level, indicating that the digital supply chain has a positive impact on firms' new quality productivity. In column (2), the coefficient remains significantly positive at the 1% level even after including control variables, confirming the robustness of the positive impact. In column (3), after including firm and time fixed effects, the coefficient of digital supply chain is still significantly positive at the 1% level, demonstrating that the positive effect of the digital supply chain on new quality productivity is robust.

This supports Hypothesis H1, which states that the digital supply chain positively affects firms' new quality productivity.

Table 4. Baseline regression results

	(1)	(2)	(3)
	lnNQP	lnNQP	lnNQP
DSC	0.040***	0.038***	0.009***
	(6.188)	(6.440)	(3.130)
Control Variables	NO	YES	YES
Observations	13972	13972	13972
Time Fixed Effects	NO	NO	YES
Individual Fixed Effects	NO	NO	YES
Robust Standard Errors	NO	NO	NO
Clustered Standard Errors	YES	YES	YES
R^2	0.016	0.107	0.127

Table 4: (continued).

Note: Figures in parentheses are t-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively (same in the following tables). Cluster-robust standard errors are calculated at the firm level.

4.2. Robustness tests

4.2.1. Instrumental variable test

Referring to the study by Liu Jiang and Zhao Pengrui [14], this paper selects the internet penetration rate in the province where the firm is registered (Inter_p) as an instrumental variable. Table 5 presents the test results using a two-stage regression method. The coefficient of DSC estimated by the instrumental variable approach is 0.483 and is statistically significant at the 1% level, which is largely consistent with the baseline regression results, indicating that the findings of this study remain robust. The F-statistic is 127.11, far exceeding the critical threshold of 16.38 for a 10% bias, suggesting no issue of weak instruments. The LM statistic is 45.864 and significant at the 1% level, further confirming the validity of using internet penetration as an instrumental variable. This provides additional support for Hypothesis H1: the digital supply chain promotes the development of new quality productive forces in firms.

Table 5. Instrumental variable regression results

Variable	(1) First DSC	(2) Second lnNQP
internet_penetration	1.108***	
	(11.55)	
DSC		0.483***
		(10.01)
Observations	13,972	13,972
R^2	0.067	0.732
Control Variables	YES	YES
Time Fixed Effects	YES	YES
Individual Fixed Effects	YES	YES
LM Statistic	45.86	
F Statistic	127.108	

Note: Figures in parentheses are t-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively (same in the following tables). Cluster-robust standard errors are calculated at the firm level.

4.2.2. Other robustness tests

Following Wu Weiwei et al. [15] this study conducts three additional robustness checks: excluding municipalities, lagging the core explanatory variable, and altering the measurement of the core explanatory variable. Detailed results are shown in Table 6.

Column (1) excludes panel data for the four Chinese municipalities—Beijing, Tianjin, Shanghai, and Chongqing. The results show that DSC has a significantly positive effect on lnNpro, consistent with the baseline regression, indicating the robustness of the positive correlation. To address potential endogeneity, Column (2) lags the explanatory variable by one period. The results again show a significantly positive effect of DSC on lnNpro, confirming the robustness of the positive correlation. Column (3) replaces the explanatory variable with a new measure: the natural logarithm of the ratio of R&D expenditure to total revenue (i.e., R&D investment intensity, ln_RDintensity). The DSC

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coefficient is 0.979 and significant at the 1% level, consistent with the baseline results, further validating the robustness of the positive relationship.

Table 6. Results of additional robustness tests

	(1)	(2)	(3)
	lnNpro	lnNpro	lnNpro
DSC	0.008^{***}	0.007^{***}	0.979^{***}
	(2.55)	(2.65)	(12.80)
Control Variables	YES	YES	YES
Individual Fixed Effects	YES	YES	YES
Time Fixed Effects	YES	YES	YES
Clustered Standard Errors	YES	YES	YES
Observations	11712	13,972	13,972
R^2	0.130	0.015	0.143

Note: Figures in parentheses are t-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively (same in the following tables). Cluster-robust standard errors are calculated at the firm level.

5. Mechanism test and heterogeneity analysis

5.1. Mechanism test

This study explores the mediating and moderating mechanisms through which the digital supply chain influences the development of enterprises' new quality productive forces, focusing on supplier concentration and managerial power. The regression results are shown in Table 7.

Column (1) examines whether supplier concentration plays a mediating role. The coefficient of DSC on Spc is -0.428 and is significant at the 5% level, indicating that the digital supply chain significantly reduces supplier concentration, thereby enhancing supply chain resilience. A strong supply chain resilience can help firms maintain stable production and supply during crises, which in turn gives rise to innovation-driven new quality productive forces. Thus, Hypothesis H2, which posits that the digital supply chain promotes the development of new quality productive forces by enhancing supply chain resilience, is supported.

Columns (2) through (6) test whether managerial power exerts a moderating effect. In Column (3), the coefficient of DSC is 0.008 and is significant at the 1% level. The interaction term coefficient is -0.002 and also significant at the 1% level, indicating that board size weakens the positive effect of DSC on lnNQP, demonstrating a significant negative moderating effect. Building on this, Francis J et al. [16] found a negative relationship between board size and debt costs, thereby weakening the development of new quality productive forces in enterprises. In Column (5), the coefficient of DSC is 0.007 and is significant at the 1% level, while the interaction term coefficient is 0.007 and significant at the 10% level, indicating that equity dispersion strengthens the positive relationship between DSC and lnNQP, showing a significant positive moderating effect. This aligns with the findings of Aghion et al. [17], who concluded that equity dispersion promotes innovation, thus positively contributing to the development of new quality productive forces. In Columns (2), (4), and (6), the signs and statistical significance of the interaction term coefficients are inconsistent or not significant, indicating no clear moderating effect. Therefore, Hypothesis H3, which posits that managerial power moderates the relationship between the digital supply chain and new quality productive forces, is partially supported. Specifically, board size weakens while equity dispersion strengthens the positive impact of DSC on lnNQP.

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Table 7. Mechanism test results

Variable	(1) Spc	(2) lnNQP	(3) lnNQP	(4) lnNQP	(5) lnNQP	(6) lnNQP
DSC	-0.428**	0.008***	0.008***	0.008***	0.007***	0.008***
	(-2.44)	(2.94)	(2.86)	(2.91)	(2.85)	(2.90)
power1		-0.004				
		(-0.64)				
power2			0.002			
			(1.16)			
power3				0.000		
				(0.11)		
power4					0.001	
					(0.08)	
power5						0.001***
						(2.04)
power1×DSC		0.002				
		(0.43)				
power2×DSC			-0.002***			
			(-1.65)			
power3×DSC				-0.001		
				(-1.33)		
power4×DSC					0.007*	
					(1.93)	
power5×DSC						-0.000
						(-1.15)
Control Variables	YES	YES	YES	YES	YES	YES
Observations	13972	13778	13778	13778	13778	13778
Time Fixed Effects	YES	YES	YES	YES	YES	YES
Individual Fixed Effects	YES	YES	YES	YES	YES	YES
Clustered Standard Errors	YES	YES	YES	YES	YES	YES
R^2	0.002	0.125	0.127	0.126	0.125	0.124
F	4.07	89.96	90.03	90.09	92.71	90.10

Note: Figures in parentheses are t-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively (same in the following tables). Cluster-robust standard errors are calculated at the firm level.

5.2. Heterogeneity analysis

Drawing on the study by Wang Ying et al. [18], this paper explores the differentiated pathways through which digital supply chain finance influences enterprise new quality productivity from three perspectives: ownership nature (ENID), enterprise size (ES), and regional location (eara). The regression results are presented in Table 8.

5.2.1. Enterprise Ownership Nature (ENID)

Column (1) shows that for state-owned enterprises, the coefficient of DSC on lnNQP is 0.006 and not statistically significant. Column (2) shows that for private enterprises, the coefficient of DSC on

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lnNQP is 0.011 and significant at the 5% level, indicating that the digital supply chain has a more pronounced effect on enhancing the new quality productivity of private enterprises.

5.2.2. Enterprise Size (ES)

Enterprises are divided into large and small firms based on total assets, with those above the average classified as large. Column (3) reports the regression results for large enterprises, while Column (4) presents those for small enterprises. The results indicate that the digital supply chain has a more significant positive effect on the new quality productivity of smaller firms.

5.2.3. Regional Location (eara)

Column (5) shows that for enterprises in the eastern region, the coefficient of DSC on lnNQP is 0.010 and significant at the 1% level. In contrast, Column (6) shows that for enterprises in the western region, the coefficient is 0.012 but not significant; Column (7) shows a coefficient of 0.003 for central region enterprises, which is also not significant. These findings suggest that the effectiveness of the digital supply chain varies by region.

Table 8. Heterogeneity analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	lnNpro	lnNpro	lnNpro	lnNpro	lnNpro	lnNpro	lnNpro
DSC	0.006	0.011**	-0.001	0.013***	0.010**	0.012	0.003
	(1.26)	(3.13)	(-0.39)	(3.40)	(2.97)	(1.55)	(0.46)
Control Variables	YES	YES	YES	YES	YES	YES	YES
Individual Fixed Effects	YES	YES	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES	YES	YES
Clustered Standard Errors	YES	YES	YES	YES	YES	YES	YES
Observations	5173	8799	6239	7733	9557	2027	2306
R^2	0.135	0.090	0.104	0.118	0.129	0.092	0.139

Note: Figures in parentheses are t-values. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively (same in the following tables). Cluster-robust standard errors are calculated at the firm level.

6. Conclusion and policy recommendations

This empirical study demonstrates a significant positive impact of the digital supply chain on enterprises' new quality productivity and confirms its robustness through various tests. Further analysis reveals that the digital supply chain enhances new quality productivity by improving supply chain resilience. Moreover, the power structure of corporate governance plays a moderating role in this relationship: larger board sizes weaken the positive effect of digital supply chains, while higher equity dispersion strengthens it. Heterogeneity analysis shows that the digital supply chain's impact varies based on ownership type, enterprise size, and geographic location. Based on these findings, the following recommendations are proposed: First, promote the comprehensive integration of the digital supply chain through a "technology–governance–ecosystem" triad. On the technological front, promote low-barrier digital tools for SMEs and enterprises in the western region, while supporting leading firms in the east in developing high-end technologies. On the governance front, optimize power structures by establishing dynamic board adjustment mechanisms and encouraging reforms to

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increase equity dispersion. On the ecosystem front, build resilient industry chain communities, enable data interconnectivity, and establish paired cooperation mechanisms among eastern, central, and western enterprises. Second, establish a decision-making implementation guarantee mechanism. Develop a dynamic monitoring system for the Digital Supply Chain Resilience Index (DS-RI), set up an interdepartmental digital supply chain policy committee, and establish a digital supply chain emergency safety fund.

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