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Research on the Mechanisms and Countermeasures for Digital Trade to Promote the Upgrading of China's Manufacturing Industry

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ABSTRACT

This paper constructs indicators for manufacturing upgrading and digital trade development using provincial-level panel data from China. It empirically analyses the impact and underlying mechanisms of digital trade on manufacturing upgrading. Findings reveal that the level of digital trade development exerts a significant and robust positive influence on manufacturing upgrading. Mechanism analysis indicates that technological innovation plays a mediating role in digital trade's promotion of manufacturing upgrading, albeit with short-term conversion lags. Based on these results, this paper proposes policy recommendations: enhancing digital trade infrastructure, improving technological innovation conversion efficiency, and strengthening industrial collaboration and talent cultivation. These aim to elucidate pathways for digital trade to foster high-quality manufacturing development, providing theoretical foundations and empirical references for policymakers and industry practitioners.

KEYWORDS

Level of Digital Trade Development; Manufacturing Transformation and Upgrading; Technological Innovation; Empirical Analysis; Policy Recommendations

1. INTRODUCTION

Amidst the rapid global expansion of the digital economy, digital trade—a new form of international commerce—is profoundly reshaping corporate production models and industrial structures. As a major global manufacturing power, China faces multiple challenges in advancing high-quality manufacturing development, including industrial restructuring, insufficient technological innovation capacity, and intensifying international competitive pressures. Manufacturing gains fresh developmental opportunities through digital trade, leveraging the efficient allocation of information flows, technological flows, and capital flows. On one hand, digital trade expands enterprises' market reach, heightens their sensitivity and responsiveness to international markets, and stimulates product and technological innovation. On the other hand, it fosters industrial chain collaboration and efficient resource utilisation, optimising the allocation of production factors to enhance overall manufacturing efficiency and value-added output.

Significant disparities exist across regions in digital infrastructure innovation capacity, industrial structure, and policy environments. Within China, pronounced variations in digital trade development at the provincial level exert substantial influence on the pathways and outcomes of manufacturing upgrading. For comprehending the mechanisms through which digital trade impacts manufacturing upgrading and formulating targeted industrial policies, a thorough analysis of these influence pathways holds significant practical importance. By incorporating intermediary variables such as technological innovation management capabilities and industrial coordination, and quantifying both the level of manufacturing upgrading and the development of digital trade, we can more comprehensively reveal the direct and indirect effects of digital trade on the transformation and upgrading of manufacturing.

Exploring the intrinsic mechanisms through which digital trade propels manufacturing upgrading in this context holds substantial practical significance for the scientific formulation of industrial policies. This study, grounded in provincial-level panel data from China, constructs manufacturing upgrading indicators to dissect both the direct impact of digital trade and its indirect effects via intermediary pathways such as technological innovation, while further proposing policy recommendations. To support China's manufacturing sector in achieving leapfrog development within global value chains, this research aims to reveal the pathways through which digital trade propels high-quality manufacturing development, providing theoretical references and empirical evidence for policymakers and industry practitioners.

2. LITERATURE REVIEW

2.1. Conceptualisation and Measurement of Manufacturing Upgrading

In 1998, Yin Xingmin first proposed the concept of manufacturing upgrading, defined as "maintaining the survival and development of manufacturing through adjustments to production factors, improvements in technical and managerial capabilities, and enhancing product value-added" [1]. Internationally, Weber (2011) was the first to define digital trade, characterising it as the exchange of valuable goods facilitated by electronic payments [2]. Subsequently, Lü Tie (2017) explained manufacturing structural upgrading from two perspectives: first, the transition from light manufacturing to heavy manufacturing; second, the shift from raw material manufacturing to processing and assembly-type manufacturing [3]. Subsequently, Yang Kuo and Guo Kexia (2019) divided manufacturing upgrading into two aspects: firstly, internal production efficiency and profitability gains arising from enhanced average technological standards and production processes within manufacturing sub-sectors; secondly, indirect upgrading driven by the structural evolution from labour-intensive to technology-intensive industries, thereby promoting manufacturing industrial restructuring [4]. Other scholars, such as Jin Bo (2011), interpret manufacturing upgrading primarily from the perspective of industrial structure upgrading. Regarding the concept of manufacturing transformation and upgrading, there remains no precise definition within the academic community [5].

2.2. Research on Factors Influencing Manufacturing Upgrading

The influencing factors of manufacturing upgrading primarily encompass internal and external elements. Firstly, micro-level internal factors within enterprises: Meng Dan (2018) highlights the positive impact of enterprise quality structure, scale structure, and ownership structure on manufacturing upgrading [6]. Na Dandan and Li Ying (2020) contend that internal technological innovation and structural optimisation are the two most influential factors affecting manufacturing transformation and upgrading [7]. Dai Yong (2013) et al. propose that proactive entrepreneurship, accumulation of key resources, and cultivation of dynamic capabilities constitute crucial determinants of manufacturing upgrading [8]. Corporate innovation capacity and innovation strategy selection are also regarded as pivotal factors driving the transformation and upgrading of manufacturing enterprises (Zhang Yanping et al., 2021; Jiao Yong, 2020) [9, 10]. Secondly, external motivating factors primarily encompass environmental regulations (Zhou Lijun and Zhang Zongqing, 2024; Bao Tong, 2023; Huang Yanmei and Zhang Huimei, 2023, et al.) [11-13], tax policies (Li Xiangju and Zhu Danfeng, 2018; Guo Jian, 2018) [14, 15], the digital economy (Fang, F. Q. & Ma, R. G., 2023;

Zhang, W. Y. & Ge, J. H., 2023, et al.) [16, 17], and financial development (Xu, Z. et al., 2022; Pan, H. Y. & Liu, Y. R., 2019, et al.) [18, 19]. Although existing scholars (Fang, F. Q. and Ma, R. G., 2023; Zhang, W. Y. and Ge, J. H., 2023; Kapoor, 2014) have examined the impact of the digital economy on manufacturing transformation and upgrading, they have not focused specifically on digital trade as an influencing factor nor drawn systematic conclusions [16, 17, 20].

2.3. Research on the Relationship Between Digital Trade and Manufacturing Upgrading

Han Minchun et al. (2023) contend that digital trade not only reduces costs and enhances transaction efficiency but also improves production efficiency by optimising resource allocation. This enables manufacturing enterprises to achieve flexible production and promotes the upgrading of the manufacturing industry structure [21]. Han Minchun and Zhang Xiao (2023) discovered that digital trade elevates the technological complexity of manufacturing exports by reducing trade costs, driving technological innovation, and enhancing financial service efficiency [22]. Chen Jian et al. (2020) indicated that heightened enterprise digitalisation improves operational efficiency, enabling better service to consumer demands and creation of greater commercial value, thereby advancing manufacturing industrial upgrading [23]. Yuan Xia (2022) observed that digital trade exerts a partial mediating effect on manufacturing industrial structure through human capital, consumer demand, and technological innovation [24]. Huang Jiegen et al. (2021) contend that enterprise digitalisation enables continuous growth in scale and efficiency, thereby enhancing corporate performance and facilitating industrial structure optimisation and upgrading [25]. Goldfarb and Tucker (2013) indicate that digital trade influences product pricing by reducing search and transaction costs for firms and consumers, thereby driving industrial upgrading [26]. Yao Zhanqi (2021) employs multiple intermediary effects to conclude that digital trade exerts a significant indirect impact on China's industrial upgrading through R&D intensity. Evidently, scholars predominantly examine the relationship between digital trade development and manufacturing upgrading from the perspective of industrial structure upgrading [27]. However, manufacturing upgrading extends beyond industrial structure transformation to encompass internal production efficiency and profitability gains stemming from enhanced average technological levels and production processes within manufacturing sub-sectors. Existing research thus exhibits certain limitations.

A review of the literature indicates that digital trade and manufacturing upgrading are current research hotspots, providing a reference framework for this project. As an emerging field, digital trade has generated substantial research on its impact on manufacturing upgrading, laying a theoretical foundation for this study. However, existing research exhibits certain limitations: firstly, studies examining the effects and pathways through which digital trade promotes manufacturing upgrading remain relatively scarce. Secondly, while existing literature confirms the promotional role of digital trade in manufacturing industrial upgrading, it has measured manufacturing upgrading solely from the perspective of industrial structure, presenting certain limitations. This study aims to address these limitations. Firstly, it constructs a comprehensive digital trade development level index. Using a two-way fixed effects model, it empirically tests the promotional effect of digital trade on China's manufacturing upgrade, exploring the direct causal relationship between the two. Secondly, the project will examine the driving role of digital trade development in manufacturing transformation and upgrading from the perspective of technological innovation mechanisms.

3. RESEARCH DESIGN

3.1. Model Construction

To examine the impact of digital trade on manufacturing upgrading, the following basic model is constructed:

$$lnMIS_{i,t}=\beta_0+\beta_1 lnDIG+contrals+u_i+v_t+\varepsilon_{i,j,t}$$

MIS, representing manufacturing transformation and upgrading; DIG, denoting the level of digital trade development;contrals,signifying the series of control variables; u_i, representing city fixed effects; v_t, indicating time fixed effects; ε_{it}, representing the random error term.

3.2. Variable Selection

Dependent variable: Manufacturing Industry Upgrading (MIS). This study categorises the manufacturing sector into 31 sub-industries according to the National Bureau of Statistics' classification standards. Building upon this framework and drawing from the research findings of Yang, Wangshan et al. (2023) on the level of high-quality development in manufacturing, the value of the MIS indicator for manufacturing upgrading is comprehensively measured by innovation level, green development, openness, economic impact, and industrial coordination [28]. The entropy method is employed to standardise and weight each sub-indicator, synthesising them into the Manufacturing Transformation and Upgrading Index.

Core Explanatory Variable: Digital Trade Development Level (DIG). Integrating the measurement methodology of Yao Zhanqi and Zhang Weihua, this paper ultimately selects 15 secondary indicators across five dimensions: e-commerce infrastructure, digital technology level, industrial digital trade, digital industrial trade, and digital trade potential [27, 29]. These form the comprehensive indicator system for assessing the digital trade development level of each prefecture-level city.

Table 1. Comprehensive Indicators for Digital Trade Development Level

Primary Indicators	Secondary Indicators	Unit	Indicator Direction	Weight
E-commerce Infrastructure	Number of Domain Names	Ten thousand	Positive	0.07492
	Number of websites	Ten thousand	Positive	0.07503
	Internet broadband access ports	Ten thousand	Positive	0.03183
	Long-distance optical cable line length	Kilometres	Forward	0.02086
Digital technology level	Number of persons employed in information transmission, software and information technology services	Ten thousand persons	Positive	0.06649
	Research and development expenditure (R&D)	¥ Billion	Positive	0.07144
	Number of Patent Applications	Items	Positive	0.07174
Industrial Digitalisation Trade	Mobile internet access traffic	Ten Thousand GB	Positive	0.08714
	E-commerce Sales	¥100 million	Positive	0.08202
	Online retail sales	¥ Billion	Positive	0.10554
Digital industrialisation trade	Information transmission, software and information technology services Total fixed asset investment	¥ Billion	Positive	0.03649
	Computers per 100 people	Units	Positive	0.02122
	Telecommunications service volume	Billion yuan	Positive	0.06859
	Software business revenue	Ten thousand yuan	Positive	0.11112
Digital Trade Potential	GDP per capita	Yuan	Positive	0.02767
	Market Openness	%	Positive	0.04789

3.3. Control Variables

To mitigate the influence of other variables on estimation outcomes, this study controls for the following variables in accordance with existing research: Economic Development Level (AGDP), represented by per capita GDP; Fiscal Discretion (FD), measured by the ratio of budgetary fiscal revenue to expenditure; Social Consumption (SC), measured by the proportion of total retail sales of consumer goods relative to GDP; Financial Development Level (FI), measured by the ratio of total deposits and loans of financial institutions to GDP; Urbanisation Level (UR), measured by the proportion of urban population relative to total population.

3.4. Data Sources

This study employs balanced panel data from 30 Chinese provinces spanning 2013–2022 to empirically analyse the impact of digital trade on the transformation and upgrading of China's manufacturing sector. All raw variables are sourced from the National Bureau of Statistics, the Ministry of Commerce website, and provincial statistical yearbooks for relevant years. Where data gaps exist, the moving average method is employed for estimation.

3.5. Descriptive Statistical Analysis

Table 2's descriptive statistics indicate that the mean of the manufacturing upgrading indicator lnMIS is 0.130 with a standard deviation of 0.100. This suggests varying levels of manufacturing upgrading across provinces. At the inter-provincial level, digital trade development exhibits uneven patterns, with the mean of the digital trade development level lnDIG being 0.110 and its maximum value reaching 0.500. Among other control variables, per capita regional GDP (lnAGDP) and financial development level (lnFI) exhibit relatively minor fluctuations. However, the urbanisation rate (lnUR) shows a minimum value of 0.340 and a maximum of 0.640. This indicates significant disparities in urbanisation levels across provinces, which may exert varying degrees of influence on manufacturing upgrading.

Table 2. Descriptive Statistics Analysis

Variable	N	Mean	SD	Min	Max
lnMIS	300	0.130	0.100	0.0400	0.460
lnDIG	300	0.110	0.100	0.0100	0.500
lnAGDP	300	10.95	0.430	10.14	12.09
lnFD	300	0.230	0.0800	0.110	0.530
lnSC	300	0.330	0.0500	0.200	0.450
lnFI	300	1.780	0.220	1.330	2.390
lnUR	300	0.480	0.0700	0.340	0.640
lnRD	300	0.980	0.360	0.390	2

4. EMPIRICAL ANALYSIS

4.1. Baseline Regression

The benchmark regression results indicate (see Table 3) that manufacturing upgrading is significantly and positively influenced by the level of digital trade development. In the model considering digital trade alone, the regression coefficient of lnMIS on lnDIG is 0.357, with a high significance level of 1%. After incorporating control variables such as fiscal expenditure on economic development, social capital, financial development, and urbanisation, lnDIG remains positively and significantly correlated (0.321***). This indicates that digital trade plays a robust role in driving manufacturing upgrading. Regarding manufacturing upgrading, the urbanisation rate lnUR exhibits a significant negative impact (-0.341**). This suggests that in regions with higher urbanisation levels, constraints may arise from industrial structure issues or resource allocation pressures, thereby inhibiting manufacturing upgrading to some extent. Notably, other control variables in this analysis did not demonstrate significant effects.

Table 3. Benchmark Regression

	(1)	(2)
VARIABLES	lnMIS	lnMIS
lnDIG	0.357***	0.321***
	(0.0427)	(0.0507)
lnAGDP		-0.0271
		(0.0334)
lnFD		0.00306
		(0.0915)
lnSC		0.0415
		(0.0411)
lnFI		-0.00497
		(0.0265)
lnUR		-0.341**
		(0.143)
Constant	0.225***	0.742*
	(0.00960)	(0.385)
Observations	300	300
R-squared	0.974	0.975
*** p < 0.01, ** p < 0.05, * p < 0.1		

4.2. Robustness Test

This paper employs a robustness test for the impact of digital trade development on manufacturing transformation and upgrading by altering the sample period. Specifically, the study restricts the sample to post-2016 data to validate the reliability of baseline regression results. Structurally, the level of digital trade development (lnDIG) continues to exert a significant positive influence on manufacturing upgrading (lnMIS). Its regression coefficient reached 0.520 and remained significant at the 1% level (*), indicating that digital trade exerts a positive influence on manufacturing upgrading. Furthermore, with an overall regression fit of R^2 at 0.982, the coefficients of other control variables showed no significant variation, further validating the robustness of the benchmark regression results.

Table 4. Robustness Test

	(1)
VARIABLES	lnMIS
lnDIG	0.520***
	(0.0816)
lnAGDP	0.0254
	(0.0431)
lnFD	0.141
	(0.120)
lnSC	-0.0689
	(0.107)
lnFI	0.0418
	(0.0357)
lnUR	-0.629**
	(0.258)
Constant	0.184
	(0.488)
Observations	210
R-squared	0.982
*** p < 0.01, ** p < 0.05, * p < 0.1	

4.3. Mechanism Analysis

The mechanism analysis employs lnRD (logarithm of R&D intensity) to measure technological innovation capacity, exploring the transmission pathway through which digital trade influences manufacturing upgrading via technological innovation. Regression results indicate a significant positive effect of digital trade on technological innovation (0.622***), suggesting that digital trade development effectively elevates provincial technological innovation investment levels, thereby providing technical support for manufacturing upgrading. However, when controlling for digital trade simultaneously, R&D investment exhibits a significant negative effect (-0.0564***) on manufacturing upgrading. This may reflect short-term conversion lags or inefficient resource allocation in provincial-level R&D investment. Nevertheless, digital trade's direct positive effect on manufacturing upgrading remains significant (0.356***). Overall, the empirical findings suggest that digital trade exerts influence not only through direct promotion of manufacturing upgrading but also via complex mechanisms within the technological innovation process. Further analysis integrating provincial industrial structures and R&D efficiency is warranted.

Table 5. Mechanism Analysis

	(1)	(2)	(3)
VARIABLES	lnMIS	lnRD	lnMIS
lnDIG	0.321***	0.622***	0.356***
	(0.0507)	(0.150)	(0.0518)
lnRD			-0.0564***
			(0.0209)
Constant	0.742*	-3.298***	0.556
	(0.385)	(1.141)	(0.387)
Observations	300	300	300
R-squared	0.975	0.983	0.976
*** p < 0.01, ** p < 0.05, * p < 0.1			

5. CONCLUSIONS AND SUGGESTIONS

This study employs empirical analysis of Chinese provincial panel data to comprehensively and systematically investigate the impact of digital trade development levels on manufacturing upgrading, alongside the underlying mechanisms. Findings indicate that digital trade exerts a significant positive influence on manufacturing upgrading. This suggests that digital trade advancement can elevate overall manufacturing standards and industrial value-added through optimising factor allocation, expanding market reach, and fostering technological innovation. Mechanism analysis reveals that technological innovation plays a mediating role in this process, though its short-term conversion effects exhibit lag at the provincial level. This may stem from constraints such as R&D investment efficiency, industrial structure alignment, and regional policy environments. These findings not only validate the direct positive impact of digital trade on manufacturing upgrading but also reveal the complexity of its operational mechanisms through pathways such as technological innovation. This provides empirical evidence for deepening our understanding of the relationship between digital trade and the high-quality development of manufacturing.

Based on the aforementioned conclusions, in order to accelerate the pace of digital trade infrastructure development and further optimise the data circulation environment and digital payment systems, this study proposes the following policy recommendations. First, governments and enterprises should enhance efficiency in cross-border e-commerce and digital services trade, fostering an optimal digital development environment for manufacturing upgrades. This entails improving technological innovation efficiency and conversion capabilities. Second, governments at all levels should accelerate the transformation of R&D outcomes into advanced production processes and high-value-added products by increasing R&D funding, strengthening intellectual property protection systems, encouraging industry-academia-research collaboration, and optimising R&D investment structures. This will reinforce digital trade's practical efficacy in driving manufacturing upgrades. Thirdly, governments should prioritise regional industrial coordination and talent cultivation. This entails fostering inter-provincial collaboration in high-skilled workforce training, advancing digital supply chain development, and enhancing corporate organisational capabilities and management standards to elevate the overall competitiveness of the manufacturing sector. In summary, future policies must concurrently refine the digital trade development environment, strengthen industrial synergy and talent support, improve technological innovation conversion efficiency, and optimise urbanisation and industrial layout. These measures collectively propel China's manufacturing industry towards a phase of high-quality development.

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