The Impact of Manufacturing Digital Transformation on the Digital Economy in China

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Abstract. Developing the digital economy has emerged as a strategic imperative for China, serving as a key driver of high-quality economic growth. This shift has unlocked numerous opportunities for advancing the manufacturing sector. This study, spanning from 2011 to 2021 and covering 30 provinces in China, delves into the nexus between the digital economy and manufacturing transformation, yielding the following findings: (1) The digital economy's development positively influences the digital transformation of manufacturing, a conclusion reinforced by rigorous robustness tests. (2) Regional disparities reveal varying impacts of the digital economy on manufacturing transformation, with the Eastern region notably benefiting from a stronger digital economy-driven impetus compared to other areas. These insights offer valuable guidance for facilitating the transformation of the manufacturing sector as China's digital economy develops.

Keywords: Manufacturing Digital Transformation, Digital Economy, Provincial Level, Panel Data Regression

1 Introduction

China is presently undergoing a progressive transition from an industrial-based economy to a digital-centric economy. Data, as an emerging factor of production, has evolved into a strategic resource pivotal for the development of a digital China and the facilitation of high-quality economic growth. The digital economy represents one of the most dynamic sectors within China's economic landscape. The scope and intensity of integration between the digital economy and diverse economic and social domains are continually expanding. It serves a pivotal role in driving consumption, encouraging investment, and generating employment opportunities. The contemporary digital economy offers improved matching mechanisms and innovation incentives, contributing significantly to the ongoing development of China's modern economic infrastructure (Jing & Sun, 2019)[4].

China has entered a new stage of high-speed growth and sustainable development. Digitalization is consistent with the current trend of China's high-quality economic development (Pan et al., 2022)[10]. According to Li (2019), the digital economy not only

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changes the structure of economic momentum, but also improves its quality[7]. With the supply-side structural reform deeply developed, digital technology is widely penetrating into other economic fields (Zhang et al., 2021)[19]. The "China Internet Development Report (2021)" reveals that China's digital economy surged to 39.2 trillion yuan in 2020, representing nearly 40% of GDP, positioning China as the world's second-largest digital economy. Following the 19th National Congress of the Communist Party of China, General Secretary Xi Jinping has consistently underscored the imperative to expedite the advancement of the digital economy and facilitate the rapid transformation of manufacturing towards digitalization, networking, and intelligence. The progression of the digital economy is deemed an inevitable imperative for fostering economic growth, refining economic structures, and bolstering international competitiveness. The digital economy can advance China's high-quality economic development through four dimensions: enhancing market efficiency, adjusting economic structure and market systems, enhancing social welfare allocation, and reducing ecological environment pollution (Zhang et al., 2021)[21]. Consequently, the methods to accelerate the digital economy's rapid expansion have become a subject of widespread academic interest.

The subsequent sections of this paper are organized as follows: Section 2 provides a concise summary of the relevant literature pertaining to recent studies in the field. Section 3 outlines the data sources, describes the variables, and elucidates the methodology employed. Section 4 introduces the theoretical framework and formulates hypotheses. This is followed by the presentation of empirical findings in Section 5. Finally, Section 7 offers conclusions regarding the research contributions and limitations of this study.

2 Literature Review

In contemporary economic discourse, the digital economy is emerging as a principal driving force. Considerable attention is directed toward examining the interplay between the digital economy and the transformation of the manufacturing industry. In the following discourse, we aim to offer scholarly insights into this domain.

2.1 Research on the Digital Economy

The digital economy, following the industrial and agricultural economies, is another significant economic form and a new engine for modern economic development. Tapscott (1995, as cited in Wang & Wu, 2020) firstly introduced the term "digital economy" and briefly elaborated on the inevitability of the digital economy becoming a new economic form in the future at the macro level[11]. The dependence of China on elements such as digital technology and digital information has continued to deepen over the past decade (Zhao et al., 2022)[20].

According to Ye & Fan (2023), the digital economy represents a nascent economic paradigm arising from the synergistic evolution of technologies such as the Internet, big data, cloud computing, and 5G communication[15]. This digital revolution is precipitating a global shift toward digitization in social production, thereby prompting a comprehensive restructuring of the entire economic framework (Fu, 2020)[2]. The advent of the third industrial revolution, marked by digitalization, intelligence, and informatization, signifies a profound transformation across various dimensions encompassing technology, business models, regulatory frameworks, and institutional structures (Huang & He, 2013)[3]. China's strategic emphasis on fostering the digital economy underscores its commitment to enhancing economic quality, efficiency, and the driving forces behind economic development (Ma & Ning, 2020)[9].

2.2 Research on the Manufacturing Transformation

The manufacturing sector holds a pivotal role in the Chinese economy, maintaining global leadership for several years and driving eco[18]nomic growth while engaging in international competitiveness (Fu, 2021)[1]. However, as China's economic landscape shifts within a new industrial chain competition framework, the manufacturing sector faces intricate challenges (Zhang & Li, 2015). Xu & Lin (2015) note that advancements in information technologies like digitalization and intelligence present both obstacles and opportunities to traditional manufacturing practices, necessitating industry-wide transformation[14]. Yu (2020) emphasizes that achieving high-quality development in manufacturing is imperative not only to uphold China's socialist ideals but also for sustainable progress[16]. Despite the widespread application of digital technologies in various sectors such as e-commerce and tourism, their integration into manufacturing remains nascent, highlighting the urgent need for digitization in traditional manufacturing processes (Liao et al., 2024)[8].

2.3 Research on the Relationship between the Digital Economy and Manufacturing Transformation

Amidst the backdrop of technological revolution and industrial transformation, the digitization upgrade of industries has emerged as a primary driver for achieving high-quality economic development. The digital economy can optimize the industrial structure of manufacturing. The deep integration of the digital economy with the entity economy has become a new motive force to promote the revitalization of the transformation manufacturing industries by expanding the organizational divisions of the industrial chain, reducing transaction costs and allocating the value (Li et al., 2020)[5]. The digital economy drives rapid advances in technologies such as big data. Zhao (2017) proposes that the digital economy drives the transformation and upgrading of the manufacturing industry by cracking the bottleneck of the innovation chain, improving the quality of the manufacturing chain, optimizing the efficiency of the supply chain, and expanding the service chain space[21].

The digital economy in China showcases notable regional disparities, with the Eastern regions typically demonstrating higher levels of development in contrast to the Western regions. Wei et al. (2021) demonstrate the locational heterogeneity of the digital economy's contribution to the high-quality development of the manufacturing sector based on inter-provincial panel data from 2005 to 2016[13]. Wang et al. (2021) analyzes panel data from 2007 to 2019 and revealed significant geographical variations in the digital economy's development[12]. Their research indicates a high level of development in the Eastern region and a comparatively lower level in the Western region. The digital economy has a significant positive impact on the manufacturing industry transformation in the Eastern region, while its effects on other regions have not been fully realized. Li & Qu (2022) indicates that regions with higher levels of economic development tend to experience stronger effects of the digital economy in driving high-quality development in manufacturing[6]. In summary, regional differences in technology and economic foundations will affect the efficiency and outcomes of industrial structural transformation.

The intersection between the digital economy and the metamorphosis of the manufacturing sector has garnered considerable scholarly interest. Both domestic and international scholars widely acknowledge the transformative potential of digital technologies within the manufacturing industry. The progressive evolution of digital technology has gradually mitigated the inherent limitations encountered during the industry's transformation, fostering a continuous trajectory of optimization and structural enhancement within industrial frameworks. While extant research has contributed valuable theoretical and empirical insights into the metamorphosis of the manufacturing industry from diverse analytical perspectives, further empirical investigations are warranted. While a predominant portion of scholarly endeavors has primarily engaged in theoretical analyses encompassing the entire nation, empirical inquiries focusing on regional diversity remain scarce. Given the diverse viewpoints regarding China's holistic developmental landscape, this study aims to broaden the research purview in the following dimensions: (1) Assessing the digital economy's scale across the 30 provinces of China, with a specific emphasis on evaluating both the digital economy's dimensions and the digitization trends within the manufacturing sector. (2) Deliberately narrowing the research ambit to the provincial level to meticulously investigate the heterogeneous impacts of the digital economy on the manufacturing sector's transformation, thereby furnishing more tailored and region-specific policy recommendations.

3 Data, Variables, and Methods

3.1 Data Source

In this research, we constructed a detailed panel dataset encompassing 30 provincial-level regions across China from 2011 to 2021. Our data compilation involved sources such as the National Bureau of Statistics (NBS), the Ministry of Science and Technology (MOST), and authoritative databases like the China Statistical Yearbook, China Urban Statistical Yearbook, China Industrial Statistical Yearbook, and provincial statistical yearbooks. Notably, Tibet province was omitted from our analysis due to the lack of crucial indicators necessary for our analytical framework.

3.2 Variables

3.2.1. The Development Level of Digital Economy

The primary focus of this study is the digital economy, which serves as the explanatory variable. We developed a comprehensive assessment framework to evaluate its level of development, consisting of three secondary indicators and 14 specific indicators. Table 1 provides a summary of these specific indicators utilized to gauge the digital economy's development level.

Table 1. Index of the digital economy development level.

Primary Index	Secondary Index	Indicator Description	Unit
Digital Economy	Digital Infrastructure	Density of Mobile Phone Base Station	PCS/km²
		Length of Long-haul Cable	km
		Mobile Switching Center (MSC) Capacity	10,000
		Quantity of IPv4 Addresses	10,000
		Density of Internet Broadband Ports	10,000/km²
	Application of Digital Industrialization	Software Revenue Ratio	%
		Digital TV Penetration Ratio	%
		Ratio of technology to revenue	%
		Information and Communication Technology Workforce Ratio	%
	Industrial Digitalization	Proportion of Enterprises Engaged in E-commerce Trade	%
		Number of Websites per 100 Enterprises	number
		Digital Financial Inclusion Index	/
		E-commerce Sales Revenue	CNY 100 million

In this scenario, we employed an enhanced entropy weighting method to ascertain the weights of each secondary indicator. Initially, we normalized the specific indicators within each secondary indicator to render them dimensionless. Subsequently, the improved entropy weighting method was applied to compute the weight of each indicator. Lastly, the comprehensive evaluation index of digital economic development was calculated using the linear weighting method, facilitating the determination of the digital economy's target level. The detailed steps include:

Standardized both the positive and negative indicators:

$$X'_{\alpha ij} = \frac{X_{\alpha ij}}{X_{max}} \tag{1}$$

$$X'_{\alpha ij} = \frac{X_{min}}{X_{\alpha ij}} \tag{2}$$

Here, parameters are as follow:

α : Represents the year.

i : Represents the region.

j : Represents the indicator.

Xmax and Xmin: Denote the maximum and minimum values of the indicators.

$X'_{\alpha ij}$ and $X_{\alpha ij}$: Represent the standardized values of indicator j for region i in year α after and before standardization, respectively.

(2) Calculate entropy value

$$e_j = -b \sum_{\alpha=1}^{d} \sum_{i=1}^{n} y_{\alpha ij} \ln(y_{\alpha ij}) \quad (3)$$

Here, d represents the time span, while n denotes the number of regions. The value of b is greater than 0 and is determined by taking the natural logarithm of the product d_n, expressed as $\ln(d_n)$

In addition, $y_{\alpha ij}$ can be calculated using the following formula:

$$y_{\alpha ij} = \frac{X'_{\alpha ij}}{\sum_{\alpha=1}^{d} \sum_{i=1}^{n} X'_{\alpha ij}} \quad (4)$$

Indicator information utility value and weight can be obtained by

$$g_j = 1 - e_j \quad (5)$$

$$W_j = g_j \div \sum_{j=1}^{m} g_j \quad (6)$$

Where the variable "m" denotes the total number of indicators considered in the evaluation framework. The symbols Wj and gj correspond to the assigned weight and information utility value attributed to each specific indicator within this framework.

Comprehensive level of index

$$S_{\alpha i} = \sum_{j=1}^{m} (W_j X'_{\alpha ij}) \quad (7)$$

Where $S_{\alpha i}$ represents the level of primary index of region i in year α.

3.2.2. Manufacturing Digital Transformation Index

Here, we utilize the Manufacturing Digital Transformation Index as a metric to investigate the correlation between the Manufacturing Digital Transformation Index and the digital economy. The index comprises a blend of the digital word frequency index and the digital sentiment index of the two metrics.

The digital word frequency index shows the number of digital transformation feature words in the annual report, reflecting the company's focus on digital transformation. The index shows the number of digital transformation words in the annual report, reflecting the importance the enterprise attaches to digital transformation and its strategic layout. Digital sentiment index shows the number of digital transformation words in the annual report, reflecting the importance of the enterprise to digital transformation and the related strategic layout. The index determines the subjective evaluation of the digital transformation process through the average sentiment index of the digital transformation words in the company's annual report. It measures the enterprise's subjective evaluation of the digital transformation process through the average sentiment index of the digital transformation terms in the annual report. The combination of the two can provide a more comprehensive. The combination of the two can reflect the digital transformation level of an enterprise more comprehensively. the digital word frequency index and the digital sentiment index with a weight of 50 each. We get the revised digital transformation index.

3.2.3. Digital Economy Indicator and Manufacturing Digitisation Indicators Analysis

In accordance with the findings elucidated by Zhang et al. (2021) [17], the rapid development of China's digital economy is evident across all regions, with continuous increases in investment. Notably, the Eastern region, encompassing Beijing, Guangdong, Shanghai, Jiangsu, and Zhejiang, stands out with a significantly higher level of digital economy development compared to other regions.

Over the past decade, the Eastern region has experienced substantial growth in its digital economy index, doubling its indicators and indicating a relatively mature digital economy landscape. In contrast, the Central and Western regions have shown slower but steady progress in digital economy development, albeit maintaining a notable gap with the Eastern region. The Northeast region, initially lagging behind with a lower digital economy indicator in 2011, has made efforts to bridge this gap despite challenges related to economic restructuring and industrial transformation. Although experiencing some growth in digital economy levels, the region faces uncertainties that require sustained efforts for further progress.

To comprehensively assess the extent of digitization across China's provinces from 2011 to 2020, this study categorizes indicators for manufacturing digitization into four regions: East, Central, West, and Northeast regions.

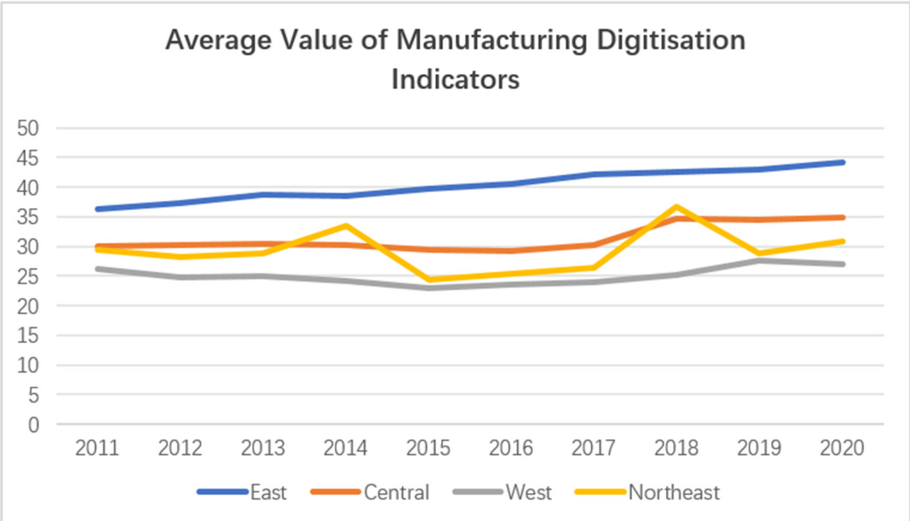

Fig. 1. Average Value of Manufacturing Digitisation Indicators

Growth rates within the digital economy sector have also increased steadily. Notably, certain provinces such as Beijing and Shanghai exhibit notably high levels of manufacturing digitization. Conversely, the Central and Northeast regions show slightly delayed digitization progress with comparatively slower growth rates, while the Western region generally demonstrates lower levels of digitization. In summary, significant disparities exist in the degree of manufacturing digitization across China. In order to comprehensively disclose the level of digitization in China's provinces from 2011 to 2020, this paper divides the indicators for manufacturing digitization into four regions, including the East, Central, West and Northeast regions. The annual average indicators reflecting manufacturing digitization across four regions of China from 2011 to 2020 are depicted in the figure 1. The data clearly illustrate the Eastern region's substantial lead in digital economic advancement compared to other regions. Over the decade, the digital economy in the Eastern region experienced rapid growth, reaching a relatively high level. A notable disparity exists between the digitization levels of the East and West regions, with the latter exhibiting slower growth rates (from 26.1938 to 27.0364) and lower average index indicators.

Despite slower growth compared to the Eastern region, the Central region has maintained a steady growth trajectory, with its index fluctuating around 30, indicating consistent investments in digitization. Conversely, the Northeast region displays lower average indicators and significant fluctuations.

3.2.4. Control Variables

Investment Efficiency (IE) in manufacturing is commonly associated with accelerated development within the manufacturing industry. This study calculates investment efficiency by considering the growth rate of total assets of industrial enterprises above a certain scale divided by the growth rate of regional GDP. Development Scale (DS) represents the increment of industrial added value in each region divided by the increment of regional GDP. The scale of development plays a role in influencing the application of the digital economy within the manufacturing sector, thereby driving upgrades to some extent. Investment in intensity of Research and Development (RD): activities contributes to enhancing a region's innovative capacity, thereby elevating the technological prowess of the manufacturing sector. The advancement of manufacturing processes promotes innovation in traditional production methods. Hence, R&D intensity is quantified in terms of R&D expenses divided by regional GDP of industrial enterprises in this paper.

3.2.5. Results of Control Variables

Descriptive statistics for the control variables for the 30 provinces in China between 2011-2021 are analyzed in the table 2. The report includes sample size, mean, standard deviation, median, minimum and maximum values.

Table 2. Results of Control variables

Variable types	Variables	Obs	Mean	Min	Max	Sd.Dev

Explained variable	Average Value of Manufacturing Digitisation Indicators (MDI)	300	31.823	10.557	60.273	10.240
Explanatory variable	Development Level of Digital Economy(DEL)	300	23.282	9.309	61.975	8.690
Control variables	Investment Efficiency(IE)	300	1.149	12.787	23.032	1.842
	Development Scale(DS)	300	0.124	-8.578	4.537	0.813
	The Intensity of R&D(RD)	300	0.011	0.002	0.032	0.006

The tabulated data highlights a substantial range in the Average value of manufacturing digitisation indicators (MDI), with a maximum value of 60.273 and a minimum of 10.557. This disparity underscores significant differences in the digital economy's development across different provinces. Such discrepancies primarily stem from diverse economic, technological, and policy factors influencing provinces within China. Specifically, the Investment Efficiency (IE) metrics reveal notable variations between the Eastern and Western regions of the country.

The initial step involved conducting a preliminary correlation test to assess the potential impact of covariance among the independent variables on the regression analyses' results. The correlation coefficient matrix, displayed in the table below, was obtained for this purpose.

Analysis of the table 3 reveals a significant positive correlation, at the 1% significance level, between the Average value of manufacturing digitisation indicators (MDI) and the Development level of Digital Economy (DEL).

Table 3. Correlation Analysis.

Variables	MDI	DEL	IE	DS	RD
MI	1				
DEL	0.6434***	1			
IE	-0.039	0.059	1		
DS	0.089	-0.067	0.114**	1	
RD	0.640***	0.441***	-0.061	0.036	1

*** p<0.01, ** p<0.05, * p<0.1

3.3 Econometric methods

The benchmark regression model is employed to analyze the impact of the digital economy on the average value of manufacturing digitisation indicators. The specifics of this analysis are outlined as follows:

$$MDI_{it} = \alpha_0 + \alpha_1 DEL_{it} + \alpha_2 Controls_{it} + \mu_i + \delta_t + \varepsilon_{it} \tag{8}$$

In the model, i and t refer to regions and time, respectively. MDI_{it} represents the level of manufacturing industry upgrading in region i in year t, while DEL_{it} indicates the level of digital economic development in region i in year t. Controlsit denotes a set of control variables, including investment efficiency IE_{it}, development scale DS_{it}, and research and development intensity RD_{it}. α_1 and α_2 represent the respective impacts of digital economy and control variables on the manufacturing industry. The μ_i and δ_t represent region fixed effects and time fixed effects. ε_{it} denotes the random disturbance term.

4 Theoretical Analysis and Hypothesis

4.1 The Direct Impact of Digital Economy on Manufacturing Digital Transformation

The emergence of the digital economy introduces novel production factors, namely knowledge and information, into manufacturing processes. This infusion directly contributes to optimizing the industrial structure within the manufacturing sector. The rapid evolution of the digital economy is instrumental in advancing cutting-edge digital technologies such as big data, Internet of Things (IoT), and blockchain. These technologies not only foster a conducive business environment for enterprises but also expedite the assimilation and utilization of high-tech solutions in manufacturing operations.

High technology, characterized by economies of scale and long-tail effects, plays a pivotal role in optimizing manufacturing processes through digital transformation. In contrast to traditional industrial inputs like land and energy, digital technology has emerged as a critical asset in shaping the industrial architecture of the manufacturing sector. The rapid maturation of the digital economy facilitates enhanced information exchange among enterprises, mitigating the risks associated with information asymmetry. Consequently, this fosters improved transaction reliability and reduced transaction costs. Given the insights gleaned from this analysis, it is plausible to posit that the digital economy exerts a direct influence on the progressive upgrading of the manufacturing industry. Building upon these observations, this paper proposes the following hypothesis:

Hypothesis 1. The development of digital economy can promote the digital transformation of manufacturing industry.

4.2 The Heterogeneous Impact of Digital Economy on Manufacturing Digital Transformation

Given China's vast size and diverse regional characteristics encompassing economic development, infrastructure availability, resource distribution, and environmental contexts, regional heterogeneity naturally emerges. This heterogeneity significantly influences how the digital economy interacts with the manufacturing industry's digital transformation. Descriptive statistical analyses reveal substantial disparities in digital economy maturity and manufacturing digital transformation across sampled regions. Therefore, a nuanced examination of the digital economy's impact on manufacturing transformation necessitates addressing these regional heterogeneities. Developed regions typically boast stronger capabilities in upgrading manufacturing structures and advancing infrastructure, factors crucial for regional digitization. They also tend to exhibit more robust urban digitization compared to developing regions. Consequently, the penetration and depth of the digital economy's application in manufacturing are typically more pronounced in developed regions. Moreover, variations in technological prowess and urban population densities directly impact industrial structural transformations and innovation efficiencies, leading to divergent levels of digital dividends across regions. Building upon these insights, this paper posits the following hypothesis:

Hypothesis 2. The digital economy has a heterogeneous impact on manufacturing upgrading.

5 Results

5.1 Result of Benchmark Regression

The paper utilizes Stata for analysis, and the Hausman test confirms that the fixed effects model provides the most robust estimation results. Table 4 displays the benchmark regression outcomes for the average manufacturing digitization indicators in relation to the levels of digital economy development, investment efficiency, development scale, and R&D intensity. All models exhibit satisfactory overall explanatory power.

In Column (1), the regression result without control variables shows a significantly positive coefficient of 0.63 for the digital economy at the 5% significance level. Columns (2)–(6) gradually introduce control variables, illustrating the relationships between MDI, IE, DS, RD, and DEL. Even after controlling for these variables, the regression coefficient for the digital economy remains positive and significant at 0.62, demonstrating its consistent impact on MDI. In terms of the control variables, the regression coefficients of the investment efficiency is negative and insignificant at -0.25. It indicate that the investment efficiency show a small inhibitory effect on the average value of manufacturing digitisation indicators. While the regression coefficients of the investment efficiency are positive. It indicates that the increase in on the development level of digital economy, development scale and the intensity of R&D provide strong support for the transformation in manufacturing.

The regression coefficients for the digital economy remain positive and statistically significant at the 5% level, regardless of the inclusion of control variables. Furthermore, the table 4 shows that the correlation signs between variables from the benchmark regression model align with expected assumptions. The results affirms that the development of the digital economy indeed fosters the digital transformation of the manufacturing industry. Consequently, Hypothesis 1 is supported.

Table 4. Benchmark Regression.

Variables	MDI (1)	MDI (2)	MDI (3)	MDI (4)	MDI (5)	MDI (6)
DEL	0.63**	0.62**	0.66**	0.72**	0.64**	0.62**
	(0.187)	(0.184)	(0.182)	(0.186)	(0.187)	(0.195)
IE		-0.95	-0.20*	-0.23*	-0.28*	-0.25*
		(0.127)	(0.121)	(0.120)	(0.123)	(0.123)
DS			0.35	0.30	0.35	0.37
			(0.282)	(0.290)	(0.292)	(0.285)

RD						127.074 (175.204)
Constant	20.030*** (2.280)	20.275*** (2.282)	20.125*** (2.264)	20.572*** (2.303)	20.380*** (2.338)	20.496*** (2.175)
R-squared	0.286	0.293	0.297	0.300	0.300	0.303
Year FE	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES
Adj_R-squared	0.281	0.286	0.287	0.288	0.286	0.287
F-statistics	7.911	7.419	7.003	7.458	14.76	14.23

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

5.2 Heterogeneity Analysis

The article extends its analysis to explore regional heterogeneity in the impacts of digital development on manufacturing upgrades. Utilizing China's statistical system and classification standards, the sample regions are categorized into eastern, central, western, and northeastern regions. Table 5 presents the specific regression outcomes.

The results indicate that the digital economy's impact on manufacturing upgrades remains significantly positive at the 10% significance level, particularly evident in the eastern region. However, the central and western regions did not exhibit significant impacts based on the tests. This suggests that the digital dividends have been effectively absorbed by the manufacturing sector in the eastern region, further enhancing its industry upgrades. This success can be attributed to the region's well-developed infrastructure and advanced digital technologies, particularly in areas like big data and the Internet of Things, which have greatly facilitated the integration of the digital economy with manufacturing processes and accelerated technological advancements in the industry.

It's notable that the northern region shows a significant negative correlation between digital economy growth and manufacturing industry upgrades, indicating a hindrance rather than a facilitation. This phenomenon can be attributed to several factors. Firstly, the northern region faces challenges such as inadequate digital resources and underdeveloped infrastructure, limiting the integration of digital technologies into manufacturing processes. Additionally, the region's historical legacy as China's heavy industry base presents structural transformation challenges. Moreover, in regions with lower economic development levels and declining populations, the potential benefits from digital dividends may not translate effectively to the manufacturing sector, let alone drive its upgrades. Overemphasizing digital economy development in such contexts might even dilute reform efforts due to limited coordination within manufacturing industries.

Table 5. Heterogeneous analysis.

Variables	MDI East (1)	MDI Central (2)	MDI West (3)	MDI Northeast (4)
DEL	0.60*	-0.66	0.50	-6. 86**
	(0.105)	(0.119)	(0.16)	(1.647)
IE	-1.543*	-0.212	-0.0030	-1.232**
	(0.454)	(0.111)	(0.132)	(0.213)
DS	1.92**	-0.20	0.08	0.02
	(0.628)	(0.102)	(0.209)	(1.015)
RD	-22.36	87.71**	23.03	38.61
	(165.788)	(261.205)	(799.306)	(621.249)
Constant	25.003***	26.041***	20.101***	100.707**
	(3.907)	(6.248)	(2.481)	(16.976)
R-squared	0.72	0.85	0.201	0.814
Year FE	YES	YES	YES	YES
Region FE	YES	YES	YES	YES

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

6 Conclusion and Discussion

This paper focuses on the digital economy, using balanced panel data from 30 Chinese provinces spanning 2011 to 2021. Employing a fixed effect model, it empirically examines the direct and mediating impacts of the digital economy on the transformation of the manufacturing industry. The study yields the following results:

China's digital economy development exhibits notable regional disparities, with the Eastern region showcasing significantly higher levels compared to the Central and Western regions. Specifically, areas such as Beijing, Guangdong, Shanghai, Jiangsu, and Zhejiang lead the national digital economy landscape, boasting well-established economic foundations, advanced technological capabilities, and robust digital infrastructures. Conversely, most Central and Western regions lag behind the national average in digital economy development, evident in both infrastructure and digital industry progress. This uneven regional distribution not only impacts local digital economies but also influences the overall national digital economy development trajectory.

The advancement of the digital economy positively impacts the transformation of the manufacturing industry, emerging as a significant driver for China's economy's high-quality development. As digital technologies gain traction and evolve, the manufacturing sector is transitioning towards digital and intelligent operations. Consequently, digital economy growth propels manufacturing transformation, supporting broader economic structural shifts and the advancement of "common prosperity" initiatives. The influence of the digital economy on manufacturing is no longer straightforwardly linear, representing a complex academic inquiry. The rapid evolution of the digital economy introduces nonlinear dynamics to manufacturing's digital transformation. The swift pace of digital economy growth, coupled with the emergence of novel digital technologies, brings about unpredictable shifts.

The external environment is crucial for the digital economy's effectiveness and integration with manufacturing. The recommendations are as follows: (a) Strengthening training and innovation promotion, with increased investment in talent and technology upgrades. Focus on R&D in less developed regions and leverage advantages in more developed areas. (b) Addressing infrastructure gaps between regions by coordinating digital development, seizing opportunities in the Western region, and ensuring smooth data flow. Overall, enhancing governance and innovation is key, requiring collaboration across sectors and utilizing free trade policies.

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