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A Study on the Impact of Digital Economy on the Upgrading of China's Manufacturing Industry Structure—Based on the Mediating Effect of Technological Innovation

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Abstract: Currently, China's manufacturing industry development status shows a certain gap compared to the world's leading developed countries, and the industrial structure require s further improvement and development. Therefore, China must prioritize industrial innovation, accelerate the integration of industrial technology, and achieve transformation and upgrading of industrial structure. Simultaneously, China's digital economy is undergoing rapid development, with its impact on the economy and society gradually increasing. The digital economy has become a crucial cornerstone for China to achieve high-quality economic development and industrial modernization. Hence, China should focus on developing the digital economy, enhancing digital infrastructure, and accelerating the integration of manufacturing and digital economy. This study examines the relationship between the development of China's digital economy and the transformation and upgrading of manufacturing industry structure using panel data from 2013 to 2020. Both theoretical analysis and empirical tests are conducted to explore the following aspects: (1) The fundamental relationship between the digital economy and the upgrading of manufacturing industry structure is investigated by reviewing relevant literature and research. (2) The hypothesis that the digital economy can promote the upgrading of industrial structure by facilitating technological innovation is proposed. (3) A two-way fixed-effect model is utilized to test the impact of the digital economy on industrial structure upgrading. (4) The regional heterogeneity of the impact of the digital economy on the upgrading of manufacturing industry structure is examined in the eastern, central, and western regions, as well as the heterogeneous impact of the two from different levels of digital economy development.

1. Introduction

1.1 Background and significance of the study

1.1.1 Background of the study

Since the initiation of the reform and opening up, China's macroeconomy has maintained a stable to favorable situation. The industrial scale has been expanding, while the industrial system has been progressing towards perfection. Furthermore, the industrial structure has undergone optimization and upgrading. Due to the low labor costs and abundance of natural resources, China has become the world's leading manufacturing factory. However, with the gradual disappearance of the demographic dividend and scarcity of natural resources, the development of China's manufacturing industry has been restrained, and the country's manufacturing industry is positioned at the low end of the global value chain. Therefore, it has become an imperative task to transform the manufacturing industry into a high value-added industry and promote the transformation and upgrading of its structure.

In recent years, the digital economy has emerged as a new driving force for China's economic growth, as total size of the digital economy in 2015-2022 shown in figure 1. With the development of digital information technology such as artificial intelligence, blockchain, and 5G technology, the digital economy is expected to reach 50.2 trillion yuan in 2022, ranking second only to the United States. The Chinese government has clearly outlined its strategy to promote the development of the digital economy, achieve digital transformation, and integrate the manufacturing industry with the digital economy. With innovation as the core driver, the government aims to empower industrial development and enhance total factor productivity. Therefore, it is crucial to explore the impact of the digital economy on the development of the manufacturing.

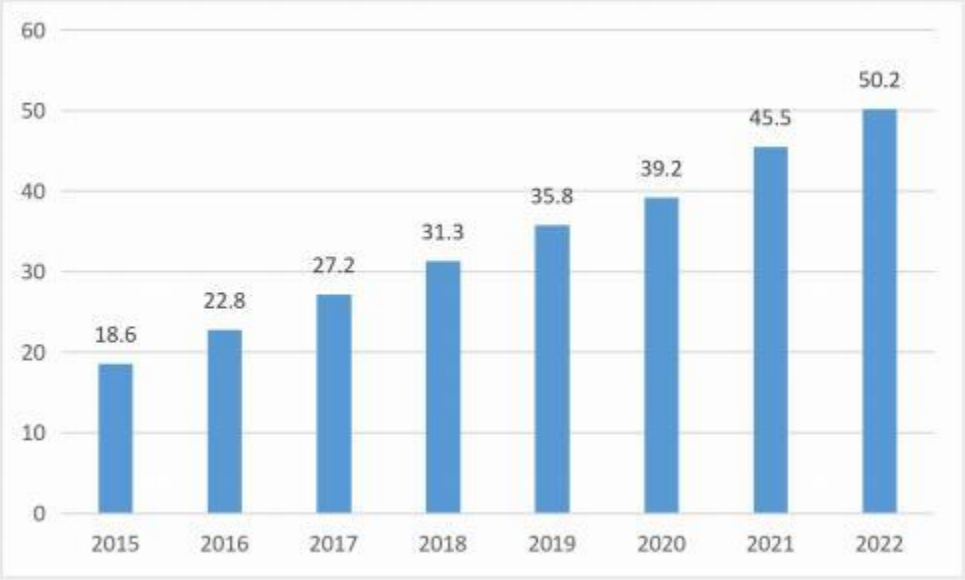

Figure 1: Total size of the digital economy, 2015-2022

1.2 Research Methodology

1.2.1 Method for Literature Analysis

Through conducting a literature search on the topics of digital economy and upgrading of manufacturing industry structure, this study has clarified the definitions and measurement methods

of both concepts. By doing so, we have provided a more comprehensive and specific measurement for digital economy and manufacturing industry structure upgrading, and we have also supplied ample literature references for investigating the causal relationship and mechanism between the two concepts.

1.2.2 Method for Fixed Effects Regression Analysis

This study utilizes a fixed-effects model to test the impact of the digital economy on the upgrading of manufacturing industry structure more robustly. By controlling for time and individual fixed effects, we can more accurately identify the causal relationship between the two concepts. Furthermore, we conduct heterogeneity analysis and robustness tests to ensure the validity of our findings.

1.2.3 Method for Intermediary Mechanism Test

In this study, we investigate the impact of the digital economy on the upgrading of manufacturing industry structure by introducing technological innovation as a mediating variable. By utilizing a mediating effect model, we aim to clarify the causal pathway between the two concepts and provide insight into the underlying mechanism of their relationship.

2. Literature Review

2.1 Relevant studies on digital economy

2.1.1 Study on the connotation of digital economy

Lane [1] posits that the digital economy originated from the development of communication technology, and the integration of computer and communication technology has transformed the form and scope of e-commerce transactions. Kim et al. [2] argue that the digital economy is a novel type of trading activity, where digital and info rmative dissemination of trading information for manufacturing enterprises' products or services is the norm.

2.1.2 Measurement of the digital economy

Most current literature on digital economy measurement utilizes the indicator system accounting method to construct a multi-dimensional indicator system and comprehensively measure the level of digital economy development. Liu Jun [3] measured the digital economy development index based on three aspects: digital transaction development, the current state of internet development and informatization, and used principal component analysis with eight secondary indicators to measure China's digital economy development. Wang Juanjuan et al. [4] measured China's digital economy development index using an index system consisting of three dimensions of digital infra structure, digital industrialization, and digital economy development environment, and explored regional development differences based on location. Bai Xuejie [5] constructed a digital economy development index measurement index based on the Digital Economy and its Core Industries Statistical Classification for the core industries of the digital economy, and measured the digital economy development index at the provincial level in China.

2.1.3 Investigation into the Effects of Digital Economy

Qingxin Lan and Kai Dou [6] posit that digital economy, through digital information technology, can enhance industrial integration, thereby optimizing and upgrading the industrial structure. Li

Qian and Lin Xiaomei [7] maintain that digital economy can boost high-quality economic development, primarily by fostering business model innovation, promoting industrial structure upgrading, and enhancing manufacturing enterprises' production efficiency in three aspects of impact effect. Zhu Hailiang [8] suggests that the digital transformation of the industry hinges on digital technology's integration and application, which propels industrial development. The digital economy has ushered in new economic forms and improved output efficiency.

2.2 Relevant Studies on the Upgrading of Manufacturing Industry Structure

Wu, Chongbo [9] contends that industrial upgrading is accomplished through new technology's development and application, thereby promoting socio-economic development and substituting traditional production processes with high-added-value processes, thereby optimizing the industrial structure. Hummels et al. [10] assert that a country's capital and technology-intensive industries are more advantageous than labor and capital if it has achieved. Acemoglu [11] discovered that innovation and the application of new technologies are the driving forces behind industrial development and a critical factor in industrial evolution by studying industrial structural upgrading. Fu Yuanhai et al. [12] explored the factors influencing the upgrading of manufacturing industry structure based on the data of rationalization of manufacturing structure and advanced manufacturing structure from 1999 to 2012, and the study showed that technological innovation is the main influencing factor. Through empirical research, Yang, Ligao et al. [13] found that the accumulation of human capital and technological innovation can promote the upgrading of manufacturing industry structure, while the promotion effect of technological innovation is greater than that of human capital.

2.3 Research on the Impact of Digital Economy on the Upgrading of Manufacturing Industry Structure

Kelvin [14] argued that the rapid development of information technology and its integration into manufacturing enterprises' manufacturing process can enhance their production efficiency. Moosa and Larry [15], based on data from Chinese listed companies, found that manufacturing enterprises, through information technology network equipment, expanded the production innovation model, expanded sales channels, and achieved networked development of production and manufacturing processes. Xie studied the effect and mechanism of direct application of information technology in digital economy nucleus and manufacturing enterprises, as well as the integration and development of information technology and manufacturing industry on the transformation and upgrading of manufacturing industry. The research results showed that the rapid development of the digital industry promoted the transformation and upgrading of manufacturing enterprises, generating a positive influence effect. Yanqiu Wei et al. [16], based on an empirical study of Chinese province-level data, found that the information technology service industry has a positive impact on the upgrading of manufacturing industries in each Chinese province, and there are provincial differences in the overall efficiency of the impact. Yulin Zhao and Chengchen Pei [17] found through their study that the influence path of technological innovation-driven manufacturing transformation and upgrading is industrial technology integration. Based on data from 2014-2018. Meanwhile, Dandan Na and Ying Li [18], based on data from 2014-2018, found through their study that industrialization and informatization contributed to the transformation and upgrading of China's manufacturing industry.

2.4 Literature Review

After conducting a literature review on the digital economy and the upgrading of manufacturing industry structure, it is evident that some scholars have examined both topics individually, but few have delved into the relationship between them. Drawing from existing literature, this study utilizes an index system accounting method to comprehensively measure the digital economy development index. The impact of digital economy development on the upgrading of manufacturing industry structure is then investigated through a combination of theoretical and empirical research, with technological innovation introduced as a mediating variable to explore the influence mechanism.

3. Analysis of the theoretical mechanism of the impact of digital economy on the upgrading of manufacturing industry structure

3.1 The direct mechanism of the digital economy's effect on the upgrading of manufacturing industry structure

The advancement and utilization of the digital economy facilitate intelligent, automated, and efficient production in the manufacturing industry. This is made possible by the implementation of cloud computing, artificial intelligence, and machine learning technologies. By leveraging these technologies, smart production, intelligent scheduling, and quality control are enabled, resulting in increased productivity and decreased production costs. Additionally, the digital economy accelerates the service and personalization of the manufacturing industry, empowering manufacturing enterprises to promptly address customer needs through digital technology support. Through digital technology, manufacturing enterprises can offer intelligent after-sales service and customer relationship management, thereby improving customer satisfaction and loyalty. Furthermore, the digital economy supports the transformation and upgrading of the manufacturing industry by improving existing production processes and product quality. Digital technology plays a crucial role in the transformation of the manufacturing industry into high value-added and high-tech industries, such as smart manufacturing, industrial Internet, new energy vehicles, and smart homes. The impact of the digital economy on the manufacturing industry is comprehensive, covering intelligent, automated, and efficient manufacturing, personalization and service, as well as transformation and upgrading. These changes benefit not only the manufacturing enterprises themselves but also have a positive impact on overall social and economic development.

3.2 Indirect mechanism of action of digital economy on the upgrading of manufacturing industry structure

The digital economy offers manufacturing companies with additional means of technological innovation. The advancement of digital and information and communicationte chnologies such as the Internet has facilitated the acquisition, processing, and transmission of information for manufacturing firms. By utilizing modern technologies such as big data, artificial intelligence, and cloud computing, manufacturing enterprises can enhance the production process and boost production efficiency and product quality. Furthermore, the digital economy has engendered several new manufacturing enterprises, which possess greater technological innovation potential and consciousness, and have become crucial players in the conventional manufacturing industry. Moreover, the digital economy has elevated the market competitiveness of manufacturing companies. With the development of digital and information and communication technologies such as the Internet, manufacturing firms can accurately grasp market demand and trends and timely adjust product structure and production techniques. Through channels such as e-commerce and

social media, manufacturing firms can expand their markets, increase brand awareness, and sales. Additionally, the development of the digital economy promotes the reconstruction and upgrading of the industrial chain and forms a novel industrial ecosystem, which holds significant importance for the growth of manufacturing companies. Finally, the digital economy has encouraged the intelligent and digital transformation of the manufacturing industry. The implementation of digital and information and communication technologies such as the Internet has facilitated the transformation of the manufacturing industry from traditional labor-intensive to the intelligent and digital direction. Manufacturing firms can leverage technologies such as the Internet of Things and the industrial Internet to automate and intellectualize production lines, improving production efficiency and product quality. The development of the digital economy also propels the integration of conventional manufacturing industries with digital economy industries, which leads to the formation of new industrial chains and business models. In conclusion, the digital economy enhances the technological innovation level of manufacturing companies, providing them with additional technical means and business models, improving their market competitiveness, and promoting the intelligent and digital transformation of the manufacturing industry.

4. Measurement and analysis of digital economy and upgrading of manufacturing industry structure

4.1 Measurement and analysis of digital economy development index

4.1.1 Measurement method of digital economy development index

This article constructs digital economy development index indicators by adopting Zhao Tao et al.'s measurement method and using the entropy value method for me asurement. The detailed index system is presented in Figure 2.

Tier 1 Indicators	Secondary indicators	Tertiary indicators	Indicator Properties
Digital Economy Development Index	Digital Financial Inclusion Development	China Digital Inclusive Finance Index	Positive
	Internet penetration rate	Internet users per 100 people	Positive
	Number of Internet-related employees	Computer services and software employees as a percentage of	Positive
	Number of mobile Internet users	Number of cell phone subscribers per 100 people	Positive
	Internet-related outputs	Total telecom services per capita	Positive

Figure 2: Indicator System

After constructing the index system of digital economy development index, it is necessary to assign the indicators so that the comprehensive score can be measured. The following are the specific steps of the entropy value method.

(1) Standardization of data:

$$x_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)}$$

(2) Measure the weight of the i-th record under the j-th indicator:

$$P_{ij} = \frac{x_{ij}}{\sum_1^n x_{ij}} (j = 1,2, \ldots, m)$$

(3) Measure the entropy value of the jth of these indicators:

$$e_j = -k * \sum_1^n P_{ij} * \log(P_{ij}), k = \frac{1}{\ln(n)}$$

(4) The coefficient of variation of the jth indicator: gj = 1 − ej

(5) The weight of the jth indicator :

$$W_j = \frac{g_j}{\sum_1^m g_j}$$

4.1.2 Analysis of the measurement results of the digital economy development index

The 30 inland provinces of China are categorized into three regions based on their geographic location, namely the eastern region, the central region, and the western region. The digital economy development index was employed to obtain results, and data visualization revealed an upward trend in overall digital economy development level from 2013 to 2020 as illustrated in Figure 3. The eastern region of China boasts a highly developed digital economy with a development level exceeding the national average. The central and western regions share similar levels of development, but after 2017, the western region experienced a faster trend of digital economy development than the central region owing to its rapid economic growth in recent years and its active undertaking of the eastern digital industry transfer. The western region has seen a growth rate of 176.65% from 2013 to 2020.

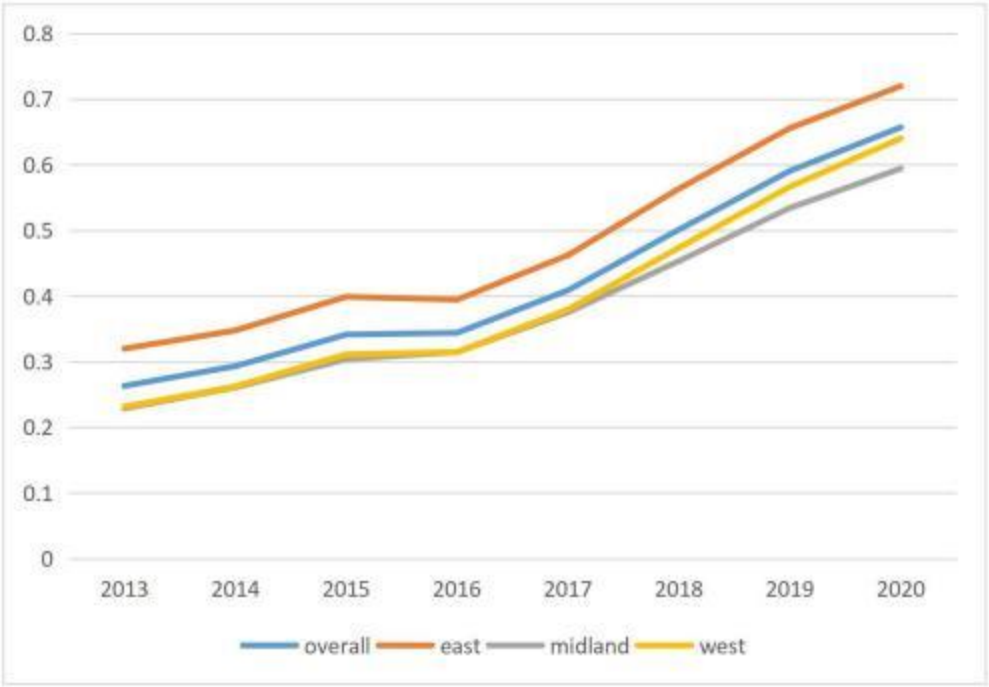

Figure 3: Digital Economy Development Trend 2013-2020

4.2 Measurement and analysis of the upgrading of manufacturing industry structure

4.2.1 Measurement method for upgrading manufacturing industry structure

This paper utilizes Fu Yuanhai et al.'s [12] metric for industrial structure upgrading in

manufacturing, which employs the ratio of technology-intensive manufacturing output value to capital-intensive manufacturing output value as a comprehensive indicator of industrial structure upgrading in manufacturing. The specific classification of manufacturing industries can be seen in Figure 4.

Type of Manufacturing	Specific industries
Technology-intensive manufacturing	Electronics manufacturing, automobile manufacturing, aviation manufacturing, biomedical manufacturing, precision machinery manufacturing, new energy manufacturing, nanomaterials manufacturing
Capital-intensive manufacturing	General equipment manufacturing, wine, beverage and refined tea manufacturing, tobacco products, paper and paper products, petroleum processing, coking and nuclear fuel processing industry, chemical materials and chemical products manufacturing, chemical fiber manufacturing, ferrous metal smelting and rolling processing industry, non-ferrous metal smelting and rolling processing industry.
Labor-intensive manufacturing	Textile industry, food manufacturing, textile and clothing, fur, agricultural and food processing industry, feathers and their products and footwear industry, wood processing and wood, apparel industry, grass products industry, furniture manufacturing, education, industry, sports and recreational goods manufacturing, printing and recording media reproduction industry, non-metallic mineral products industry, metal products industry, rubber and plastic products industry.

Figure 4: Manufacturing industry classification

4.2.2 Analysis of the measurement results of the upgrading of manufacturing industry structure

By assessing the upgrading of the manufacturing industry's structure, the data for the manufacturing industry structure upgrade index from 2013-2020 has been illustrated in Figure 5. The manufacturing industry structure upgrade index has demonstrated an upward trend in recent years, and the manufacturing industry structure in the eastern region has become increasingly advanced and refined. There has been a 71.24% increase in the manufacturing industry structure upgrade index in China from 2013 to 2020, with a 63.49% increase in the manufacturing industry structure upgrade in the eastern region, an 83.84% increase in the central region, and a 74.82% increase in the western region. Thus, it is apparent that the manufacturing industry structure in the central region is evolving more swiftly.

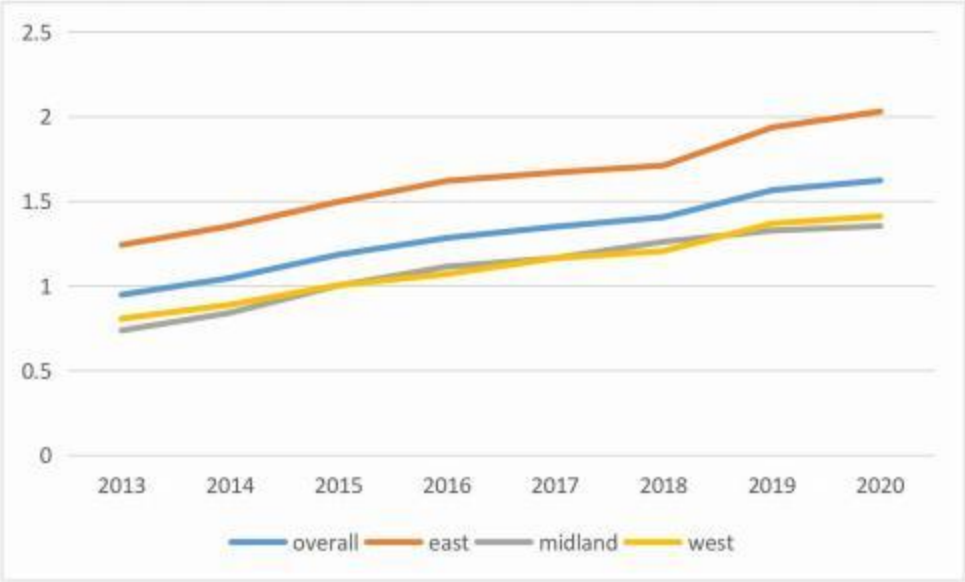

Figure 5: Development trend of manufacturing industry structure, 2013-2020

5. Empirical analysis of the impact of digital economy on the upgrading of manufacturing industry structure

5.1 Model Setting

This study employs panel data from 30 provinces to investigate the influence of the digital economy on the upgrading of the manufacturing industry structure. The constructed model is presented below.

$$Upgrade_{it} = \beta_0 + \beta_1 Digital_{it} + \beta_2 X_{it} + \alpha_t + \mu_i + \varepsilon_{it}$$

The subscript i denotes the province and the subscript t denotes the year. $Upgrade_{it}$ is manufacturing industry structure upgrading index, and $Digital_{it}$ is digital economy development index, and X_{it} are the control variables, and α_t is year fixed, μ_i is individual fixed, and ε_{it} is the residual term.

5.2 Variable description and data description

5.2.1 Explained variables

The explanatory variable in this paper is the upgrading of manufacturing industry structure, and the measure is the ratio of technology-intensive manufacturing output to capital-intensive manufacturing output. The data source is the database of National Research Network.

5.2.2 Core explanatory variables

The primary explanatory variable of this paper is the digital economy. To construct five secondary indicators, this study employs Zhao Tao's measure and employs the entropy method. The China Statistical Yearbook and Peking University's Digital Inclusive Finance Index are the sources of data for this study.

5.2.3 Control variables

(1)Human Capital Level(LNEducation)

Human capital represents the degree of knowledge a region's labor force has, and regions with higher human capital are more conducive to the development of manufacturing. This paper measures human capital using the ratio of the number of people with higher education in a region to the total population, and the original data source is the China Statistical Yearbook.

(2) Foreign direct investment(Fdi)

Foreign direct investment can directly promote regional economic development, and also promote local enterprises through the introduction of foreign high technology. In this paper, the actual amount of foreign investment used in each region is used to measure FDI, and the data source is the National Bureau of Statistics.

(3) Transportation infrastructure(Road)

Transportation infrastructure is conducive to the transportation of raw materials and the production and sale of products by enterprises, which is conducive to improving operational efficiency and promoting industrial upgrading. In this paper, the total number of railroad and road miles is used to measure transportation infrastructure, and the original data source is China Statistical Yearbook.

(4) Level of urbanization(Urbanization)

The level of urbanization and the degree of local economic development have a close and mutually reinforcing relationship. The development of local manufacturing industries is more favorable with the increase in the level of urbanization. To measure the level of urbanization, this paper utilizes the ratio of urban population to the total population in each region, with data sourced from China Statistical Yearbook.

5.2.4 Mediating variables

Based on the theoretical influence mechanism analysis above, this paper selects technological innovation as the mediating variable. Specifically, the development of digital economy facilitates technological innovation in manufacturing enterprises, which, in turn, enables the transformation and upgrading of manufacturing industry structure. The regional innovation index is used in this paper to measure technological innovation, with the original data source being the China Statistical Yearbook.

5.3 Baseline regression analysis

5.3.1 Descriptive statistics

Table 1: Descriptive statistics

VARIABLES	N	mean	sd	min	max
Upgrade	240	1.300	0.711	0.572	5.297
Digital	240	0.425	0.152	0.196	0.982
Fdi	240	5.401	1.679	-1.220	7.495
Road	240	3.361	1.135	1.674	8.131
Urbanization	240	2.496	0.847	0.231	3.675
LNEducation	240	-66.55	6.731	-76.24	-49.04
Innovation	240	5.689	0.925	3.297	8.005
Number of code	30	30	30	30	30

Table 1 presents the descriptive statistics of the variables. The results demonstrate significant

variation between the maximum and minimum values of the manufacturing industry structure upgrading index and the digital economy development index, indicat ing substantial regional disparities.

5.3.2 Data testing and model estimation

To mitigate the issue of multicollinearity, this paper calculates the variance inflation factor (VIF) among the variables. As presented in Table 2, both the mean and maximum VIF values are considerably smaller than the threshold value of 10, thereby indicating that there is no significant covariance among the variables.

Table 2: VIF test

Variable	VIF	1/VIF
Road	2.550	0.392
Urbanization	2.040	0.490
LNEducation	1.800	0.556
Digital	1.490	0.669
Fdi	1.140	0.875
Mean	VIF	1.800

5.3.3 Baseline regression results

In this study, the effect of the digital economy on the upgrading of the manufacturing industry structure is assessed by gradually incorporating control variables with two-way fixed effects. The results of the benchmark regression are presented in Table 3. The initial regression reveals that a 1% increase in the digital economy results in a 1.9284% increase in the upgrading of the manufacturing industry structure. After controlling for all variables, the digital economy stimulates a 1% increase and the upgrading of the manufacturing industry structure increases by 2.0552%. These findings indicate that the development of the digital economy can promote the upgrading and optimization of the manufacturing industry structure. Moreover, all control variables selected for this study significantly contribute to the upgrading of the manufacturing industry.

Table 3: Baseline regression

variables	upgrade	upgrade	upgrade	upgrade	upgrade
digital	1.9284*** (3.34)	1.8917*** (3.23)	2.6350*** (4.33)	2.6931*** (4.38)	2.0552*** (3.44)
fdi		0.0093 (0.40)	0.0260 (1.11)	0.0256 (1.09)	0.0514** (2.24)
road			0.1297*** (3.50)	0.1365*** (3.56)	0.1260*** (3.46)
urbanization				0.1548(0.71)	0.3688*(1.74)
lneducation					0.4312***(4.84)
constant	0.4398*** (2.86)	0.3990** (2.15)	-0.2621 (-1.00)	-0.6684 (-1.06)	27.0385*** (4.70)
fixed time	yes	yes	yes	yes	yes
individual fixation	yes	yes	yes	yes	yes
observations	240	240	240	240	240
r-squared	0.742	0.743	0.757	0.758	0.784
number of code	30	30	30	30	30

where the symbols ***, **, and * indicate significant levels at 1%, 5%, and 10%

5.4 Heterogeneity test

5.4.1 Regional heterogeneity

This study investigates the heterogeneous effects of the digital economy on the upgrading of manufacturing industry structure, taking into account the variations in economic development and regional industrial advancement across different areas. The results presented in Table 4 show a significantly positive impact of the digital economy on the upgrading of manufacturing industry structure at a 1% level in eastern China. However, the effect of the digital economy on the upgrading of manufacturing industry structure is not statistically significant in central and western China. It is plausible that the digital economy infrastructure in these regions is underdeveloped, the industrial structure is not yet mature, and the economic foundation is not strong enough to support the transformation and development of the industrial structure.

Table 4: Regional heterogeneity

VARIABLES	East Upgrade	Midwest Upgrade
Digital	4.1524*** (5.57)	0.4567 (0.53)
Fdi	0.0680* (1.77)	0.0446* (1.76)
Road	0.1558*** (3.40)	0.1255** (2.47)
Urbanization	2. 1766*** (6.67)	-0.2577 (-0.93)
LNEducation	0.8591*** (6.77)	0.2722* (1.92)
Constant	47.6288*** (6.30)	19.1929* (1.96)
Fixed time	YES	YES
Individual fixation	YES	YES
Observations	88	152
Number of code	11	19
R-squared	0.885	0.792

where the symbols ***, **, and * indicate significant levels at 1%, 5%, and 10%

5.4.2 Heterogeneity in the level of development of the digital economy

China's digital economy exhibits significant regional differences and imbalanced development. In this study, provinces ranking in the top 50% of the digital economy development index are classified as high-level digital economy areas, while those in the bot tom 50% are classified as low-level digital economy areas. Regression analysis results, as shown in Table 5, indicate that the impact of the digital economy on the upgrading of manufacturing industry structure is significantly positive at the 1% level in areas with a high level of digital economy development, while such impact is not significant in areas with a low level of digital economy development. The possible reason for the lack of impact is that enterprises in areas with a low level of digital economy development possess a low degree of digitalization, pay little attention to the application of digital technology, and lack digital talents. Consequently, the enhancement of the digital economy cannot promote the upgrading of the manufacturing industry structure in areas with low digital economy

development levels.

Table 5: Heterogeneity of digital economy development levels

VARIABLES	High Upgrade	Low Upgrade
Digital	4.3117*** (5.13)	1.1109 (0.96)
Fdi	0.0280 (0.89)	0.0678** (2.04)
Road	0.1352*** (2.87)	0.1216** (2.14)
Urbanization	0.9991*** (3.77)	-0.0570 (-0.16)
LNEducation	0.6424*** (5.40)	0.2987 (1.55)
Constant	37.1781*** (5.09)	20.5009 (1.57)
Fixed time	YES	YES
Individual fixation	YES	YES
Observations	120	120
Number of code	15	15
R-squared	0.831	0.795

where the symbols ***, **, and * indicate significant levels at 1%, 5%, and 10%

5.5 Robustness tests

5.5.1 Core Variable Tail Reduction 1%

Table 6: Core variables indented by 1%

VARIABLES	Upgrade_w
Digital_w	1.3626*** (3.95)
Fdi	-0.0013 (-0.07)
Road	0. 1688*** (6.53)
Urbanization	-0.1926 (-1.13)
LNEducation	-0.0048 (-0.07)
Constant	0.2337 (0.05)
Fixed time	YES
Individual fixation	YES
Observations	240
Number of code	30
R-squared	0.782

where the symbols ***, **, and * indicate significant levels at 1%, 5%, and 10%

This study conducts regression analysis to eliminate the impact of outliers by scaling down the digital economy development index and manufacturing industry structure upgrading index by 1%. The regression results are presented in Table 6, and the analys is shows that the results are still robust.

5.5.2 Core explanatory variables lagged by one period

This study examines the mutual promotion of the digital economy and manufacturing industry development. Specifically, highly developed manufacturing regions can also boost the development of the digital economy in the opposite direction. To address the potential issue of reverse causality, the digital economy is regressed with a one-period lag. The regression results in Tables 7 demonstrate that the digital economy has a significantly positive impact on the structure of the manufacturing industry at the 1% level, and these results remain robust.

Table 7: Core explanatory variables lagged by one period

VARIABLES	Upgrade
LDigital	3.1443***
	(4.40)
Fdi	0.0522**
	(2.24)
Road	0.1053***
	(2.99)
Urbanization	0.4537**
	(2.05)
LNEducation	0.4089***
	(4.56)
Constant	25.2280***
	(4.37)
Fixed time	YES
Individual fixation	YES
Observations	210
Number of code	30
R-squared	0.766

where the symbols ***, **, and * indicate significant levels at 1%, 5%, and 10%

5.6 Mechanism testing

In this paper, in order to test the validity of the influence channel of technological innovation, this paper draws on the mediating effect of Zhonglin Wen and Baojuan Ye. The model is underlined.

$$Upgrade_{it} = \alpha_0 + \alpha_1 Digital_{it} + \alpha_2 X_{it} + u_t + v_i + \varepsilon_{it}$$

$$Innovation_{it} = \beta_0 + \beta_1 Digital_{it} + \beta_2 X_{it} + u_t + v_i + \varepsilon_{it}$$

$$Upgrade_{it} = \delta_0 + \delta_1 Digital_{it} + \delta_2 Innovation_{it} + \delta_3 X_{it} + u_t + v_i + \varepsilon_{it}$$

The results of the regression analysis are presented in Tables 8. In the absence of any mediating variables, a 1% increase in the digital economy is associated with a 2.0552% increase in the upgrading of manufacturing industry structure. However, when mediating variables are introduced, the effect decreases to 1.4581%, indicating the existence of a mediating effect. This suggests that the development of the digital economy can promote technological innovation, which in turn can

facilitate the upgrading of ma nufacturing industry structure.

Table 8: Mechanism test

VARIABLES	Upgrade	Innovation	Upgrade
Digital	2.0552*** (3.44)	2.8809*** (3.58)	1.4581** (2.46)
Innovation			0.2073*** (4.08)
Road	(2.24) 0. 1260*** (3.46)	(-1. 14) -0.0358 (-0.73)	(2.65) 0. 1334*** (3.80)
Urbanization	0.3688* (1.74)	(4.86)	0.0808 (0.37)
LNEducation	0.4312*** (4.84)	-0.2307* (-1.92)	0.4790*** (5.54)
Constant	27.0385*** (4.70)	-14.3707* (-1.85)	30.0171*** (5.38)
Fixed time	YES	YES	YES
Individual fixation	YES	YES	YES
Observations	240	240	240
R-squared	0.784	0.963	0.801
Number of code	30	30	30

where the symbols ***, **, and * indicate significant levels at 1%, 5%, and 10%

6. Research conclusions and policy recommendations

6.1 Research findings

This paper explores the influence of the digital economy on the upgrading of the manufacturing industry structure from both theoretical and empirical perspectives using panel data from 30 provinces in inland China from 2013 to 2020. The study also examines the influence pathway of the digital economy on the manufacturing industry structure by considering the mediation effect. The findings suggest that the development levels of both the digital economy and the manufacturing industry structure showed an upward trend from 2013 to 2020. The overall development level was higher in the eastern region than in the central and western regions due to more advanced infrastructure, but the central and western regions have developed more rapidly in recent years. The study also shows that the digital economy has a positive impact on the upgrading of the manufacturing industry structure, with a 1% increase in digital economy development level resulting in a 2.0552% increase in the upgrading of the manufacturing industry structure. This impact is achieved through the promotion of technological innovation. Moreover, the impact of the digital economy on the upgrading of the manufacturing industry structure shows regional and digital economy development level heterogeneity.

6.2 Policy Recommendations

6.2.1 Strengthen the cultivation of digital talents

(1) Reform of education system: teaching and research of digital technology should be strengthened, advanced digital technology courses and laboratory equipment should be introduced,

and teachers' digital technology level and teaching quality should be improved. (2) Accumulation of practical experience: students need to accumulate experience in digital technology in practice, and opportunities can be provided by offering internships, projects, and competitions. At the same time, schools should actively establish links with enterprises and research institutions to provide students with a wider range of practical opportunities. (3) Cooperation between industry and government: digital technology is widely used, and industry and government can attract and cultivate digital talents by providing training, scholarships, and practical opportunities. (4)Increase of social attention: Society can increase the publicity and attention to the cultivation of digital talents, guide more people to choose the digital field for development, and encourage digital talents to play an active role in society. (5) Support of national policies: The government can introduce corresponding policies and measures to encourage the cultivation and development of digital talents, such as providing tax concessions and establishing R&D bases for digital technologies

6.2.2 Improve digital infrastructure construction

(1) Strengthen network infrastructure: The Chinese government needs to vigorously develop high-speed network infrastructure, including 4G and 5G mobile networks, fiber-optic broadband networks and satellite networks. In addition, the government is actively promoting IPv6 network construction to meet higher network demands in the future. (2) Promote IoT technology: The Chinese government should actively promote the development of IoT technology, including strengthening IoT standardization and promoting 5G+ IoT applications. (3) Strengthen data center construction: Data center is an important infrastructure for digital economy, which can provide data storage and processing capacity for enterprises and government, so government departments should increase investment in data center construction.

6.2.3 Accelerate the development of digital economy in the central and western regions

(1) The government can increase investment in transportation infrastructure such as highways, railroads and airports in the central and western regions, and accelerate the construction of digital infrastructure, including 5G networks, data centers, and cloud computing, to support infrastructure construction. (2) In order to accelerate the cultivation of digital industries in the central and western regions, the government can provide financial subsidies, tax incentives, and talent introduction to support the development of the digital economy. Meanwhile, SMEs can be encouraged to develop digital economy and industrial clustering can be promoted. (3) To achieve regional coordination, the central and western regions can strengthen cooperation with the eastern coastal regions, promote resource sharing and mutually beneficial cooperation, and establish a digital economy cooperation mechanism between the central and western regions and the eastern coastal regions to jointly promote the development of the digital economy.

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