Does the Digital Economy Promote Industrial Transformation and Upgrading? an Empirical Test Based on the Three Eastern Provinces

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Abstract: Taking the three northeastern provinces as the research object, this paper constructs a digital economy development index system based on three dimensions: digital infrastructure, digital economy application and digital industry development, and measures industrial transformation and upgrading in terms of advanced industrial structure and rationalization of industrial structure. Using a regression model to study the impact of the digital economy on industrial transformation and upgrading in the northeast, this paper finds that there are obvious differences in the impact of the digital economy on industrial transformation and upgrading among the three northeastern provinces, with the promotion effect of Liaoning > Jilin > Heilongjiang; Liaoning and Jilin should vigorously strengthen the construction of digital industry development, while Heilongjiang needs to meet certain threshold conditions to effectively promote transformation and upgrading. The findings of this paper are useful for the analysis of the three northeastern regions. The findings of this paper help to make an accurate assessment of the development of the digital economy in the three northeastern provinces and provide reference for the governments of the northeast region to formulate policies related to industrial transformation and upgrading.

Keywords: Northeast provinces; digital economy; industrial transformation.

1. Introduction

Throughout the development process of international industrial transformation, the digital economy has become the main driving force under the new development stage, making digital economy applications and digital industry development more helpful in unblocking the arteries of supply and demand in the large domestic cycle. In recent years, the economic development of the Northeast region has achieved leaps and bounds, but due to the constraints of external factors such as technology and capital, as well as the existence of enterprises' weak capacity for independent innovation, incomplete and asymmetrical information market system and other shortcomings, making it face the problem of industrial transformation and upgrading difficulties. The "2020 Northeast Asia Economic Forum" clearly pointed out that the use of Internet technology to promote the digital transformation of the manufacturing industry is an effective measure to promote the upgrading of the industrial structure of the Northeast region, thereby realizing the comprehensive revival and revitalization of the Northeast region in the new era. However, it should be noted that the traditional manufacturing industry in the Northeast was once a major part of China's economic structure, but with the changes in the global environment and the further development of the macroeconomic situation at home and abroad, the traditional production structure dominated by heavy industry has been unable to adapt to the market mechanism, and a large number of capital-intensive enterprises have gradually lost their competitive advantage in the fierce market competition, and the efficiency of economic development has been rapidly declining. The problem of systematization is also becoming increasingly prominent (Lu,S.S., 2019[1]). This has led to a weakening of the competitive advantage of enterprises in the northeast region in the international arena, making the digital economy a practical necessity for the future development of the northeast region. Based on this background, in order to seize the opportunity of China's booming digital economy in the new era, the governments of China's three eastern provinces are accelerating the construction of the digital economy to achieve the goal of economic construction by improving the efficiency of services, upgrading traditional industries, fostering technological innovation and improving social and livelihood services, and using

this as an important breakthrough and focus point to promote the high-quality development of the northeast region, thereby growing the rapid development of China's digital economy. This will serve as an important breakthrough and focus for the rapid development of China's digital economy.

In recent years, the development of the industrialisation of the digital economy has received great attention from the Central Party and the State Council. In the context of digital business, user value orientation and alternative competition have become the two basic drivers of industrial management transformation, which not only promote the transformation of industrial objectives and the innovation of management structures, but also enhance a series of reforms in the internal management mechanism of the industry (Qi,Y.D.,& Xiao, X., 2020[2]). The Fourteenth Five-Year Plan of the National Economic and Social Development of the People's Republic of China and the Outline of the Vision 2035 states that it is necessary to create a new trend of dynamic development of the digital economy and society, actively promote the in-depth integration of the digital economy and the real economy, and empower the transformation and upgrading of the industrial structure.

2. Questions to ask

The digital economy has become a mainstream trend in socio-economic development because of its more advanced and sustainable economic form, and it is an important means to promote the adjustment of industrial structure and gradually achieve high-quality economic development. It also promotes the rationalisation and advancement of the industrial structure through the application of digital economy and the development of digital industry. In particular, digital technologies such as the Internet of Things, the software industry and artificial intelligence provide new services and impetus for economic development; emerging technologies such as information transmission and big data enable the high-quality development of traditional industries and improve the traditional production efficiency of enterprises.

In this context, the question arises as to whether the digital economy is a new driving force for the efficient development of industries in Northeast China. The purpose of this paper is to answer this question and to help evaluate the actual effectiveness of the digital economy at the micro level, to understand the driving effect of the digital economy on industrial transformation and upgrading and the quality development of industries in the Northeast, and to provide a basis for the formulation of relevant policies and regulations.

3. Review of the Literature

(i) Transformation and upgrading of industrial structure

Industrial structure transformation refers to the process of rationalization and advanced upgrading of an industry's structure, which is not only a major driving force for the sustainable economic growth of enterprises, but also a key means to enhance the efficiency of social resource allocation and promote energy conservation and emission reduction (Su,F.L.,&Li,W.Y., 2015[3]). Some foreign scholars believe that income changes can change consumer demand for products and promote changes in demand structure, which in turn affects industrial structure (Kuznets,S., 1985[4]), and in Tiedemann and Johnson (1982[5]) found that industrial policy had an important influence on the development of heavy industry through a study of Japanese industrial policy. And Humphrey and Schmitz (2002[6]) argue that developing economies will go through four stages of industrial upgrading in the process of integrating into global value chains: process upgrading, product upgrading, upgrading of functional upgrading chains or sectoral upgrading. In China, the promotion of advanced industrial infrastructure has been taken as an important arrangement in the construction of a modern industrial system, with the aim of implementing the new development concept, establishing a new economic development layout and achieving high-quality development of the national economy (Zhu,M.H. et al., 2021[7]). However, based on Fu Linghui's (2010[8]) on the relationship between industrial structure upgrading and economic growth in China from 1978 to 2008, it was found that

although the development of China's economic scale obviously promoted industrial structure upgrading, the role of industrial structure upgrading on economic growth was not prominent. Moreover, Che,M.H. et al. (2019[9]) also pointed out in their study that there is a non-linear correlation between the advanced industrial structure and the rapid development level of the national economy, and the water criterion of industrial structure rationalization is the most important threshold and setting variable to determine the quantitative correlation between them. However, there is regional heterogeneity in the development level of industrial structure rationalization for regional economic growth, for example, the strict regulation of the investment environment in Northeast China and the eastern region inhibits the growth of the local economy by improving the rationalization of the industry structure (Tang,X.H.,& Sun,Y.J., 2019[10]). Accordingly, Li,C.F. et al. (2020[11]) found from the dissection of industry data that the deeper integration of the digital economy and the real economy will become a new driving force for the revitalisation and development of China's real economy and the transformation and upgrading of the industry. As can be seen, the existing domestic literature does not systematically analyse the transformation and upgrading of the industrial structure in the northeast region, but only reviews the development of the northeast region with the analysis of the national layout. Therefore, this paper will use the three northeastern provinces as the first perspective to analyse the role of the digital economy in promoting the transformation and upgrading of the industrial structure.

(ii) Digital economy

The digital economy is a core factor for innovation and transformation of the economic development model, which can not only bring new impetus to the growth of enterprises, but also promote the transformation and upgrading of traditional industries and improve development efficiency (Cao,Z.Y., 2018[12]). Foreign scholar Don Tapscott (1996[13]) formally introduced the term digital economy in The Digital Economy: Hope and Danger in the Age of Network Intelligence. Subsequently Paul Miller et al. (2001[14]) point out that it is a technological revolution based on the Internet with rich innovative connotations, a driving force for a new economy that uses digital technology to reduce the environmental impact of economic activities and to strengthen community cooperation and social ties. With the rapid development of information technology and its increasing integration with the way the economy operates, the digital economy has been regarded as a "new engine" for national economic growth and has taken on an important role in the economic development strategies of many countries around the world (Xu,X.C.,& Zhang,M.H., 2020[15]). This has made the measurement of the digital economy a hot topic for in-depth research in the field of economics. Li,X.Z. et al. (2020[16]), in their analysis of regional differences in the transformation and upgrading of industrial structure driven by the digital economy, constructed an indicator system for the level of digital economy development through four aspects: the level of digital economy infrastructure, the level of digital economy application, the level of digital economy industry development and the level of digital economy development environment. While Ning,C.S. (2020[17]), in exploring the impact of digital economy on high-quality economic development, analyzes the three-dimensional perspective of quality, efficiency and power as a measurement system. Unlike the former, Xu,Q.Y. et al. (2018[18]), on the other hand, conducted a systematic analysis and review of the digital economy measurement index system at home and abroad, so it is clear from the content of their study that internationally, it is common to use the Digital Economy and Society Index (DESI), recommendations on the evaluation of the digital economy, measuring the digital economy, network readiness (NRI), and ICT development index (IDI) as the index system for the digital economy; while in China, it is usually based on the measurement of the global digital economy competitiveness index, the "Internet+" digital economy index, the Chinese digital economy index, and the Chinese city digital economy index. These standards have guided later scholars in their approach to the digital economy. These criteria were also used to vigorously implement the development strategy of the digital economy in the 13th Five-Year Plan, to narrow the gap with developed countries in terms of scientific research and application of core technologies, and to gradually improve the construction of the legal system of information technology, adjust the industrial structure, and promote the development of

China's digital economy (Zhao,X., 2016[19]). Based on this, this paper will use digital infrastructure, digital economy applications and digital industry development as indicators to measure the development of the digital economy in the northeast region, to measure the digital economy in the northeast region and analyze whether it can promote industrial transformation and upgrading.

(iii) The relationship between the digital economy and industrial transformation and upgrading

With the booming of the digital economy, datafication has become an important direction for the new development of traditional industries. Foreign scholars have found that technological progress can improve the technological content and market competitiveness of enterprises' products (Humphrey and Schmitz, 2002[6]), drive the flow of production factors from inefficient to efficient production sectors (Reeve, 2002[20]), helping to upgrade the industrial structure. While domestic scholars Li,Y.H. et al. (2019[21]), in their research through big data analysis theory, similarly showed that big data would become a development factor of the current digital economy, which could drive the transformation and upgrading of traditional industries and produce positive effects for the development of traditional industries, thus alleviating the current problems of high production costs and low informationization of traditional industries. At the same time, from Li,C.F. et al. (2020[11]), if the digital economy becomes a new driving force for China's industrial transformation and upgrading, along with the accelerated expansion of the consumer network to the industrial Internet, it will drive the transformation and upgrading of China's manufacturing industry with a new intrinsic mechanism of action. This leads to the key conclusion that under the new historical conditions, the development of China's industrial structure to the middle and high end must be driven by the digital economy (Zhang,Y.Z., 2018[22]). While scholars Li,X.Z. et al. (2020[16]), in using the PVAR model and impulse response model to analyse the dynamic interaction between the development of the digital economy and the transformation and upgrading of the industrial structure within a region, as well as studying the co-driving effect of the development of the digital economy on the industrial structure through the system GMM, found that although the digital economy and its subsystems can form a positive driving effect on the transformation and upgrading of China's industrial structure, there are There is a long-term, continuous, positive and dynamic interaction between the digital economy and the transformation and upgrading of the industrial structure, but there is a non-reciprocal mutual pull between the two. In order to investigate whether the regional digital economy promotes the transformation and upgrading of industrial structure, this paper will select the three northeastern provinces as the research object for investigation.

4. Study Design

(i) Variable setting

1. Explanatory variables

With the level of digital economy development as the core explanatory variable and the current trend of China's digital economy and social development, this paper takes the digital economy as a category of indicators and determines the three main levels covered by its secondary indicators: information infrastructure, digital economy application and digital industry development. After the entropy weight method is applied, the weights of the indicators are weighted and summed up, and the indicators are filtered by appropriate subdivisions, so as to construct a comprehensive digital economy development index for the three provinces in the northeast region. The digital economy development indexes designed in this paper are shown in Table 1.

Table 1 System of indicators for the level of development of the digital economy

Tier 1 indicators	Secondary indicators	Tertiary indicators	Indicative weighting	Data sources
Digital Economy	Digital Infrastructure	Mobile phone penetration rate (Number per 100 people)	10.921%	China Statistical Yearbook
		Number of mobile phone base stations (per km)	8.924%	China Statistical Yearbook
		Number of Internet domain names (10,000)	9.877%	China Statistical Yearbook Information Industry Yearbook
		Number of pages (million)	10.476%	China Statistical Yearbook
		Length of fibre optic cable (km)	9.247%	China Statistical Yearbook
		Number of Internet broadband access ports (10,000)	8.526%	China Statistical Yearbook Information Industry Yearbook
	Digital economy applications	Information transmission, software and information technology services urban units employed (10,000 people)	5.568%	China Electronic Information Industry Statistical Yearbook Information Statistics Yearbook
		Software industry revenue ($ million)	8.458%	Information Industry Yearbook
		Number of people with Internet access (10,000 people)	6.779%	China Statistical Yearbook Information Industry Yearbook
	Digital Industry Development	Telecommunications business volume (Billions of dollars)	9.986%	China Statistical Yearbook
		Level of online mobile payments ($ million)	11.236%	China Statistical Yearbook

2. Explained variables

As an explanatory variable, the paper focuses on two dimensions: rationalisation of the industrial structure and upgrading of the industrial structure.

Industrial structure rationalisation (indr), i.e. the quality of coupling within each industry, reflects the degree of rational use of resources on the one hand, and the degree of coordination between industries on the other. Here, according to Han,Y.H. et al. (2016[23]), the index of industrial structure rationalization is constructed according to the deviation of industrial structure:

$$\mathrm{indr} = \sum_{j=1}^{3}(Y_j/Y)\left|(Y_j/L_j)/(Y/L) - 1\right| \quad j = 1,2,3 \tag{1}$$

In equation (1),Y represents the total output value of the three industries,L represents the number of people employed in the three industries,j represents industries. If indr is 0, it means that the industrial structure has reached equilibrium; if indr is not 0, it means that the industrial structure has left the equilibrium state, which means that the industrial structure is not reasonable.

Industrial structure heightening (indh) describes the process in which the industrial structure develops from low level to high level in an orderly manner, and follows the internal logic of economic development and the basic path of resource allocation. In order to reduce the "false heightening" of the internal structure of industries, we refer to the experience of Liu,W. et al. (2008[24]) and take into account the industrial structure hierarchy coefficient and labour productivity, and reflect the indicators of advanced industrial structure as follows:

$$\mathrm{indh}^{*} = \sum_{j=1}^{3}(Y_j/Y)(Y_j/L_j) \quad j = 1,2,3 \tag{2}$$

Y、Lhas the same meaning as in equation (1). Because of theYj/Lj the existence of the dimension, this paper will adopt the Z-Score approach for standardization, and at the same time, for the convenience of the follow-up study, we will introduce Han,X.F. et al.'s new (2019[25]) approach to data processing by normalizing the values again to the region of [0,1], i.e.$\mathrm{indh} = [Z_i/(\max(Z_i) - \min(Z_i))] \times 0.4 + 0.6$, whereZi The higher the indh value, the more advanced the industrial structure is.

(iii) Empirical model

In order to address the question of whether the digital economy can promote industrial transformation and upgrading, this paper incorporates the digital economy into the analytical framework of industrial transformation and upgrading and establishes the basic regression model as follows.

$$stru_m = \alpha_0 + \alpha_1 lnA_{1m} + \alpha_2 lnA_{2m} + \alpha_3 lnA_{3m} + \varepsilon_m \tag{3}$$

In equation (3), the$stru_m$ denotesm the province's industrial structure upgrading indicators, i.e. indr and indh, respectively.A_{1m} represents the digital infrastructure indicator for province m, andA_{2m} represents them province's digital economy application indicator, andA_{3m} representsm the digital industry development indicators of province m, andα_0 denotes the intercept term of the model, andε_m is a random variable, andα_1 andα_2 andα_3 are the coefficients of the explanatory variables, which reflect their impact on the upgrading of industrial structure.

(iv) Data sources and explanations

Based on the panel data collected and collated from 2011 to 2020 in three northeastern provinces, the paper empirically analyses the development trend of the digital economy and its impact on the upgrading of industrial structure. The data obtained and applied were obtained from the Information Industry Yearbook, China Electronic Information Industry Statistical Yearbook, China Statistical Yearbook, provincial statistical yearbooks and official websites such as the statistical bureaus of each province. In the process of data collection, the indicators of employment in the three industries in Heilongjiang from 2011 to 2013 were not publicly released, so this paper deals with the missing parts by using the moving average method on the relevant data from 2003 to 2010 in Heilongjiang. The descriptive statistical results of the main indicators are shown in Table 2.

Table 2 Results of descriptive statistics for key variables

Variables	Province	Average	Standard deviation	Minimum value	Maximum value
indr	Liaoning	0.41009	0.08088	0.337289758	0.580803943
	Jilin	1.01724	0.11088	0.83591562	1.158368859
	Heilongjiang	0.50282	0.24863	0.289668161	0.941547765
indh	Liaoning	0.71462	0.06182	0.649875525	0.815921435
	Jilin	0.73204	0.06028	0.660142992	0.807264055
	Heilongjiang	0.67644	0.07804	0.606686433	0.791901948
Digital Infrastructure	Liaoning	108768.84907	45156.67722	47354.47764	181947.4233
	Jilin	58481.93651	30434.96856	21699.99662	104084.8964
	Heilongjiang	84553.80078	45589.30545	36486.39467	154391.3296
Digital economy applications	Liaoning	1837388.0111	485899.16583	1276795.828	2589308.67
	Jilin	356750.68876	118366.28613	181598.38	564244.6709
	Heilongjiang	94217.54318	42694.84584	39076.60293	160353.6199
Digital Industry Development	Liaoning	332.52413	152.08603	190.7284704	648.7031699
	Jilin	186.019	103.63973	90.1685784	402.6525138
	Heilongjiang	219.06565	104.03497	113.2768884	429.4731068

5. Analysis of Empirical Results

Data from columns (1) and (2) were used to analyse Liaoning Province. Digital infrastructure is negatively significant at the 1% significance level for indr, inhibiting its rationalisation, and positively significant at the 5% significance level for indh, promoting its advanced development. Digital economy applications are negatively significant at the 1% significance level for both indr and indh, inhibiting both their rationalisation and advanced development, but the significance level for indh is insignificant relative to indr. Digital industry development is positively significant for indr at the 10% significance level, but does not contribute significantly to rationalisation.

Data in columns (3) and (4) were used for the analysis of Jilin Province. Digital infrastructure is negatively significant for both indr and indh at the 10% level of significance, inhibiting its rationalisation and advanced development. Digital economy applications are positively significant for both indr and indh at the 10% significance level, contributing to their rationalisation and advanced development, but the significance of indh relative to indr is not significant. Digital industry development is positively significant for indh at the 10% significance level and promotes advanced development.

Using the data in columns (5) and (6), the analysis was conducted for Heilongjiang Province. It is evident that digital infrastructure, digital economy application and digital industry development are all negatively significant for indh and indr, inhibiting the development of rationalisation and advanced development in Heilongjiang Province, but there is a significant difference in the level of significance.

Table 3 The level of significance

Explanatory variables	Explained variables					
	Liaoning		Jilin		Heilongjiang	
	(1) Indr	(2) Indh	(3) Indr	(4) Indh	(5) Indr	(6) Indh
Digital Infrastructure	-0.244088***	0.119294**	-0.700544*	-0.137710*	-0.172229*	-0.035618
	(-4.965292)	(3.386120)	(-1.417756)	(-1.219410)	(-0.798553)	(-0.430784)
Digital economy applications	-0.195305***	-0.096512***	0.447000*	0.128899*	-0.273496**	-0.100625**
	(-5.426834)	(-3.741962)	(1.514710)	(1.911118)	(-2.414965)	(-2.317669)
Digital Industry Development	0.095349*	-0.013125	0.609972	0.197633*	-0.444126	-0.159026*
	(1.747768)	(-0.335705)	(1.471763)	(2.086441)	(-1.371421)	(-1.280917)

Note: t-statistic values of estimated coefficients in parentheses; ***, **, * denote 1%, 5%, 10% significance levels respectively

6. Conclusions of the Study

The main conclusions of this paper are as follows: (1) Based on the analysis of data from the Northeast region in the past ten years, it is found that the effect of digital economy development on the advanced industrial structure and rationalization of industrial structure differs among the three Northeastern provinces, namely: Liaoning > Jilin > Heilongjiang. Therefore, the three eastern provinces cannot be considered as a whole in the study, and each province needs to adopt measures corresponding to its own development goals. (2) Taking the results of the three provinces, there are relatively obvious geographical differences among the three provinces. In the analysis of Heilongjiang Province, it is found that the level of development of the digital economy needs to meet certain threshold conditions in order to effectively promote the transformation and upgrading of the industrial structure, so that the promotion effect will gradually increase. (3) The digital economy will serve as a new driving force for the efficient development of Liaoning and Jilin, and the benefits of industrial transformation and upgrading can be comprehensively enhanced by strengthening investment in the information transmission, software and information technology industries and increasing the construction of human resources as well as the digital business innovation capacity of resource-based enterprises.

The Northeast should further increase the construction of digital infrastructure and vigorously enhance the level of digital economy development. The development of the digital economy has had a significant impact on the upgrading of industrial structures, but at this stage there is still much room for development of the digital economy in the Northeast. Unlike traditional infrastructures, most of the new digital infrastructures are business-run products, so they should give full play to the decisive role of the market in resource allocation, thereby encouraging cooperation between different entities using market mechanisms to broaden the sources of funding for the new digital infrastructures, and innovate investment and financing methods to further optimise the allocation of resources for the digital economy. The relevant governments should formulate corresponding policies for the development of the digital economy, and guide social capital to shift to the field of digital economic infrastructure, so as to bring into play the efficiency advantages of social capital under the condition of limited resources and promote the high-quality development of China's digital economy as a whole.

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