Digital Economy Promotes the Upgrading of The Manufacturing Industry: Influence Path and Empirical Analysis Based on Provinces in China

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Abstract. This paper conducts empirical research by utilizing panel data from 30 provinces in China spanning the years 2011 to 2020. The primary objective is to examine the impact of the digital economy on the upgrading of the manufacturing industry. To achieve this, the study employs fixed effect models for rigorous analysis and inference. The results show that the development of the digital economy can significantly enhance the upgrading of the manufacturing industry. Moreover, further examination shows that the impact of the digital economy on the manufacturing industry has heterogeneity characteristic. The effect of the digital economy is the best in East region, while the effect in other regions is not significant.

Keywords: Digital Economy; Manufacturing Industry; Influence Path; Empirical Analysis

1 Introduction

Understanding how Digital Economy drive upgrading of the manufacturing industry presents a substantial economics challenge (Wang et al. 2023; Ji et al. 2023). The digital economy is intricately intertwined with industrial development and holds significant potential in expediting the attainment of carbon neutrality (Wang et al. 2022; Zhang et al. 2020). This is poised to play a pivotal role in supporting China's efforts to realize General Secretary Xi Jinping's visionary objectives of achieving carbon peak by 2030 and attaining carbon neutrality by 2060. Based on pertinent research findings, the manufacturing industry in China currently accounts for approximately two-thirds of the total energy consumption and carbon emissions within the secondary industry, while the secondary industry as a whole contributes to roughly one-third of China's total energy consumption and carbon emissions (Zhang et al. 2020). Indeed, fostering continuous enhancements in the upgrading of China's manufacturing industry emerges as a crucial trajectory for achieving both high-quality development and environmental preservation. Resolving the pertinent question of how to further optimize this upgrading process becomes of utmost importance.

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2 Literature Review

2.1 Research on the digital economy

Presently, there is no consensus regarding the precise definition and indicators of the digital economy. Different definitions have arisen from various perspectives, focusing on specific aspects. Some scholars argue that the digital economy primarily or entirely relies on digital technology for economic production activities (Bukht and Heeks, 2017). On the other hand, others emphasize the digital economy's characteristics such as the platform economy, rapid growth, and innovation (Li, 2019). There is a common understanding among scholars that the new era of the digital economy has significantly influenced resource allocation, improved market conditions, facilitated the transformation of traditional industries, and promoted advancements in emerging industries (Liu et al., 2022).

Research on the digital economy has primarily centered on two distinct perspectives: the measurement and quantification of the digital economy and the role it plays in various contexts.

Extensive scholarly investigations have been conducted concerning the measurement and quantification of the digital economy. Despite the application of numerous indicators by scholars to assess the development level of the digital economy, a direct method or dataset for its comprehensive measurement has yet to be proposed (D. Ma and Q. Zhu, 2022). Moreover, according to the existing literature, most of them have chosen the entropy method to measure the level of digital economy by adding different indicators (Zhang et al., 2020).

Studies on the role of the digital economy. According to the literature, the study on the role of digital economy mainly consists of the following three aspects: micro level, the middle level, and the macro level, which are classified according to the role of digitalization in economic growth (Dou and Gao, 2022). First, in the micro level, it primarily concentrates on the digital consumption. The development of the digital economy not only expands the scale of consumption choices (Ma, 2021), but also generates positive externalities (Du, 2017). Second, in the middle level, research focused on the transformation of the traditional industries by integrating the digital economy (Xiao and Qi, 2019; Zhou et al, 2022). Third, in the macro level, the economic growth is the core topic of this level. The digital economy combines the data resources, a new production factor, with the traditional production factors so that the quality and efficiency of the production have been improved (Ghasemaghaei et al., 2019).

2.2 Research on the upgrading of the manufacturing industry

At present, literature on the upgrading of the manufacturing industry mainly focused on the green growth and transformation of it. Many scholars have developed how to achieve industrial green growth and what factors can influence this process. It is believed that technological innovation is one of the most important factors of industrial green progress (Karakaya et al, 2014), and green growth should not only

focus on reducing environmental pollution, but also focus on improving the ecological system forwardly (Seferlis et al, 2014). Moreover, the innovation capability has a moderating effect on the sustainable development of the industrial structure and environment (Fernando et al, 2019).

Despite the qualitative description of green transformation of the manufacturing industry, some scholars also take various of quantitative methods to evaluate the performance of green growth. In recent years, the Green Total Factor Productivity(GTFP), which incorporates environmental factors into the productivity analysis, has been a popular indicator to measure the green performance of the manufacturing industry (Yu, Li et al, 2021). For example, H. Deng et al (2022) used the LHM indicator and nonparametric BP technology to estimate the GTFP in the Chinese manufacturing industry. Ying Qu et al (2017) applied the DEA model with input and output factors in measuring the green efficiency of the Chinese manufacturing industry.

2.3 Research on the relationship between the digital economy and the manufacturing industry

In terms of the relationship between the digital economy and the manufacturing industry, many scholars have explored whether there exists a positive impact of the digital economy on the manufacturing industry and what the influence path is (Liu et al., 2022; Wang et al., 2022). So far, many valuable studies have been done in terms of the digital economy and the manufacturing industry. However, there are still following shortcomings: first, there doesn't exist a common method to measure the level of the digital economy and the upgrading of the manufacturing industry, most of the quantitative methods are based on what the authors researched. Second, few studies have been done to investigate the effect of the digital economy on the upgrading of the manufacturing industry.

3 Data, Variables, and Methods

3.1 Data Source

In this study, we have assembled a comprehensive panel dataset encompassing 30 regions at the provincial level across China, spanning the period from 2011 to 2020. The data sources utilized include authoritative databases such as the National Bureau of Statistics, Ministry of Science and Technology, China Statistical Yearbook, China City Statistical Yearbook, China Industrial Statistical Yearbook, and the provincial statistical yearbooks. Notably, the province of Tibet has been excluded from our panel due to the unavailability of certain essential indicators necessary for the analysis.

3.2 Variables

Explanatory Variable: The Development level of Digital Economy

The digital economy serves as the explanatory variable. To assess its development level, a comprehensive evaluation system has been constructed, consisting of three secondary indexes and 14 specific indicators. Table 1 presents an overview of these specific indicators used to measure the extent of the digital economy's advancement:

Table 1. Index of the digital economy development level.

Primary Index	Secondary Index	Indicator Description	Unit
Digital Economy	Digital Infrastructure	mobile phone base stations density	PCS/km²
		Long distance cable line length	km
		Mobile phone exchange capacity	10,000
		Number of IPv4 addresses	10,000
		Internet broadband port density	10,000/km²
	Application of Digital Industrialization	Ratio of software revenue	%
		Ratio of digital television users	%
		Proportion of technical contract turnover	%
		Share of employees in information transmission, software and information technology services	%
	Industrial Digitalization	Proportion of enterprises with e-commerce trading activities	%
		Number of websites per 100 enterprises	number
		Digital Financial Inclusion Index	/
		E-commerce sales	CNY 100 million

We adopt the improved entropy approach to determine the weight of each secondary index. First, each of all indicators under the secondary index are standardized to carry out the process of dimensionless. Secondly, the weight of each index is calculated by the improved entropy method. And last, the comprehensive evaluation index of digital economy development is obtained by using the linear weighting method. Thus, the targeted level of the digital economy can be obtained.

Explained Variable: Upgrading of the Manufacturing Industry

This paper uses two secondary indexes and four specific indicators to construct an evaluation system to measure the upgrading of the manufacturing industry. Table 2 shows the indicators of the evaluation system, and this paper takes the improved entropy method above to calculate the particular value of the upgrading of the manufacturing industry.

Table 2. Index of the upgrading of the manufacturing industry.

Primary Index	Secondary Index	Indicator Description
Manufacturing Industry	Digital Infrastructure	Ratio of total labor productivity
		Ratio of the main business income
	Higher level transformation	The proportion of high-tech industries
		Energy consumption per unit of income

Control Variables

Control variables were selected as follows: (1) The Efficiency of Investment (IE). This paper uses the increase ratio of total asset of Industrial enterprises above designated size/the increase ratio of regional GDP to calculate the efficiency of investment. (2) Development Scale(DS), calculated by the increment of industry added value/the increment of GDP for each region. (3) The position of Value Chain(VC), measured by the total profit of the manufacturing industry/the revenue of the manufacturing industry. (4) The Upgrade of Structure(SU), measured by the main business income of High-technology Industry/the main business income of Manufacturing Industrial enterprises above designated size. (5) The Intensity of R&D (RD). As R&D investment increases, this paper takes the R&D expense of Industrial enterprises above designated size/regional GDP to represent it's value.

Table 3 present the descriptive statistics. The results indicate that no outlier is found in this paper.

Table 3. Descriptive Statistics.

Variable types	Variables	Obs	Mean	Min	Max	Sd.Dev
Explained variable	MI	300	31.007	10.000	58.860	10.300
Explanatory variable	DEL	300	21.307	7.060	55.520	8.999
Control variables	IE	300	1.149	-12.787	23.032	1.842
	DS	300	0.124	-8.578	4.537	0.813
	VC	300	0.057	-0.401	0.187	0.034
	SU	300	0.121	0.004	0.607	0.087
	RD	300	0.011	0.002	0.032	0.006

3.3 Econometric methods

The benchmark regression model is used to examine the effect of the digital economy on the upgrading of the manufacturing industry. The specific is as follows:

$$MI_{it} = \alpha_0 + \alpha_1 DEL_{it} + \alpha_2 Controls_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where the i and t refer to the region and the time; MIit represents the upgrading level of the manufacturing industry for city i in year t; DELit refers to the development level of the digital economy for city i in year t; Controlsit is a set of control variables; α1 and α2 indicate the impact of the digital economy and control variables on the manufacturing industry; μi and δt are the region fixed effect and time fixed effect; εit is the random disturbance term.

4 Theoretical analysis and hypothesis

4.1 Direct effect of digital economy on the manufacturing industry

As an emerging economic form, the digital economy instills new production factors, knowledge and information, into the manufacturing production sector, which is directly positive in promoting the optimization of the manufacturing industry structures (Yuan, 2018). The fast-developing digital economy enhances the development of cutting-edge of digital technology, such as Big Data, the Internet of Things, Blockchain and so on. All these technologies not only provide a better business environment for enterprises (Hu, 2018), but also accelerate the integration and application of high technology in the manufacturing industry, which optimizes the upgrading of the manufacturing industry through digital transformation with economics of scale and long-tail effects (Jiang, 2022). The digital technology, compared with the traditional industrial production factors like land and energy, has become a significant dividend directing the construction of the manufacturing industrial structure (Tang et al, 2021). With the high-speed development of digital technology, the digital economy strengthens the flow of information among different enterprises and reduces the risk of information asymmetry, thus enhancing the reliability and reducing the cost of transactions. Based on the above analysis, it is reasonable to hold that the digital economy has a direct effect on the upgrading of the manufacturing industry. Therefore, this paper proposes:

Hypothesis 1(H1). The development of digital economy can promote the upgrading of the manufacturing industry.

4.2 Heterogeneous effect of digital economy on the manufacturing industry

It is clear that China, with a large population and vast territory, must exit heterogeneity among different regions due to the discrepancy in economic development, infrastructure construction, resources endowment and environmental conditions. According to this, the influence of the digital economy on the upgrading of the manufacturing industry can be affected by the heterogeneity characteristic as well. Hence, it is necessary to examine the relationship between the digital economy and the upgrading of the manufacturing industry by combing the heterogeneity issue. Developed region is often regarded to have more power to upgrade the manufacturing industrial structure and promote the infrastructure construction, which can affect the regional digitalization. The developed regions have more advantages in level of urban

digitalization than developing regions, so that the application of digital economy in the manufacturing industry among developed ones is more profound than their counterparts (Chen & Ye, 2021). Furthermore, the difference in technological advantages (Chen & Zhou, 2017), the urban population density can affect the transformation of industrial structure and efficiency of innovation (D. Ma and Q. Zhu, 2022), which causes the discrepancy in the level of digital dividends a region can release (Murthy et al., 2021). Thus, this paper argues:

Hypothesis 2(H2). The digital economy has a heterogeneous effect on the upgrading of the manufacturing industry.

5 Empirical Results

5.1 Benchmark regression

This paper chooses a fixed effect model with the time-fixed effect added. The Benchmark Regression results are showed in Table 4. The outcome of column (1) shows that the explanatory variable digital economy has significantly positive effect on the upgrade of manufacturing industry without control variables. The coefficient is 0.463 and at the 5% significant level. Column (2)-(6) indicate that with the adding of control variables, the coefficient of digital economy is positive significant. Thus, Hypothesis 1 is supported.

Table 4. Benchmark Regression.

Variables	MI	MI	MI	MI	MI	MI
	(1)	(2)	(3)	(4)	(5)	(6)
DEL	0.463**	0.462**	0.466**	0.472**	0.464**	0.462**
	(0.187)	(0.184)	(0.182)	(0.186)	(0.187)	(0.195)
IE		-0.195	-0.220*	-0.223*	-0.218*	-0.225*
		(0.127)	(0.121)	(0.120)	(0.123)	(0.123)
DS			0.315	0.330	0.325	0.317
			(0.282)	(0.290)	(0.292)	(0.285)
VC				-7.511	-7.647	-8.801
				(10.869)	(10.574)	(10.926)
SU					3.296	1.713
					(7.784)	(8.125)
RD						127.074
						(175.204)
Constant	24.030***	24.275***	24.125***	24.572***	24.380***	23.496***
	(2.280)	(2.282)	(2.264)	(2.303)	(2.338)	(2.175)
Observations	300	300	300	300	300	300
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	0.261	0.266	0.267	0.268	0.266	0.267
F-statistics	7.811	7.219	7.103	7.958	12.76	12.23

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

5.2 Heterogeneity analysis

This paper further examines the heterogeneous regional impacts. Based on the China statistical system and classification standard, all sample regions are classified as eastern, central, western and northeastern regions. The specific regression results are shown in Table 5. It can be seen that the effect of the digital economy on the upgrading of the manufacturing industry is still significantly positive at 10% significance, while the central and western regions don't pass the significant test. The digital dividends have been sufficiently absorbed by the manufacturing industry in eastern region and better promoted its upgrading level there.

However, a point that can't be neglected is that the effect of the digital economy on the upgrading of the manufacturing industry is significant negative in the northern region, which means the increase of the digital economy impedes the upgrading of the manufacturing industry there. A reasonable explanation is: besides the lack of digital endowments and undeveloped infrastructure in the northern region, the particular historical context of this region as heavy-industry base of China may cause difficulties in transferring industry structure. Moreover, with the low economics development and massive population loss, the release of digital dividends can not be effectively adopted in the manufacturing industry, let alone to promote its upgrading.

Table 5. Heterogeneous analysis.

Variables	MI East (1)	MI Central (2)	MI West (3)	MI Northeast (4)
DEL	0.460*	-0.066	0.450	-8.616**
	(0.205)	(0.319)	(0.296)	(1.525)
Control variable	YES	YES	YES	YES
Constant	25.463***	26.631***	20.039***	100.213**
	(3.907)	(6.248)	(2.481)	(16.976)
Observations	100	60	110	30
R-squared	0.672	0.825	0.293	0.829
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

Based on the panel data of 30 provinces in China from 2011 to 2020, this paper first used the improved entropy method to evaluate the level of the digital economy and the upgrading the manufacturing industry. The analysis results illustrate that the development of the digital economy has a significant overall positive effect on the upgrading of the manufacturing industry and that both of them show an upward trend with a heterogeneity characteristic in East, Central, West and Northeast regions.

According to the analysis and results above, this paper can conclude the following policy implication: First, it is necessary for the government to continuously accelerate the construction and promotion of digital infrastructure and industrial digitalization. Second, due to the different situations faced by different regions, it is reasonable to

implement diverse policies in these regions. Specifically, based on the advanced economic level and digital technology, the East region should concentrate more on the quality of the integration of the digital economy with the manufacturing industry rather than the quantity of it.

The limitations of this paper are apparent. First, due to the availability of the data and the selection of the samples, there exists a shortage of sample size for this paper. Thus, in future studying, the sample size needs to be expanded for more robust regression results. Second, how the development level of the digital economy and the upgrading of the manufacturing industry of one region influence the adjective regions is not researched. The spatial effect of the digital economy on the upgrading of the manufacturing industry needs to be further examined in the future.

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