Research on the Influence of Digital Economy on the Upgrading of Manufacturing Industry in Beijing-Tianjin-Hebei Region of China

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Abstract: How to accelerate the transformation from a "big but not strong" manufacturing economy to a "big and strong" manufacturing economy, and how to achieve high value-added and move to upstream of Global Value Chains (GVC) are key challenges for the upgrading of Chinese manufacturers. The 19th National Congress of the Communist Party of China suggested that the key task for Chinese manufacturing industry is to accelerate the digital economic construction, promote the rapid integration of the real economy with the digital economy, continuously encourage the deep integration of informatization and industrialization, support the rapid upgrading and transformation of the traditional manufactories, so as to achieve intelligence, networking, service and greening. The Beijing-Tianjin-Hebei (BTH) area represents the biggest and fastest growing economic region of North China. The coordinated development of this region is crucial. Taking the BTH region as an object, this study explores the theoretical mechanism of the digital economic influence on manufacturing upgrading, conducts an empirical study by using the comprehensive score of the digital economic development and the manufacturing upgrading of the Beijing-Tianjin-Hebei region.

Keywords: Manufacturing upgrading, Digital economy, Entropy method.

1. Introduction

As Chinese economy enters the new normal and the concept of green and coordinated development is put forward, China's manufacturing restructuring and upgrading is imminent. Although China has become a big manufacturing country thanks to its population advantage and investment drive, considering the current actual situation, China's manufacturing has the problem of "big but not strong". Chinese economic growth rate slowed as the economy transitions to a new normal, while the production costs of manufacturing enterprises were rising. This makes a backward country like Viet Nam, which is rich in cheap labor, be selected as a factory manufacturing country by developed countries, thus impacting the position of China at low-end of GVC. Meanwhile, developed countries are implementing "re-industrialization", which also brings obstacles and challenges to high-end manufacturing development in China. Therefore, the problem of low added-value traditional manufacturing industry still needs to be solved. How to speed up the transition of the manufacturing economy from "big but not strong" to "big and strong", and how to achieve high value-added and move to the high-end of GVC are major challenges for upgrading China's manufacturers.

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According to the data of China Communication Institute's White Paper on the Development and Employment of Digital Economy in China (2022), in 2021, affected by the three-year epidemic and the deepening world economic downturn, China's digital economy remains on a fast track, with a scale of 45.5 trillion yuan, which doubled in five years, at 39.8% of GDP, it had a more stable position in the economy and its role as a support industry was more explicit. At present, Chinese Government places high priority on developing digital economy and its impact on various industries. The transformation of digital economy is being actively promoted. Digital economic development level of China is expected to be continuously upgraded and deep integrations across wide-range of industries, which will drive the upgrading of Chinese manufacturing industry.

2. Literature review

The influences of digital economy on manufacturing upgrading and its mechanism were examined by numerous researchers from various aspects over the past few years.

In terms of the impacts of the digital economy on industrial upgrading of China, Xiaoli Fan and Qiufang Li (2021) measured the degree of digital economy development, evaluated the industrial upgrading level with the rationalization and upgrades of industrial structures, and built an econometric model with the data above to verify the digital economy's contribution to driving industry upgrading [1]. Zhiguo Li et al. (2021) analyzed the industrial upgrading from industrial transformation speed and industrial structure rationalization, and thought that digital economy was a new kinetic energy and engine for economic development to improve quality and efficiency. They found that digital economy could substantially facilitate the industrial upgrade speed, upgrading and rationalization. [2]

In terms of mechanism research, Dehui Wang and Ziang Wu (2020) are convinced that digital economy is having breakthrough effects on manufacturing's ability to innovate, and can increase the economic value added of manufacturing industry. Digital technologies can make manufacturing produce efficiently, and digital economy can bring significant change on operation modes of the traditional manufacturers [3]. Xinlin Liao and Y Zhengyuan ang (2021) taking 41 cities from the provinces of Jiangsu, Zhejiang, Shanghai, and Anhui as panel data for the period 2015-2019, applied entropy methods to calculate digital economy development level and manufacturing upgrading level in the panel GMM model, measured the specific impacts of digital economy on manufacturing upgrading, and analyzed the realization path using intermediary effect model [4]. Wenbin He (2020) believes that digital economy will reconstruct China's manufacturing and promote its development in a higher-end and more knowledge-intensive direction; Digital investment generates positive effects significantly at the high-end GVC of low- and medium-high knowledge intensive industries, which would help to improve manufacturing industries position in international competition [5].

This study mainly innovates in the following aspects, hoping to provide reference for theoretical research and policy formulation. First, the coordinated development strategies of BTH region are very important regional development strategy in China at present, but the whole of BTH region is seldom studied in previous studies. This paper takes the whole of BTH region as main study area to identify the influences of digital economy on manufactures upgrading. Second, related studies currently concentrate mostly on digital application, technological innovation and industrial chain optimization of enterprises within the manufacturing industry, as well as external factors such as the macro environment. To better mirror current upgrading level of digital economy and manufactures, this paper selects multi-dimensional indicators, and when conducting empirical analysis, it includes both basic impact analysis and spatial effect analysis, making the empirical results more comprehensive and accurate. This makes the research of this paper closer to reality and can provide some policy support for developing digital economy and manufacturing upgrading in the coordinated development strategy of Beijing-Tianjin-Hebei.

3. Theoretical mechanism.

3.1 Industrial chain integration to enhance innovative capacity of manufacturing industries

The rapid growth of digital economy had subversive impacts on traditional manufacturing production mode. The interaction between consumers and producers is more precise and personalized. Digital technology can respond to consumers' precise needs and personalize R&D and production of enterprises. Digital technology can also have a positive impact on production efficiency and product quality in the manufacturing process. With the support of digital platform, consumers can participate in new products' design, and R&D of manufacturing enterprises. Meanwhile, the R&D and design departments of manufacturing enterprises can use big data to mine more valuable information, obtain consumer demand information in real time and efficiently, accurately locate consumer demand, reduce innovation risk, reduce innovation production cost and R&D cycle of new products, enhance innovation efficiency of manufacturing companies, stimulate innovation vitality and potential of manufacturing companies to realize the value climb of manufacturing industry, so as to achieve high added value and move to high end of GVC.

3.2 Flexible production promotes manufacturing enterprises to integrate production factor resources

Flexible production is a market-oriented production organization mode, characterized by on-demand production, which can flexibly change production plans, adjust production layout and production lines according to customer needs and market changes, and improve production flexibility. Compared with advanced manufacturing enterprises in developed countries, traditional manufacturing enterprises in China still have some shortcomings in collecting accurate data to observe and analyze market demand. However, the digitalization process of manufacturing technology has accelerated with the high-speed growth of digital economy, provided innovative solutions for traditional manufacturing enterprises, promoted digital transformations and upgrades, and realized networking and intelligence of manufacturing industry. Using digital techniques including big data, and Internet of Things, we integrate production factors, rely on the flexible production of digital factories, closely contact online virtual factories and offline physical manufacturing factories, optimize product production links, and realize the structural optimization of manufacturing enterprises.

3.3 Digital technology to promote efficient management of manufacturing enterprises

Digital technology can help manufacturing enterprises understand the industry situation efficiently and accurately and produce reasonably according to market demand. Achieving an efficient resources allocation and a more effective industrial divisions of labor will optimize the management mode of enterprises in the manufacturing industry chain and reduce unnecessary losses caused by human errors, thus facilitating the rapid transition and improvement of manufacturers. Using digital technology, internet of things technology, and information technology, input service and output service of manufacturing have been continuously improved. Relying on efficient networking platform, infrastructure construction and Internet technology, a network system has been formed among social resources, enterprise resources and talents' intelligence. With the continuous development of digital service network platform, manufacturing enterprises can use digital technology to allocate resources more accurately, meet customer needs in a faster, better, and more convenient way, further improve production efficiency, reduce costs, improve quality and service, and thus obtain higher customer satisfaction and better market competitiveness. Digital service improves efficiency, and then realizes efficient management of manufacturing enterprises.

4. Calculation of digital economy development level in Beijing-Tianjin-Hebei

4.1 Digital economy development index system construction and measurement

This article refers to studies on the digital development level by scholars such as Heping Ge [6] and Juanjuan Wang [7] establishes an index system for measuring digital economy development level from three angles: digital foundation, digital industrialization, and industrial digitalization. The specific index construction basis is as shown in Table 1.

The entropy method is applied to determine digital economy development level in Beijing, Tianjin and Hebei, and the weights of various influencing factors are determined by objective methods, so as to avoid the defects of subjective assignment to some extent, and the weights of the individual indices are derived in the following way:

Table 1. Digital economy index system and contribution weight of each index

Primary index	Weight (%)	Secondary index	Weight (%)	Three-level index	Indicator attribute	Weight (%)
Digital foundation	34.715	Hardware facilities	30.585	Optical cable route density (km/km2) X1	+	3.653
				Internet broadband port density (10,000/km2) X2	+	26.932
		Information transmission	4.13	Mobile phone penetration rate (department/100 people) X3	+	2.949

				Internet penetration rate (%) X4	+	1.181
Digital industrialization	46.158	Telecommunication	15.331	Total telecom business (100 million yuan) X5	+	8.741
				Total post and telecommunications business X6	+	6.590
		Industry technology application	21.866	Software business income (100 million yuan) X7	+	11.927
				Technology market turnover (ten thousand yuan) X8	+	9.939
		Innovation driven	8.961	R&D investment intensity (%) X9	+	4.408
				Proportion of financial investment in science and technology (% X10	+	4.553
Industry digitalization	19.127	Digital life	11.233	E-commerce sales (100 million yuan) X11	+	8.833
				Digital inclusive finance index X12	+	2.400
		Smart manufacturing	7.894	Proportion of enterprises with ecommerce transactions (%) X13	+	4.122
				Number of computers used by enterprises per 100 people (units) X14	+	3.773

4.2 Calculation results and discuss

In accordance with the above-mentioned index system and the calculated weights, the comprehensive scores of digital economy development level are finally obtained. Beijing, Tianjin, and Hebei show evident differences in the digital development level, but they all show an upward trend on the whole, reflecting the good vitality of digital development in the three areas. By region, the average value of digital economy in Beijing from 2010 to 2021 is 0.398, which is more than double that of Tianjin and Hebei in the same period, and it will increase the fastest in 2020. Tianjin's digital economy development remains comparatively slow. The average value of digital economy in 2010-2021 is 0.149, which rises to the highest level in 2020, possibly due to the influence of COVID-19 epidemic, and slightly decreases in 2021. The average development water of digital economy in Hebei during 2010-2021 was 0.140, and the digital economy development increased rapidly, reaching the highest in 2020, which may also be affected by COVID-19 epidemic, and declined slightly in 2021.

5. Calculation and evaluation of manufacturing upgrading level

5.1 Construction of the index system of manufacturing upgrading

Based on the study conducted by Xubin Luo and Liang Huang (2020) [8], the present study calculates the manufacturing upgrading index based on the four first-level indicators of intelligence, service, networking and greening, which are divided into 16 second-level indicators.

Entropy method is still used for measurement here. Based on above-mentioned established index system and related data, the weights of the evaluation indexes of manufacturing upgrading level in Beijing, Tianjin, and Hebei during 2010 -2021 are as shown in Table 2:

Table 2. Description and weight of evaluation indexes of manufacturing upgrading level

Primary index		Secondary index	unit	Indicator attribute	Weight %
intelligentize	X1	Number of effective invention patents in manufacturing industry/full-time equivalent of R&D personnel in manufacturing	Piece/person	+	6.512
	X2	R&D expenditure intensity of manufacturing industry	%	+	5.603
	X3	Sales revenue of new product in manufacturing /operating income of manufacturing owners	%	+	2.835
	X4	Number of enterprises in computer, communication, and other electronic equipment manufacturing	individual	+	2.105
Servitization	X5	The value added of transportation, warehousing, and postal service	hundred million yuan	+	11.290
	X6	Fixed investment in transportation, warehousing, and service industry	hundred million yuan	+	7.662
	X7	Number of legal entities in information transmission, software, and information technologies services	individual	+	7.781
	X8	Value added of information transmissions, software, and information technology services	hundred million yuan	+	14.483
networking	X9	Long-distance optical cable line length/land area	ten thousand kilometers/ten thousand square kilometers	+	16.543
	X10	Enterprise e-commerce purchase amount	hundred million yuan	+	13.392
	X11	Telecom business income	hundred million yuan	+	3.448
	X12	Number of websites per 100 enterprises	individual	+	1.711

Greening	X 13	energy consumptions per unit of GDP	tons of standard coal/ten thousand yuan	-	1.435
	X 14	Power consumptions per unit GDP	kwh/ten thousand yuan	-	3.706
	X 15	Industrial wastewater discharge/industrial value-added	ten thousand tons/100 million yuan	-	1.142
	X 16	Industrial sulfur dioxide emissions/industrial value-added	ten thousand tons/100 million yuan	-	0.353

5.2 Calculation results and analysis

According to the weights established and calculated by the above-mentioned indicators, the comprehensive score of Beijing-Tianjin-Hebei manufacturing upgrading level from 2010 to 2021 can be obtained.The upgrading level of manufacturing industry in Beijing, Tianjin, and Hebei during 2010-2021 shows an upward trend on the whole, although it has dropped slightly occasionally, the manufacturing upgrading level in Beijing increasing even more, while that in Tianjin is smaller than that in 2010. From 2010 to 2021, Beijing's manufacturing upgrading level has been rising. The upgrading level of Tianjin's manufacturing industry first rose, then fell for three consecutive years and then rose continuously. Hebei's manufacturing upgrading level first rose, then fell and then rose. The level of Tianjin's manufacturing industry reached its peak in 2015, which may be mainly related to the relevant policies at that time. Since 2015, Tianjin has undertaken the industrial transfer from Beijing and constantly adjusted and improved the manufacturing industrial structure in this region. During 2015-2021, the upgrading level of Tianjin's manufacturing first declined and then rose, reflecting the adjustment of the economic developing model of Tianjin's manufacturers in the transition phase of industrial transformation to meet the requirements of sustainable low-carbon economic developments. In 2017, the manufacturing level of Hebei Province experienced a slight decline, which may be due to the fact that since 2017, with the change of regional economic development from pursuing development volume to enhance internal performance and the economic growth efficiency, the challenges faced by manufacturing industry in Hebei Province have increased, and the downward pressure on the economy has increased.

6. The influences of digital economy on Beijing-Tianjin-Hebei manufacturing upgrading

6.1 Variables Selection and Data Sources

6.1.1 Variables Selection

(1) Explained variables

Manufacturing upgrading level (ISA). Previously, we used entropy methods and referred to existing literature for index system constructions of manufacturing upgrading level, which was referred to as ISA as the explained variable.

(2) Explanatory variables

Development level of digital economy (DE). The entropy method is also used to build a reasonable index system of digital economy development level, and DE is used as an explanatory variable.

(3) Control variables

Foreign direct investment (FDI): The introduction of foreign capital can positively influence industrial development to some extent, thus enhancing the technical level and promoting the upgrading of the manufacturing. we use the share of foreign direct investment to local GDP (%) to characterize FDI.

Economic development level (ED): Economic development can promote the transformation and upgrading of industries. We use the logarithm of GDP per capita to represent the economic development level.

Government participation degree (GI): The fiscal expenditure of local government and the implementation of relevant policies often play a strong intervention role in local markets, which can make up for the lag of spontaneous market regulation and further promote the local manufacturing industries upgrading. In the present study, government involvement is represented by the ratio of general government expenditure to GDP.

Industry scale (IS): The expansion of industry scale is one of the ways to speed up the process of matching supply and demand as manufacturing upgrades. Therefore, the larger the industry scale, the faster the manufacturing upgrading. This study uses the industrial value-added to regional GDP ratio to characterize industrial scale.

R&D expenditure: R&D expenditure can bring scientific and technological progress and innovation to a certain extent, thus bringing high value-added products, and then promoting the GVC of Chinese manufacturing to a higher level. Therefore, R&D expenditure can greatly support the technological progress.

6.1.2 Data sources

The data are from China Industrial Statistical Yearbook, China Statistical Yearbook, China Environmental Yearbook, statistical yearbooks of provinces and cities and National Bureau of Statistics from 2011 to 2022, and interpolation is applied to fill in some missing data.

6.2 Model establishment

This paper selects 2010 to 2021 panel data for empirical analysis and builds the regression equation below:

$$ISA_{it} = \alpha_0 + \alpha DE_{it} + \sum_k \alpha_k Control_{it} + \mu_{it} + \varepsilon_{it} \tag{1}$$

i indicates province, t indicates year, ISA indicates the level of manufacturing upgrading, DE indicates digital economy development level, and control indicate control variables, μ_{it} indicates individual fixed effects, ε_{it} indicates the random disturbance term.

6.3 Empirical analysis

6.3.1 Descriptive statistics

Before the empirical analysis, the statistical data of Beijing-Tianjin-Hebei in 2010-2021 were analyzed by stata software, and the statistical results of each variable were as shown in Table 3:

Table 3. Descriptive Statistical Results of Variables

variable	sample size	mean value	variance	maximum value	minimum value
ISA	36	0.329	0.019	0.624	0.152
DE	36	2.809	0.039	0.726	0.019
FDI	36	1.132	0.460	2.493	0.347
ED	36	1.581	0.002	1.661	1.482
GI	36	3.087	0.025	3.473	2.751
IS	36	3.292	0.213	3.754	2.471
RD	36	4.772	0.632	6.108	3.389

Note: Data are from China Industrial Statistical Yearbook, China Statistical Yearbook, China Environmental Yearbook, statistical yearbooks of provinces and cities and National Bureau of Statistics. Same as below.

6.3.2 Unit Root Test

To eliminate the false regression in panel data empirical examination, the unit root test is conducted first. LLC test and ADF test with unit root test are adopted in the study.

According to the LLC test and ADF test, all the data are below 0.1, the original hypothesis can be rejected at the 10% confidence interval, so all the variables in this paper are stationary sequences, which meet the panel data modeling standards, and then the data are modeled and analyzed.

6.3.3 Model Selection and Regression Results

(1) Model selection

Panel data models include random effect (RE), fixed effect (FE) and mixed effect (ME) model. Before empirical test, F test, LM test and houseman test are adapted to choose which panel data model to use. Firstly, F statistics is used to judge whether the panel data model chooses FE model or ME model, then LM statistics is used to judge whether the model chooses ME model or RE model. When the p values of F statistics and LM statistics are below 0.05, the ME model is excluded and the RE model or FE model is selected. Finally, houseman test is used to choose FE model or RE model. When the p value of houseman test is below 0.1, the FE model is selected, otherwise the RE model is selected.

According to the results of the three tests conducted based on the above operations, the p-values of both the F-test and LM test are 0.0000, which is less than 0.05. Therefore, we reject the null hypothesis and exclude the mixed-effects model. The p-value of the Hausman test is also 0.0000, which is less than 0.1. Hence, we reject the null hypothesis and ultimately choose the fixed-effects model.

(2) Regression results

Fixed effects model regression results indicate, first, the impacts of digital economy development on manufacturing upgrading plays a positive role at 1% significance level, with an impact coefficient of 0.102. Second, the variable of foreign direct investment passed 1% significance level and played positively in stimulating the manufacturing upgrading process, with the regression coefficient of 0.009. Third, the economic development variable positively promotes the manufacturing industry upgrading through 1% significant level, with a regression coefficient of 0.538.Fourthly, government participation positively influences the upgrading of manufacturing, but it fails to pass significance level test, showing that after implementation of local government financial expenditure and related policies, the policy has not played a strong intervention role in the local market, cannot make up for the lag of spontaneous market regulation, and failed to raise the awareness of developing high-end manufactures.Fifth, the industry scale positively influences the upgrading of manufacturing, and the regression coefficient is 0.005 through 5% significance level test. Sixth, the input of science and technology positively influence manufacturing upgrading, and the regression coefficient is 0.006 through 1% significance level test.

6.4 Endogenous test

When verifying the influence between digital economy and manufacturing upgrading, it is acquiesced that there are no two-way promotion relationships between digital economy and manufacturing upgrading in Beijing, Tianjin, and Hebei, and many factors are affecting the level of manufacturing upgrading. Because all control variables cannot be considered, this paper only selects some factors. Therefore, in order to avoid the problem of omission and reverse causality, we try to use instrumental variables to solve the problem of endogenous variables to ensure the robustness. In this paper, the dependent variable with one period lag is selected as the tool variable for endogenous test.

In this paper, OLS regression is used as a reference, and then instrumental variables are introduced for 2SLS test and limited information maximum likelihood estimation (LIML). The estimated values of the two methods are equal to verify the existence of endogenous problems. Finally, in order to verify whether heteroscedasticity exists, GMM test is used, and the result is the same as 2SLS. The estimation results show that the model results have not changed significantly when the explanatory variable of the first lag period is used as the tool variable.

6.5 Robustness test

Robust regression (robust regression) is used to test the robustness of ISA and DE. DE regression coefficient of explanatory variable is 0.493, with p value is below 0.01, that is, the DE has positive impacts in supporting the upgrading of manufactures. This is in line with the above fixed effects model. It has passed the robustness test.

7. Conclusions and policy implications

First, during the period of 2010-2021, although digital economy development in Beijing, Tianjin, and Hebei displayed an overall upward trend, there were obvious differences among provinces and cities. Beijing ranked first in digital economy development level, Tianjin ranked second, while Hebei Province lagged behind the first two. Meanwhile, in the index system of digital economy development level, digital basic hardware facilities contribute the most to the development level of digital economy. Thus, areas with limited and weak development of digital economy need to find their own advantages, increase capital investment and policy support, attach importance and give priority to constructing infrastructure related to the digital economy, encourage new generation information technologies development, make scientific layout, build a technical platform, support coordinated development of Beijing, Tianjin and Hebei to build digital economy industrial chains.

Secondly, besides hardware facilities, according to digital economy development level calculated in this study, the order of the indexes is technology application, telecom industry, digital life, innovation drive, intelligent manufacturing, and information transmission. Therefore, to support the integrated development of digital economy and manufacturing in BTH region, it is necessary to further facilitate integrating advanced technologies including cloud computing, big data, and the Internet of Things with the manufactures, addressing the issues of manufacturing costs and efficiencies, and enhancing the operational efficiency and credit of the traditional manufacturers. A package of supportive strategies has been implemented to stimulate manufacturers to upgrade to digital, speed up the building of digital manufacturing industrial parks, and improve product quality and production efficiency through digital manufacturing. Intelligent manufacturing aims to improve efficiency and quality of manufacturing industry, reduce cost, and enhance the competitiveness of enterprises. Establish a perfect intelligent manufacturing system, realize the whole process quality control and all employees participate in collaborative work, thus realize the comprehensive upgrade and transformations of intelligent manufacturing. Establish a platform economy suitable for BTH regional manufacturing, and promote the coordinated development of supply and demand sides through the platform economy, so as to accelerate the upgrading of manufacturing digitalization and establish in-depth integration of platform economy and traditional industries.

Third, in addition to the development level of digital economy, foreign direct investment, economic development, industry scale and expenditure on science and technology can also promote the overall manufacturing upgrading of BTH. Therefore, to promote upgrading of manufactures in BTH region, we should not only increase efforts to stimulate economic development and promote the development of digital economy, but also increase scientific and technological funds and promoting scientific and technological progress. The digital economy needs an innovative ecological environment. The government can establish an innovative ecological circle of the digital economy and encourage enterprises, universities, scientific research institutions and other parties to cooperate together to jointly promote the innovative development of the digital economy.

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