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The influence of the development level of digital economy on the competitiveness of China's manufacturing industry in foreign trade

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Abstract

The article selects data on digital economic development and manufacturing foreign trade from 30 provinces in China between 2012 and 2021, using a two-way fixed effects model to empirically investigate the impact of digital economic development levels on the competitiveness of manufacturing foreign trade and the moderating effect of manufacturing export structure. The study finds that an increase in the level of digital economic development can significantly enhance the competitiveness of manufacturing foreign trade. The export structure of manufacturing plays a positive moderating role. Heterogeneity analysis based on geographical location reveals that the promotion effect of digital economic development levels on the competitiveness of manufacturing foreign trade is more pronounced in central and eastern regions.

Keywords: economic development, manufacturing industry, foreign trade

1. Introduction

As globalization deepens and information technology advances, the digital economy, first proposed by Tapscott (1996), is becoming a key force for China's economic growth and industrial development. The digital economy, with its unique network effects, economies of scale, and innovation-driven characteristics, has not only transformed traditional production methods and business models but also brought new opportunities to manufacturing. In the "14th Five-Year Plan for Digital Economy Development" released by the State Council, it is clearly stated that promoting industrial integration between the digital economy and manufacturing will be a priority in future digital economic development. Since the reform and opening up, China's manufacturing sector has achieved remarkable success. According to the OECD report, China's total manufacturing output reached over 30% of global manufacturing output in 2023, maintaining its position as the world's leading manufacturing power for 14 consecutive years. However, in recent years, due to increasing Western technological barriers and declining demographic dividends, China's manufacturing industry has gradually fallen into a disadvantageous position at the lower end of the value chain, facing a situation of "low-end lock-in." Against this backdrop, China urgently needs to promote the transformation and upgrading of its manufacturing sector, converting its quantitative advantages into qualitative ones, and enhancing the competitiveness of its manufacturing exports.

To sum up, this paper believes that the development of digital economy can bring new development opportunities for the foreign trade of manufacturing industry. By sorting out the relationship between the level of digital economy development and the competitiveness of foreign trade of manufacturing industry, it is hoped to contribute certain development countermeasures to improve the competitiveness of foreign trade of Chinese manufacturing industry, which is of great significance for the high-quality development of Chinese manufacturing export.

2. Literature review

The theme of this paper is to study the impact of digital economy development level on China's manufacturing foreign trade competitiveness based on the perspective of manufacturing export structure. Related literature mainly focuses on the following aspects:

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2.1 Research on measurement methods of digital economy development level

Through the integration of existing literature, it can be seen that different scholars have certain differences in the definition of digital economy, and there is no unified standard for the measurement method of digital economic development level. At present, there are two main measurement methods:

One approach is through the direct method of measuring scale. Xu Xianchun and Zhang Meihui (2020) [2] and Jin Xingye *et al*. (2020) [3] defined the connotation and scope of the digital economy, using an added value model to measure the scale of the digital economy; Cai Yuezhou and Niu Xinxiang (2021) [8] divided the digital economy into digital industrialization and industrial digitalization, constructing an added value measurement framework and panel models to measure the scale of the digital economy ; the China Academy of Information and Communications Technology (2022) [5] measured the scale of China digital economy based on layers such as digital industrialization, industrial digitalization, and digital governance.

Another approach is the indirect method of constructing indicators. Regarding the indirect measurement methods for the level of digital economic development, existing research has primarily formed three major methodological systems: the alternative indicator method, the impact effect method, and the model construction method. In terms of the alternative indicator method, scholars have constructed measurement systems by selecting proxy variables closely related to the digital economy. Guo Jiatang and Luo Pinliang (2016) [6] used basic indicators such as internet penetration rate to construct a provincial digital economic development index; Zhang Xun *et al*. (2019) [7] innovatively introduced the dimension of digital finance, providing new insights for measuring at the county level. The impact effect method achieves indirect measurement by analyzing the penetration effect of the digital economy on traditional economic systems. Cai Yuezhou and Chen Nan (2019) [8] incorporated digital economy factors into the production function framework, systematically calculating their substitution elasticity with traditional production factors; Xu Xianchun and Zhang Meihui (2020) [2] constructed a social accounting matrix based on input-output analysis, effectively capturing the radiation effect of the digital economy on industrial systems; Liu Jun *et al*. (2021) used the growth kernel algorithm to isolate the contribution of the digital economy to total factor productivity; Jorgenson and Vu (2016) conducted cross-country comparative studies, revealing the regional heterogeneity characteristics of the impact effect of the digital economy. The model construction method mainly focuses on methodological innovation. Lan Qingxin, based on Porter's "Diamond Model," established an evaluation index system for digital trade competitiveness; Liu Jun *et al*. (2020) [12] used structural equation modeling to handle the multidimensional characteristics of the digital economy; Wang Jiandong and Tong Nan (2020) [13] introduced complex network theory to characterize the digital economy ecosystem; foreign scholar Bukht (2017) [14] proposed a pyramid model that provides an applicable analytical framework for developing countries.

2.2 Research on trade competitiveness of manufacturing industry

It can be seen from the integration of existing literature that there is no unified conclusion in the academic circle on the connotation of trade competitiveness, and the relevant research on trade competitiveness focuses on two aspects: the measurement of trade competitiveness and the influencing factors of trade competitiveness.

In the measurement of trade competitiveness, several mainstream indicators in academia include market share (MS), trade competitiveness index (TC), and revealed comparative advantage index (RCA). Chen Jiagui and Zhang Jinchang (2002) [15] comprehensively selected the MS index, TC index, and RCA index to analyze the industrial competitiveness of China and the United States; Li Xiaodan and Wu Yangwei (2021) [16] separately used the RCA index and NRCA index to measure the trade competitiveness of Chinese manufacturing industries; He Chuantian *et al*. (2022) [17] compared the levels of cultural trade development competitiveness in China using the MS index, TC index, and RCA index, identifying the strengths and weaknesses of Chinese cultural trade competition in the international environment. Therefore, in actual research, different research objectives should be considered, and corresponding research methods should be adopted based on specific scenarios.

In terms of the factors influencing trade competitiveness, numerous elements are involved. Mao Risheng (2006) [18] conducted a comparative analysis between manufacturing trade specialization competitiveness and actual competitiveness, concluding that the main factors affecting manufacturing trade competitiveness include the level of trade specialization, degree of capital deepening, innovation capability, and foreign direct investment; Wu Yangwei and Li Xiaodan (2021) [16] used an extended factor and moderating effect model to analyze and found that the elements of economic globalization significantly enhance manufacturing trade competitiveness; Cheng Yinghui and Yang Guijun (2023) [20] constructed a theoretical framework for promoting high-quality trade development through industrial structure upgrading and analyzed that digitalization in manufacturing can boost its trade competitiveness.

2.3 Research on the relationship between digital economy, export structure of manufacturing industry and trade competitiveness of manufacturing industry

It can be seen from the integration of existing literature that the research on the relationship among the three is mostly focused on two pairs. Many scholars focus on the impact of digital economy on the export structure of manufacturing industry and the impact of digital economy on the trade competitiveness of manufacturing industry, while few studies combine the three.

In exploring the relationship between the digital economy and the export structure of manufacturing, Shen Yunhong and Huang Hang (2020) [21] identified three factors of the digital economy: digital infrastructure construction, the level of digital industries, and the level of digital technology innovation. They empirically found that these factors can promote the optimization and upgrading of traditional manufacturing industry structures; Yin Zhongming *et al*. (2023) [22] focused on the relationship between the digital economy and foreign trade, arguing that the digital economy can optimize the export structure of manufacturing through four aspects: data elements, digital technology, digital industrialization, and industrial digitalization;Peng Xiaonan and Zhao Jingfeng (2023) [23], from the perspective of global value chains, comprehensively analyzed and concluded that compared to traditional manufacturing, the digitalization of emerging manufacturing can better propel China's manufacturing industry toward the mid-to-high end of the global value chain.

In exploring the relationship between the digital economy and manufacturing trade competitiveness, existing research can primarily be divided into direct effects and indirect effects: In terms of direct effect studies, He Shuquan (2021) *et al* [24]., starting from an industry perspective, empirically found that the level of digital economic development in trading partner countries can directly enhance the value-added of domestic exports, thereby improving export competitiveness; Yu Shan *et al*. (2021) [25] discovered that the digital economy has a positive impact on the technological complexity of provincial-level exports in China's manufacturing sector, which is conducive to leading high-quality development in export trade; In terms of indirect effect studies, Liu Zhijian (2021) [26], based on the scale, efficiency, and complexity of digital economic development, empirically concluded that an increase in the level of digital economic development can significantly enhance manufacturing export competitiveness; Yao Zhanqi (2022) [27], using innovation output and innovation efficiency as mediating variables, analyzed and found that the digital economy can improve China's trade export competitiveness by enhancing innovation efficiency and increasing innovation output.

2.4 Literature review

According to the above literature, the existing research mainly focuses on the complexity of export technology, global value chain and high-quality development, and few scholars study the impact of digital economy development on China's manufacturing trade competitiveness from the perspective of manufacturing export structure.

Based on this, this paper analyzes the mechanism of how digital economy affects the export competitiveness of manufacturing, and empirically explores the impact effects and pathways among the digital economy, the structure of manufacturing exports, and the trade competitiveness of manufacturing, using provincial panel data from China. The main marginal contributions of this paper are: first, incorporating the digital economy, the structure of manufacturing exports, and the trade competitiveness of manufacturing into a single research framework, and analyzing the impact mechanism of the digital economy on the trade competitiveness of manufacturing through mediation effect analysis; second, empirically testing the impact mechanism of the digital economy on the trade competitiveness of manufacturing, aiming to provide some insights for leveraging the positive role of the digital economy in enhancing the foreign trade of manufacturing.

3. Theoretical analysis and research hypothesis

3.1 Development of digital economy and competitiveness of manufacturing industry in foreign trade

First, the digital economy can enhance manufacturing efficiency by introducing digital technologies such as cloud computing, big data, and artificial intelligence. These technologies promote automation and process optimization in production, thereby reducing costs. Second, with the improvement of digitalization, the rise of e-commerce and supply chain management platforms makes transactions more convenient, accelerates information search, and reduces transaction costs, positively impacting transaction efficiency. Manufacturing companies can respond faster to market demands and optimize resource allocation during transactions. Finally, the digital economy can accelerate product iteration and shorten R&D cycles through technological innovation and progress, increasing the technical content and added value of products, thus providing a solid foundation for enhancing the export competitiveness of manufacturing. Based on this, Hypothesis 1 is proposed:

Hypothesis 1: The development of digital economy has a positive effect on the competitiveness of foreign trade in manufacturing industry.

3.2 The regulating effect of manufacturing export structure

The upgrading of the export structure in manufacturing refers to the optimization of industries and the enhancement of product technology content and complexity by export enterprises. This is achieved through technological innovation, increased R&D investment, improved production efficiency, optimized supply chain management, and the adoption of advanced manufacturing technologies, all of which drive export enterprises to produce high-value-added products and promote the development of export structures towards higher-end and smarter directions. First, from the perspective of technological innovation, as the export structure of manufacturing tends to optimize, companies focus on high-end products, and innovative R&D models help export enterprises accurately analyze market trends, quickly adapt to market changes, and shorten the lifecycle of new products. The digital economy has brought information technology such as big data, artificial intelligence, and the Internet of Things to manufacturing, significantly enhancing the efficiency of manufacturing innovation under the empowerment of the digital economy. This enables companies to more accurately produce products that meet international market demands and have high added value. Furthermore, from the perspective of industrial synergy, the upgrading of the export structure in manufacturing promotes coordinated development between upstream and downstream industries. The digital platforms provided by the digital economy enable real-time information sharing, collaborative design, and flexible production. Coordinated development between upstream and downstream industries can enhance the agglomeration effect of enterprises, integrate advantageous resources for production, and improve the overall production efficiency of exported products. Finally, from a cost perspective, the digital economy primarily promotes intelligent production management. By leveraging digital platforms for transactions, export companies can reduce transaction and logistics costs. As the export structure advances towards higher-end segments, cost advantages can provide more profit margins for export companies, ensuring their competitive edge in global markets. In summary, during the process of upgrading the export structure of manufacturing, the digital economy significantly enhances the competitiveness of manufacturing exports through multiple mechanisms such as technological innovation, cost optimization, and industrial collaboration. Compared to traditional trade stages, its positive effects are even more pronounced. Based on this, Hypothesis 2 is proposed:

Hypothesis 2: The export structure of manufacturing industry plays a positive role in regulating the level of digital economy development and the competitiveness of manufacturing industry export

4. Model design and variable selection

4.1 Model design

In order to test the influence of digital economy development level on China's manufacturing export competitiveness, this paper sets the econometric model as a two-way fixed panel model. In order to test the correctness of hypothesis 1, model (1) is established:

$$LnExpy_{it} = \alpha_0 + \alpha_1 Dig_{it} + \alpha_j Controls_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (1)$$

Where i and t represent the province and year, respectively. Expyit denotes the manufacturing export structure index of province i in year t; Digit represents the level of digital economy development in province i in year t; Controlsit denotes a series of control variables; t and t represent individual fixed effects and time fixed effects, respectively, α_0 represents the constant term, and ε_{it} represents the random disturbance term. To examine the moderating effect of the manufacturing export structure on the relationship between the level of digital economy development and manufacturing export competitiveness, an interaction term between the level of digital economy development index and the manufacturing export structure is introduced, and Hypothesis 2 is tested based on Model (2):

$$LnExpy_{it} = \alpha_0 + \alpha_1 Dig_{it} + \alpha_2 Dig_{it} \times TC_{it} + \alpha_j Controls + \delta_i + \mu_t + \varepsilon_{it} \quad (2)$$

4.2 Indicator construction

4.2.1 Dependent variable: Foreign trade competitiveness of manufacturing industry

Based on the traditional methods of measuring trade competitiveness in literature reviews, this paper selects the Trade Competitiveness Index (TC) to measure the foreign trade competitiveness of 30 provinces in China from 2012 to 2021. This index can reflect, to some extent, the development status of both domestic and international markets, which aids in further analyzing the export trade situation of manufacturing. The specific calculation method is the difference between the export value and import value of manufactured goods in each province of China over the years, divided by the total import and export trade volume. The formula is as follows:

$$TC_{it} = \frac{X_{it} - M_{it}}{X_{it} + M_{it}} PRODUC \quad (3)$$

4.2.2 Core explanatory variable: digital economy development level

Currently, scholars both domestically and internationally have not yet formed a unified set of indicators for measuring the level of digital economic development. Different scholars; measurements of the digital economy based on different indicators show certain differences. Pan Weihua *et al*. (2021) divided the digital economy into four parts: digital economy foundation, digital industrialization, industrial digitalization, and digital governance for measurement; Fei Yue (2021) measured the digital economy from four aspects: digital foundation, digital technology, digital scale, and digital talent; Yin Zhongming (2023) [22] constructed an indicator system from four dimensions: digital infrastructure construction, innovation capability and institutional environment, digital life and application, and level of digital industrialization. This paper draws on the ideas presented in these references to construct an evaluation indicator system from four dimensions: digital technology innovation, digital industrialization, industrial digitalization, and digital foundation. Based on this, a 15-level secondary indicator system is created, and the weights corresponding to each indicator are calculated using the entropy method, as detailed in Table 1 below:

Table 1: Digital economy index system

Primary Indicator	Secondary Indicator	Weight
Digital Infrastructure 0.398	Internet Broadband Subscribers (10,000 households)	0.079
	Mobile Phone Penetration Rate (units per 100 people)	0.089
	Number of Domain Names (10,000)	0.060
	Number of IPv4 Addresses (10,000)	0.084
	Length of Long-Distance Optical Cable Lines (10,000 km)	0.086
Digital Industrialization 0.236	Telecom Business Revenue (100 million yuan)	0.063
	Software Industry Revenue (10,000 yuan)	0.046
	Software Revenue as % of Regional GDP (%)	0.060
	Employment in Information Services (10,000 people)	0.066
Industrial Digitization 0.184	E-Commerce Sales (100 million yuan)	0.060
	Express Delivery Volume (10,000 parcels)	0.035
	Digital Inclusive Finance Index	0.090
Digital Technology Innovation 0.182	Technology Contract Transaction Value (100 million yuan)	0.045
	Number of Patent Grants (10,000)	0.057
	Regional R&D Expenditure Intensity	0.080

4.2.3 Regulating variables: manufacturing export structure

This paper selects the export structure of manufacturing as an intermediary variable, drawing on Yin Zhongming's measurement method, and uses the technical complexity of high-tech product exports to represent it. The higher this value, the more it indicates that high-tech products account for a larger proportion in China's manufacturing exports, with higher added value, reflecting an improvement in foreign trade competitiveness. The specific calculation method follows Hausmann (2007), which can be expressed as:

$$Pr\,o\,duct_k = \sum j \frac{x_{jk}/x_j}{\sum j x_{jk}/x_i} Y_j \tag{4}$$

$$Expy_j = \sum k \frac{x_{jk}}{x_j} Pr\,o\,duct_k \tag{5}$$

Among them, k represents the high-tech industry product k in a certain period, Yj is the per capita GDP of province j, Productk refers to the technical complexity of exporting high-tech industry product k in a certain period, j represents the province, Expyj is the technical complexity of exporting high-tech products, Xj represents the total export value of high-tech products from province j, xjk represents the export amount of high-tech industry product k from province j.

4.2.4 Control variables

The control variables selected in this paper include: the degree of openness (open), represented by the ratio of total imports and exports to GDP; industrial development level (indus), indicated by the ratio of secondary industry value added to regional GDP; foreign direct investment level (fdi): this paper uses actual foreign direct investment as the data for this indicator; R&D intensity (res), measured by the proportion of internal R&D expenditure in the province's GDP; government support level (gov),

4.3 Sample selection and data sources

Due to the lack of data for some years in Tibet, Hong Kong, Macao, and Taiwan, this study focuses on the remaining 30 provinces of China from 2012 to 2021, generating a total of 300 balanced panel observations. The original data used in this study comes from the "China Statistical Yearbook," "China Science and Technology Statistical Yearbook," "China Labor Statistical Yearbook," "China Industrial Statistical Yearbook," "China Financial Yearbook," and the National Research Network database. For missing values in individual years and provinces, linear interpolation is used to fill them. Below are the descriptive statistics for each variable:

Table 2: Descriptive statistics of variables

Variable	Sample Size	Mean	Std. Dev.	Min	Max
TC	300	0.239	0.333	-0.601	0.786
Dig	300	0.194	0.114	0.052	0.630
Expy	300	8.996	0.616	7.514	10.51
Open	300	0.264	0.268	0.015	1.217
Indus	300	0.329	0.076	0.115	0.469
Fdi	300	12.79	1.731	7.412	14.88
Res	300	0.021	0.005	0.010	0.038
Gov	300	0.263	0.111	0.121	0.723

5. Empirical analysis

5.1 Benchmark regression and test

5.1.1 Benchmark regression analysis

The benchmark regression results are shown in the table below: (1)-(3) list the regression results with fixed effects added sequentially. The digital economy development level of sample provinces is positively correlated with the manufacturing sector's foreign trade competitiveness at a 1% significance level, indicating that a robust digital economy can significantly enhance the competitiveness of manufacturing in foreign trade. This supports Research Hypothesis 1. The digital economy may boost international competitiveness in manufacturing through measures such as enhancing information technology application, optimizing production processes, and improving market access. This is especially true in the context of rapid globalization and informatization, where promoting the development of the digital economy could become a key factor in strengthening manufacturing competitiveness.

Table 3: Results of benchmark regression analysis

VARIABLES	(1) TC	(2) TC	(3) TC
Dig	0.723***	0.559***	0.445**
	(4.44)	(3.81)	(1.99)
Open	-0.415***	0.129*	0.307***
	(-8.61)	(1.93)	(4.09)
Indus	1.928***	0.622*	1.541***
	(8.00)	(1.90)	(4.42)
Fdi	-0.060***	-0.004	-0.006
	(-3.38)	(-0.29)	(-0.48)
Res	-21.250***	0.649	-1.354
	(-7.25)	(0.20)	(-0.27)
Gov	-1.060***	-0.631**	-0.574**
	(-5.11)	(-2.37)	(-2.12)
Constant	1.066***	0.094	-0.181
	(3.83)	(0.49)	(-0.92)
Individual Fixed Effects	NO	YES	YES
Year Fixed Effects	NO	NO	YES
Observations	300	300	300
R-squared	0.497	0.939	0.947
r2_a	0.487	0.931	0.938
F	72.76	6.768	8.777

Robust t-statistics in parentheses； *** p<0.01, ** p<0.05, * p<0.1

5.1.2 Endogeneity and robustness test

To enhance the reliability of the research conclusions, this paper conducts endogeneity and a series of robustness tests. First, to avoid potential endogeneity issues that could interfere with the research results, we use the lagged one-period level of digital economy development as an instrumental variable. This instrumental variable passes the non-identification constraint test (P-value = 0.000) and the weak instrument test (Wald F=529.862> 10% maximal IV size = 16.38). The regression results using the instrumental variable are shown in column (1), indicating that there is still a positive correlation between the level of digital economy development and the competitiveness of manufacturing in foreign trade at the 1% significance level. Additionally, we replace the indicator of whether the level of digital economy development exceeds the average level of all provinces and cities in the same year with a 0-1 variable for re-regression, and perform propensity score matching based on this dummy variable. The regression results are presented in columns (2) and (3), confirming the same conclusion. Finally, we randomly select 80% of the sample for testing, with the results shown in column (4), which also confirms the same conclusion. In summary, the research conclusions of this paper are relatively robust, indicating that improving the level of digital economy development helps enhance the competitiveness of manufacturing in foreign trade.

Table 4: Results of endogeneity and robustness tests

Variables	(1) IV Regression	(2) Replace Explanatory Var.	(3) Propensity Score Matching	(4) Random Sampling
Dig	0.796*** (2.62)	0.070*** (3.36)	0.068** (2.40)	0.777** (2.54)
Open	0.378*** (3.96)	0.241*** (3.59)	0.534** (2.48)	0.287*** (3.35)
Indus	1.889*** (4.59)	1.392*** (4.32)	2.089*** (5.69)	1.631*** (4.59)
Fdi	-0.012 (-0.91)	-0.007 (-0.54)	-0.052*** (-3.28)	-0.018 (-1.33)
Res	2.218 (0.38)	-5.519 (-1.16)	16.974** (2.18)	4.709 (0.80)
Gov	-0.697** (-2.39)	-0.553* (-1.94)	-0.279 (-1.21)	-0.557** (-2.10)
Constant	-1.226*** (-4.73)	0.040 (0.20)	-0.130 (-0.47)	-0.243 (-1.10)
Individual Fixed Effects	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES
Observations	270	300	161	240
R-squared	0.951	0.947	0.961	0.947
Adjusted R² (r2_a)	0.942	0.938	0.950	0.935
F-statistic	612.4	9.561	8.046	

Robust t-statistics in parentheses； *** p<0.01, ** p<0.05, * p<0.1

5.2 Test of regulatory effect

To further investigate the mechanism of how the export structure of manufacturing affects digital economic development and foreign trade competitiveness, based on the theoretical analysis in the previous section, the export structure of manufacturing (Expy) is used as a moderating variable, and an interaction term between the index of digital economic development and the export structure of manufacturing is introduced. Regression using model (2) yields results shown in Table 5. The coefficient of the interaction term is positive and significant at the 1% level, indicating that the export structure of manufacturing has a significant positive moderating effect on the impact of digital economic development on the competitiveness of manufacturing's foreign trade. This means that when the export structure of manufacturing upgrades, transitioning to higher-value-added and technology-intensive products, the development of the digital economy will have a more pronounced effect on enhancing trade competitiveness. When the export structure places greater emphasis on high-end and diversified products, the promoting role of the digital economy can be better leveraged, helping companies improve their market adaptability and gain a favorable position in global competition.

Table 5: Test results of regulatory effects

Variables	(1) Y
Dig	0.036 (0.16)
Expy	-0.107*** (-4.12)
Dig×Expy	0.017*** (2.68)
Open	0.197*** (2.79)
Indus	1.232*** (3.44)
Fdi	-0.007 (-0.58)
Res	-4.737 (-0.95)
Gov	-0.508** (-2.03)
Constant	1.062*** (3.06)
Individual Fixed Effects	YES
Year Fixed Effects	YES
Observations	300
R-squared	0.952
Adj. R²	0.944
F-statistic	9.239

Robust t-statistics in parentheses； *** p<0.01, ** p<0.05, * p<0.1

5.3 Heterogeneity analysis

Due to the significant differences in digital economic development levels and manufacturing characteristics across provinces, the impact of digital economic development on the competitiveness of manufacturing in foreign trade may exhibit regional heterogeneity. To explore the heterogeneous effects across different regions, this paper divides 30 sample provinces into western, central, and eastern regions based on existing research and conducts regional regression analysis. The regression results are shown in the table below:

Table 6: Results of heterogeneity analysis

Variables	(1) Western Region	(2) Central Region	(3) Eastern Region
	TC	TC	TC
Dig	-0.562 (-0.59)	1.268* (1.96)	0.420** (2.40)
Open	0.702 (1.34)	1.375** (2.48)	0.179* (1.90)
Indus	0.803 (0.69)	1.636*** (4.12)	1.827*** (3.24)
Fdi	-0.013 (-0.41)	-0.040* (-1.98)	-0.003 (-0.12)
Res	-15.477 (-1.24)	13.253* (1.75)	12.819* (1.87)
Gov	-0.597 (-1.35)	-0.516 (-0.76)	-0.222 (-0.54)
Constant	0.744 (1.19)	-0.331 (-0.86)	-0.814*** (-4.16)
Individual Fixed Effects	YES	YES	YES
Year Fixed Effects	YES	YES	YES
Observations	90	90	120
R-squared	0.836	0.972	0.983
Adj. R²	0.779	0.962	0.978
F-statistic	3.157	7.936	6.036

According to the results in the table above, it can be seen that the coefficients and significance levels of digital economic development vary across the western, central, and eastern regions, indicating that the impact of digital economic development levels on the competitiveness of manufacturing in foreign trade differs regionally. The results in column (2) show that the coefficient of digital economic development is significantly positive at the 1% level, indicating a significant positive effect of the digital economic development level in the central region on the competitiveness of manufacturing in foreign trade. As the digital infrastructure in the central region becomes increasingly complete and digital technologies are more widely adopted, the growth rate of the digital economy is fast, and it is currently in a period of benefiting manufacturing through digitalization. Moreover, the manufacturing industry in the central region is at a critical stage of transitioning from labor-intensive to technology-intensive, and the introduction of the digital economy can improve production efficiency and reduce costs, thereby further enhancing the competitiveness of foreign trade in the central region.

6. Conclusions and recommendations

This paper is based on panel data from 30 provinces in China between 2012 and 2021. It employs bidirectional fixed panel effect models and moderation effect models to conduct multidimensional empirical analysis of the impact of digital economic development on China's manufacturing export competitiveness and the moderating effect of manufacturing export structure. The main conclusions drawn from this study are as follows: First, an increase in the level of digital economic development can significantly enhance China's manufacturing export competitiveness; the promotion effect of digital economic development on manufacturing export competitiveness is characterized by central regions> eastern regions> western regions. Second, when the manufacturing export structure is upgraded, the improvement in the level of digital economic development has a more significant impact on trade competitiveness, with a positive moderating effect

Based on the above conclusions, this paper proposes the following recommendations: First, continuously promote the development of the digital industry to enhance competitiveness in foreign trade. By improving digital infrastructure, driving the digital transformation of manufacturing, optimizing policy environments, and promoting deep integration between the digital economy and the real economy, we can promote high-quality development in manufacturing, effectively boost China's international competitiveness in manufacturing, and help China transition from a "manufacturing giant" to a "manufacturing powerhouse." Second, based on regional differences in the level of digital economic development, formulate relevant coordinated development paths. The eastern region should focus on the deep development and innovation of the digital economy, promoting the integrated development of advanced manufacturing and digital services, further expanding its international influence; the central region should prioritize the construction of digital infrastructure, assisting traditional manufacturing in its digital transformation, leveraging existing advantages to form a new pattern of coordinated development between the digital economy and manufacturing; the western region should increase investment in digital infrastructure, using late-mover advantages to narrow the gap, and develop new models of green manufacturing and digital economy integration based on resource endowments. Third, leverage the regulatory role of manufacturing structure upgrades to promote the upgrading of export structures and the deep integration of the digital economy. At the government level, there should be increased policy support for high-tech and high-value-added manufacturing, improving digital infrastructure, and encouraging and guiding enterprises to transform into high-end manufacturing sectors; at the enterprise level, they should use the digital economy to advance the optimization and upgrading of export structures, utilizing big data, artificial intelligence, and other technologies to optimize production processes, improve product quality, and enhance international competitiveness

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