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Empirical Study on Digital Economy Enabling High-Quality Development of Manufacturing Industry: Taking the Yangtze River Economic Belt as an Example

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Abstract: The rapid development of the digital economy provides an important impetus for the high-quality development of China's manufacturing industry. Using panel data from the Yangtze River Economic Belt, this paper measures the level of development of the digital economy and the manufacturing industry, and analyses the relationship between them. It is found that although the digital economy and the manufacturing industry as a whole show a growth trend, the regional development is unbalanced. The digital economy can obviously promote the high-quality development of the manufacturing industry, but there are also negative spatial spillover effects, and the growth of the digital economy in one region may crowd out the space for the development of the manufacturing industry in neighbouring regions.

Keywords: Digital economy; High quality development of manufacturing; Yangtze River Economic Belt; SDM.

1. Introduction

With the rapid development of the digital economy, information technology has deeply influenced various fields and become a new engine to promote economic and social development[1]. In the context of the digital economy era, not only is it building a new kinetic energy, a new economy and a new industry, but it can also be viewed from two large modules for the manufacturing industry[2]. One is industrial digitalisation[3]. Under the impetus of the digital economy, the manufacturing production chain will be in a state of automatic operation and maintenance, more accurate and orderly operation and maintenance[4]. At the same time, automation technology, can increase the production chain to protect, optimise the data processing dimension, greatly reduce the cost of labour, increase the leanness of the manufacturing production process, and to digitally lead to the efficiency of manufacturing enterprises[5]. Another is digital industrialisation. Around the digital engineering, the placement of industry, access to new business opportunities[6]. Using the digital economy to apply the new business models brought about by the development of the Internet, strengthen the economic management of enterprises and their ability to resist risks, and promote the supply-side structural reform of the market[7]. The Yangtze River Economic Belt is located in the core of China's economic and geographical advantages, with broad market potential and perfect industrial cluster advantages[8]. The development of digital economy will bring a rare opportunity for the transformation and upgrading of its manufacturing industry[9]. However, there are significant differences between different regions in terms of resource conditions and infrastructure levels, and the obstacles to the empowerment of the digital economy still need to be broken[10].

2. Theoretical Analysis and Assumptions

2.1. Digital economy and high-quality development of manufacturing industry in the region

As a new economic form, the digital economy has profoundly affected the changes in human production, life and governance. It also affects the development mode, industrial form and structural layout of the manufacturing industry, thus forming the following influence mechanisms:

The digital economy is conducive to generating economies of scale. Unlike the traditional industrial model, digital technology reduces the production and transaction costs of enterprises and helps them meet personalised demands[11]. Through the precise matching mechanism, it realises the dynamic balanced allocation of factor supply and demand, expands the market scope of enterprises and reduces the average cost, forming economies of scale[12].

The digital economy can enhance factor efficiency. Information and data have become key production factors. Increasing its input can optimise traditional factor combinations, enhance the carrying capacity of factors such as technology, management and human resources, make factor integration closer, and improve industrial core competitiveness.

The digital economy is conducive to promoting industrial integration and development. Through new technologies such as the industrial Internet, the digital economy is deeply integrated with the manufacturing industry. This will lead to changes in technology research and development models, innovation in management models, upgrading of business models, reconfiguring the industrial value chain, giving rise to new business forms and patterns, expanding industrial connections, and promoting the high-quality development of the manufacturing industry.

2.2. Digital economy and high-quality development of manufacturing industry in neighbouring regions

The digital economy implies a huge network technology radiation capacity, in driving the high-quality development of the region's manufacturing industry at the same time can produce spatial spillover effects, which can be divided into two aspects:

First, the digital economy's own characteristics increase the degree of spillover. It has attributes such as high innovation and strong permeability, and these features jointly promote spatial spillover. The upgrading of the digital economy improves factor mobility, breaks through regional constraints, enhances information technology exchanges, and improves the ability to integrate resources between regions.

Second, knowledge and technology overflow promotes regional exchanges. With the application of digital technology, such as the industrial Internet, it can help the manufacturing industry to transcend geographical constraints and achieve the exchange of technical knowledge in different regions. This is conducive to narrowing the gap between developed regions and the relative backwardness, improving the dissemination of information within and outside enterprises, and enhancing regional interconnection and cooperation.

Third, the digital economy reduces the cost of regional cooperation and promotes the dissemination of knowledge and technology spillovers. This facilitates neighbouring regions to learn from advanced experiences and achieve high-quality upgrading.

Based on the above arguments, the digital economy, while guiding the high-quality development of the manufacturing industry in the region, also promotes the transformation and upgrading of the manufacturing industry in neighbouring regions to achieve high-quality development through the spillover mechanism formed by its own characteristics. Thus forming a spatial integration effect.

In summary, hypothesis H2 is proposed: the digital economy has a spatial spillover effect on the high-quality development of manufacturing industry in neighbouring regions.

3. Digital Economy and Manufacturing in the Yangtze River Economic Belt

3.1. The concept of the digital economy

With the rapid development of information technology, data and information have penetrated into all fields of enterprises. The digital economy creates greater business value for enterprises by tapping into the digital resources of enterprises and the market, optimising the processes of each link, and promoting industrial restructuring and digitalisation to flourish. The National Bureau of Statistics (NBS) has subdivided the digital economy into digital industrialisation and industrial digitisation. Digital industrialisation refers to the transformation of digital technology into specific industries to form digital technology and information industries, including the Internet, telecommunications, electronic information, software information services and other fields. Industrial digitisation refers to the use of information technology to achieve automation and intelligence in the entire process of existing industries. For example, Alibaba has realised full automation in all aspects of "decision-making - ordering - warehousing - manufacturing - sales - settlement" to improve the efficiency of the industrial chain. Through big data analysis to optimise operations and promote the optimisation of supply-side structure. At the same time, it promotes the digital transformation of industries, builds multi-level industrial networks, and promotes the modernisation and digitalisation of industrial chains. Overall, the digital economy is reshaping the industrial model, promoting enterprises to improve efficiency and management capabilities through automation and data analysis, and boosting the high-quality development of the economy.

3.2. Issues of manufacturing development in the Yangtze River Economic Belt

The manufacturing sector in the Yangtze River Economic Belt faces two major problems. One is the problem of overcapacity, which is mainly reflected in low-end and medium-volume products. This has become a common problem for China's manufacturing industry. High-quality economic development needs to rely on the support of high-tech industries. Take Foshan as an example, Foshan's manufacturing industry is dominated by consumer goods such as ceramics and home appliances, with low-end and medium-end production capacity lagging behind, a lack of pillar emerging industries, and insufficient market competitiveness. The second is the problem of a single industrial structure. Due to geographical proximity, the industrial structure is similar across the region, and homogeneous competition in the industry has intensified. This prevents the region from taking advantage of their respective strengths and synergistic development. This leads to a lack of endogenous momentum in the overall industry, making it difficult to support transformation and upgrading. The growing digital economy provides brand new opportunities for the manufacturing industry. As the economic centre of China, the Yangtze River Economic Belt has a large scale of manufacturing industries, and after the country explicitly proposed the construction of the economic belt in 2014, industry transfer and cooperation has become a key focus. As information technology continues to mature, the digital economy will bring changes to regional industrial upgrading. This is both a transition problem, but also will be an opportunity for the Yangtze River Economic Belt manufacturing industry to move towards high quality.

It can be said that the transformation and development of the manufacturing industry has become an inevitable trend of the times, the country's heavy equipment is in urgent need of "turn", and common economic zone as China's most developed economic zone, manufacturing enterprises are densely populated, but also naturally become the focus of the breakthrough direction. Since the 2014 "Government Work Report" clearly put forward the "construction of the Yangtze River Economic Belt", to promote industrial transfer and collaboration will be listed as one of the key planks, and it so happens that the digital economy, a new kinetic energy, a new industry, but also for the Yangtze River Economic Belt, the high-quality development of the manufacturing industry to provide solutions.

The digital economy is also a solution for the high-quality development of the manufacturing industry in the Yangtze River Economic Zone. Even if the manufacturing industry of the Yangtze River Economic Belt is the core of the national economy, it inevitably has the mission of transformation and development, and the digital economy is a serious challenge and opportunity.

4. Measurement of the Digital Economy and High-quality Development of Manufacturing

4.1. Indicator system for measuring the level of digital economy

The digital economy level measurement index system given in this paper is scientifically and comprehensively designed, which can give the evaluation of regional digital economy development level from different dimensions. Communication network infrastructure indicators can reflect the level of regional information infrastructure construction. Among them, the high penetration rate of fixed telephone and broadband network indicates that the regional information interaction and service capacity is strong. Information application indicators reflect the actual application effect of digital technology in various economic and social fields. The scale of online transactions represents the role of the digital economy in promoting the circulation of goods. Enterprise IT investment measures the degree of digital adoption. The innovation and entrepreneurship environment indicator examines the regional digital economy ecosystem. A high number of technology enterprises implies a strong regional digital technology innovation capacity and good talent mobility.

The indicator system asserts the level of digital economy from different levels, including all aspects of infrastructure, application, and innovation. It makes up for the fact that it is difficult for a single indicator to reflect complex issues.

Table 1. Indicator system for the level of development of the digital economy

Indicator category	Indicator	Definition of indicators
Communications network infrastructure	Fixed-line telephone penetration rate	Fixed telephone subscribers per 100 households
	Broadband network coverage	Share of population covered by each type of broadband network
information application	Scale of online transactions	Total online transactions as a percentage of GDP
	Percentage of enterprise IT investment	Percentage of enterprise IT investment
Innovation and Entrepreneurship Environment	Number of science and technology enterprises	Number of legally registered science and technology-based enterprises

4.2. Indicator system for high-quality development of the manufacturing industry

The design of manufacturing high-quality development indicator system can better reflect the level of transformation and upgrading of regional manufacturing industry from different levels. Industrial scale indicators directly measure the scale of regional manufacturing development, and can initially judge its economic status. The importance of product structure indicators reflects whether the manufacturing industry is shifting to high-tech fields. The high proportion of high-tech industries indicates the obvious effect of industrial upgrading. Export structure indicators focus on the quality of output. A high proportion of high-tech products exported represents a strong international competitiveness. Enterprise efficiency indicators reflect whether the digital economy enhances the intrinsic vitality of enterprises. Profit level directly reflects economic efficiency. Resource and environment indicators focus on industry standards. The degree of energy saving and emission reduction can evaluate the level of sustainable development.

Table 2. Construction of the indicator system for the level of high-quality development of the manufacturing industry

Indicator Category	Indicators	Definition of Indicators
Industry Scale	Value Added of Manufacturing Industry	Value added of regional manufacturing industry or its share in local GDP
Product Structure	Value added of high-tech industry	Value added or share of high-tech industry
Export Structure	Exports of high-tech products	Share of exports of high-tech products in total exports
Enterprise Efficiency	Total Profit	Total annual enterprise profit or growth rate
Re-capacity	Total Energy Saving and Emission Reduction	Total amount of standard coal saved in a year

5. Empirical Research

5.1. Entropy weight method

The basic idea of entropy weight method is to determine the objective weights according to the magnitude of indicator variability. Generally speaking, if the information entropy of an indicator is smaller, it indicates that the indicator is worth the greater degree of variability, the more information it provides, the greater role it can play in the comprehensive evaluation, and the greater its weight. On the contrary, the larger the information entropy of an indicator is, the smaller the degree of variability of the indicator is, the smaller the amount of information it provides, the smaller the role it can play in the comprehensive evaluation, and the smaller its weight is.

5.2. Spatial Durbin model

5.2.1. Spatial autocorrelation test

The spatial autocorrelation test is performed using Moran's I index, and then the 0-1 spatial adjacency matrix is constructed , which indicates that the boundaries of region i and region j are adjacent when w_{ij} = 1, and are not adjacent otherwise. In order to ensure whether the observations are spatially correlated and to verify the rationality of including spatial variables, the measure is obtained by the global Moran's index with the following formula:

$$I=\frac{n\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}\left(x_i-\overline{x}\right)\left(x_j-\overline{x}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{n}w_{ij}\sum_{i=1}^{n}\left(x_i-\overline{x}\right)^2} \tag{1}$$

where n is the sample size, x_i、x_j are the observations at spatial locations i and j, and is the 0-1 spatial adjacency matrix. The sign of the global Moran's index indicates the direction of the influence effect of spatial correlation, with a value in the range of [-1, 1], and when the Moran's index is equal to 0 there is no spatial correlation.

Table 3. Global Moran Index

Indicator	Level of development of the digital economy			Level of high-quality development of manufacturing		
Year	Moran Index	statistic	P-value	Moran Index	statistic	P-value
2006	0.349***	2.554	0.007	0.431***	2.699	0.004
2007	0.407***	2.679	0.005	0.451***	2.901	0.004
2008	0.401***	2.667	0.005	0.567***	3.299	0.002
2009	0.419***	2.709	0.005	0.463***	3.014	0.001
2010	0.455***	3.012	0.003	0.512***	3.229	0.002
2011	0.473***	3.045	0.003	0.482***	3.345	0.001
2012	0.487***	3.123	0.003	0.461***	2.998	0.003
2013	0.486***	3.155	0.003	0.452***	2.978	0.002
2014	0.452***	2.889	0.005	0.421***	2.987	0.004
2015	0.452***	2.878	0.004	0.477***	3.129	0.006
2016	0.434***	2.912	0.005	0.487***	3.064	0.003
2017	0.459***	2.909	0.003	0.481***	2.964	0.005
2018	0.431***	2.898	0.003	0.465***	2.935	0.003
2019	0.431***	2.903	0.003	0.466***	3.011	0.002
2020	0.449***	3.102	0.003	0.469***	2.998	0.003
2021	0.445***	3.009	0.002	0.472***	3.019	0.003

Note: *, **, ***, indicate passing 10%, 5%, and 1% significance tests, respectively.

5.2.2. Model Selection

Prior to spatial econometric analysis, a Location Model (LM) test is required to verify the fit of the model. If both LM-Error and LM-Lag statistics are not significant, it indicates that the spatial effects can be ignored and the regular regression analysis model can be used. If only LM-Error passes the significance test, the spatial autoregressive model (SEM) that takes into account the error term is selected. If only LM-Lag passes the test, the spatial autoregressive model (SAR) considering the explanatory variables is selected. If both LM-Error and LM-Lag pass the test, the results of the LM-Error and Robust LM-Lag tests need to be further compared to determine the most robust model choice-if the former passes, the SEM model is chosen; if the latter passes, the SAR model is chosen. Through the LM test, different models can be compared and the spatial econometric model that matches the characteristics of the data can be selected, thus obtaining more reliable analysis results.

Table 4. LM test results

Test method	Statistic	P-value
LM-Error	129.98	≤0.0001
Robust LM-Error	99.29	≤0.0001
LM-Lag	39.90	≤0.0001
Robust LM-Lag	29.79	≤0.0001

The LM-Error and LM-Lag tests for both SEM and SAR models showed 1% significance, validating the need to analyze the data using spatial measurement models. Since both LM-Error and LM-Lag statistics under robustness were significant, further Likelihood Ratio (LR) test and Wald test were conducted to determine whether the SDM model would degenerate into SAR or SEM model. According to the test results, both LR test and Wald test rejected the hypothesis of SDM model degradation, indicating that the SDM model matches the data characteristics best. In addition, the results of Hausman test show that its p-value is less than 0.01, indicating that the individual fixed effects model is more suitable. In conclusion, this study chooses the SDM individual fixed effects spatial measurement model to empirically analyze the data, and this model matches the data characteristics and can give reliable results for analysis.

Table 5. LR and Wald test

Test method	Statistic	P-value
LR-spatial-lag	87.74	≤0.0001
LR-spatial-error	76.59	≤0.0001
Wald-spatial-lag	163.21	≤0.0001
Wald-spatial-error	198.22	≤0.0001

5.3. Empirical results

In order to comparatively analyze the differences in the relationship between digital economy and high quality of manufacturing industry, this paper chooses to conduct non-spatial panel regression analysis in addition to the SDM spatial panel model. Through the robust Hausman test (p-value less than 0.01), the fixed effect non-spatial panel model is chosen for empirical research. The results show that at the 1% significant level, every 1% increase in the level of the digital economy will pull the high quality level of the manufacturing industry up by 0.4675%. In addition, the results of SDM model show that the spatial interaction effect is positive and significant at 1% level. That is, every 1% increase in the high quality level of manufacturing in the region will push up the corresponding level in neighboring regions by 0.3912%. Comparison of the results of the two models reveals that the coefficient size, direction and significance of each variable remain consistent, which verifies the parameter stability of the model variable estimation. In summary, different models have empirically supported the hypothesis of the relationship between the digital economy and the upgrading and transformation of the manufacturing industry.

Table 6. Results of the spatial measurement model

variable	FE model	SAR model	SEM model	SDM model
LD	0.4675***	0.4212***	0.5124***	0.6565***
	(7.54)	(5.63)	(8.34)	(8.35)
LF	-0.3776***	-0.3215***	-0.3451	0.3555
	(-3.34)	(-3.24)	(-1.88)	(1.89)
UR	0.4324*	0.4124*	-0.3454	-0.6663***
	(1.65)	(1.98)	(-1.68)	(-3.21)
FI	0.11123***	0.1233***	0.0474***	0.0991***
	(5.14)	(4.46)	(5.16)	(4.56)
T	0.0253	0.0345	0.0588	0.0921**
	(0.65)	(0.47)	(1.26)	(2.49)
RS	0.3298***	0.3346***	0.3944***	0.4876***
	(11.22)	(8.34)	(10.01)	(12.31)
$w \times LD$	—	—	—	-0.4821***
	—	—	—	(-4.87)
$w \times LF$	—	—	—	-0.2454*
	—	—	—	(-1.99)
$w \times UR$	—	—	—	1.5124***
	—	—	—	(4.87)
$w \times FI$	—	—	—	0.0715*
	—	—	—	(1.83)
$w \times T$	—	—	—	-0.0909*
	—	—	—	(-1.85)
$w \times R$	—	—	—	-0.2911***
	—	—	—	(-6.21)
Constant	0.2135*	—	—	—
	(1.83)	—	—	—
rho	—	—	0.5632***	0.3912***
	—	—	(5.12)	(4.71)
sigma2		0.0088***	0.0069***	0.0054***
		(9.12)	(8.12)	(8.83)
Log-L		150.2609	158.3467	192.2296
R2	0.9585	0.9437	0.9246	0.9117

Since the estimation results of the spatial panel model are difficult to directly reflect the true extent of the impact of the digital economy on the high-quality development of the manufacturing industry, this study further adopts impact decomposition analysis.

Table 7. Decomposition of spillover effects

Variable	Direct effect	Indirect effect	Total effect
LD	0.5545***	-0.4563***	0.2334*
LF	0.1279	-0.3167	-0.1934
UR	-0.4221**	1.7539***	1.4592**
FI	0.1239***	0.1456***	0.2358***
T	0.04524**	-0.1846	-0.0142
RS	0.5571***	-0.2645***	0.3234***

The direct impact of the digital economy on the high quality of the local manufacturing sector is positive and significant, but the indirect impact on neighboring regions is negative, as the development of the local digital economy may depend mainly on attracting digital resources such as manpower from neighboring regions. The direct and indirect impacts of financial development are not significant. The urbanization rate of the region has a negative direct impact on the manufacturing industry and a positive indirect impact, probably due to the shift of the industry as a result of industrial restructuring. The direct and indirect impacts of foreign business are both significantly positive, and foreign business may bring a positive exogenous incremental effect of capital, technology, and human resources. Transportation has a significant positive impact on the local impact, but the indirect impact is not significant. The direct impact of scientific research supports the digital economy positively, while the indirect impact is negative, possibly due to the dependence of neighboring regions affecting independent innovation. Overall, factors such as the digital economy affect the high quality level of manufacturing in local and neighboring regions through different mechanisms, and their transmission patterns need to be carefully analyzed.

6. Conclusion

This study explores the impact mechanism of digital economy on the high-quality development of China's regional manufacturing industry. The following conclusions and recommendations are mainly drawn.

Firstly. The digital economy as a whole has a significant positive impact on promoting the high quality level of regional manufacturing industry. It can promote the transformation and upgrading of regional manufacturing industry through the mechanisms of scale economy effect and factor efficiency improvement. The direct impact of the digital economy in promoting the high quality of local manufacturing industry is significant, and the indirect impact on neighboring districts is also positive, but to a limited extent.

Second, the regional internal and external condition differences will affect the digital economy conduction effect. For example, the local urbanization process directly constraints on the local manufacturing industry, but indirectly promote the adjacent areas; and scientific and technological innovation to directly support the local digital economy and manufacturing industry, but the indirect impact of the adjacent areas may be dependent on the results of the transfer of insufficient and negative.

Third, foreign investment as a whole pulls regional manufacturing high quality level, may be due to its capital, technology and talent spillover effect is strong. The government should optimize the environment to attract foreign investment to continue to invest in the region.

Fourth, the construction of transportation facilities has not yet formed an obvious inter-regional spillover effect. In the future, the regional connectivity system should be further improved to promote in-depth exchange of resource elements.

Fifth, the development of the digital economy is characterized by "local priority", which can easily take up the resources of neighboring regions and affect their development. Regional cooperation should strengthen resource sharing to make up for the differences between inside and outside the region.

Sixth, scientific and technological innovation also needs to pay attention to the transformation and application of outputs, and cultivate the mechanism of technological exchanges and cooperation within and outside the region, so as to promote the transfer of results sharing.

In summary, the digital economy to promote the high-quality development of the regional manufacturing industry needs to optimize the internal and external conditions of the region, cultivate the positive spillover effects of the digital economy, and eliminate the negative impacts. Regional governments should conduct in-depth studies on the conditions in their regions, collaborate with neighboring regions to achieve win-win cooperation, realize in-depth integration and optimal allocation of digital economy results, and promote China's regional synergistic development.

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