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Exploring the Integration of Digital Economy and High-quality Manufacturing in Lianyungang: Coupling and Coordination Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

With the in-depth development of the new round of scientific and technological revolution and industrial change, digital technologies such as big data, Internet, cloud computing, blockchain, artificial intelligence and other digital technologies have a far-reaching impact on the manufacturing industry, and the digital economy has become an important engine for the promotion of high-quality development of the manufacturing industry. Therefore, in order to vigorously promote the digital economy of Lianyungang City to empower the high-quality development of the manufacturing industry, the use of Lianyungang City data from 2011-2021, the establishment of the digital economy and the high-quality development of the manufacturing industry evaluation index system, based on the entropy value method and the coupling coordination model, to explore the degree of coupling and coordination of Lianyungang City's digital economy and the high-quality development of the manufacturing industry. The study found that: from 2011 to 2021, Lianyungang digital

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economy index and manufacturing high-quality development index are showing an upward trend; from 2011 to 2021, Lianyungang's digital economy and manufacturing high-quality development in the coupling and coordination of the degree of upward trend, to reach the extreme coupling and coordination, but the gap from the developed cities is large, there is a large space for improvement. The conclusions of this study provide a certain reference for the promotion of coupled and coordinated development of digital economy and manufacturing industry in Lianyungang City in the future.

Keywords: Lianyungang; digital economy; manufacturing high-quality development; coupling coordination model.

1. INTRODUCTION

“The report of the 20th Party Congress proposes to accelerate the development of the digital economy, promote the deep integration of the digital economy and the real economy, and create an internationally competitive digital industry cluster. Manufacturing is an important cornerstone for the high-quality development of the real economy, and the level of development of the manufacturing industry can laterally reflect the level of a country's comprehensive national strength. At present, the global manufacturing industry is accelerating to digitalization, intelligence, traditional industries + Internet, real economy + digital economy, new economic development model is constantly spawned. The booming development of digital technology continues to change the development of the manufacturing industry, in this case, in-depth study of the coupling mechanism of the digital economy and the high-quality development of the manufacturing industry, can effectively help the country in-depth implementation of the digital economy policy, and boost the high-quality development of the manufacturing industry. Lianyungang City, as a typical advanced manufacturing city in the development of the manufacturing industry, the high-quality development of manufacturing has great potential, clarify the coupling mechanism of the digital economy and the high-quality development of the manufacturing industry, how to accelerate the integration of manufacturing and digital economy is to enhance the core competitiveness of the industry urgently need to solve the problem” (Don Tapscott, 1996) [1].

1.1 Review of Literature Related to Digital Economy and High-Quality Development of Manufacturing Industry

Research on digital economy: In the 1990s, Don Tapscott (1996) [1], the "father of the digital economy", first proposed the concept of "digital economy", and Pang Jian (2013) [2] and Li Changjiang (2017) [3] said that “the digital economy is the following. The economic activity of using digital technology and trading digitized products. The index method is commonly used to measure the overall level of digital economy”. In the construction of the digital economy evaluation index system, most scholars based on the "digital economy" four perspectives to build the digital economy measurement index, there are also some scholars Banknote Xiaojing et al. (2023) [4], from the perspective of the morphological attributes of the digital economy, the introduction of the platform economy, the sharing economy dimensions of the construction of a comprehensive evaluation index system. The digital economy mostly affects the development of various social industries through big data technology, digital finance, digital transformation, etc.

Research on high quality development of manufacturing industry: Currently about the high-quality development of manufacturing industry has become a hot spot of scholars' research, and the research method is mainly entropy value method. Lin Chunyan and Qiao Wen (2023) [5] used two-stage entropy value method and time series weighted average operator to carry out static and dynamic measurement to analyze the high-quality development of China's manufacturing industry and its spatial and temporal evolution characteristics, and found that the overall high-quality development of the manufacturing industry in the period of 2010-2020 has been gradually improved. The study found that the development trend of high quality development of manufacturing industry in the Yangtze River Delta region is relatively stable; Jiang Di, Wu Huazhu (2023) [6] used “entropy value method-gray correlation analysis to comprehensively evaluate and comparatively analyze the level of high quality development of manufacturing

enterprises in Jiangsu and other manufacturing provinces to find out the problems of high quality development of manufacturing industry in Jiangsu". From the aspect of indicator selection, Zhang Wenhui et al. (2018) [7] believe that "the seven dimensions of innovation-driven, structural optimization, speed and efficiency, factor efficiency, quality and brand, integration and development, and green manufacturing can construct an indicator system to measure the level of high-quality development of China's manufacturing industry", and Zhang Jun (2019) [8] integrates innovation, coordination, green, openness, and sharing into the construction of the indicators for measuring high-quality development in five dimensions, and Jiang Xiaoguo et al. (2019) [9] supplemented high-end development indicators when constructing the evaluation index system for high-quality development of the manufacturing industry, arguing that it can reflect the high-quality development of the manufacturing industry .

Research related to the digital economy and the high-quality development of the manufacturing industry: Existing literature on how the digital economy affects the high-quality development of the manufacturing industry is relatively rich, the digital economy promotes the high-quality development of the manufacturing industry through the green total factor productivity, and the level of development of the digital economy has different effects on different economies. However, there is a lack of research related to the coupling and coordination of the digital economy and the high-quality development of the manufacturing industry, Fu Weizhong and Liu Yao (2021) [10] studied the coupling and coordination mechanism of industrial digitization and the high-quality development of the manufacturing industry; Xiong Yan and Wu Tingting (2023) [11] studied the coupling and coordination of the digital innovation and the high-quality development of the manufacturing industry as well as the evolution of the digital innovation and the high-quality development of the manufacturing industry; Zhao Hanguang,Liu Yali (2024) [12] studied "the level of coupling coordination and driving factors of digital economy and manufacturing high-quality development in the Yellow River Basin".

It can be found that the research on the coupling and coordination of digital economy and high-quality development of manufacturing industry is mostly based on countries and economic regions, and there are fewer prefecture-level cities. In this paper, on the basis of systematic theoretical sorting and research, based on the basic connotation of the digital economy and the high-quality development of the manufacturing industry, constructing an index system for evaluating the development level of the two, based on the entropy weight method and the coupling coordination model to explore the degree of coupling coordination of the digital economy and the high-quality development of the manufacturing industry in Lianyungang City in 2011-2021, in order to provide reference for the promotion of the integration of the digital economy and the manufacturing industry in Lianyungang City.

2. THE DIGITAL ECONOMY AND MANUFACTURING HIGH-QUALITY DEVELOPMENT COUPLING AND COORDINATION DEGREE MEASUREMENT

Evaluation index system construction: Drawing on the research basis of Zhao Tao and Zhu Jie et al. (2020) [13] and Fu Weizhong et al. (2020) [14], combined with the connotation of the digital economy and manufacturing industry, the establishment of the indicator system for measuring the development of the digital economy and the high-quality development of the manufacturing industry in Lianyungang City, as shown in Table 1.

Research Methods: Drawing on the entropy weight method model (Guo Feng, 2023) [15] and the coupled coordination model (Wang Shujia et al., 2021) [16], the level of high-quality development of the digital economy and manufacturing industry in Lianyungang City is measured, and this method helps to measure the level of high-quality development of the digital economy and manufacturing industry in Lianyungang City more objectively and reasonably by assigning the weights to the indicators and analyzing the data.

Data Sources: The data for all evaluation indicators are derived from Jiangsu Statistical Yearbook (2011-2022), Lianyungang Statistical Yearbook (2011-2022), and Peking University's Digital Financial Inclusion Index, and some of the missing values are handled by the mean value method and interpolation method.

Table 1. Indicator system of digital economy and high-quality development of manufacturing industry

Digital economy	Primary indicators	Secondary indicators	Indicator attributes	Weights
	Digital infrastructure	Mobile telephone exchange capacity (10,000 households)	Positive	0.0583
		Internet penetration rate (%)	Positive	0.1146
	Digital industrializati on	Total postal business (million yuan)	Positive	0.3015
		Percentage of employees in the information transmission, computer services and software industry (%)	Positive	0.2188
	Industrial digitization	Number of computers used by industrial enterprises per 100 people (units)	Positive	0.0455
		Cumulative number of express delivery services (million pieces)	Positive	0.1343
	Digital economy development	Peking University Digital Financial Inclusion Index	Positive	0.0505
		Number of high-tech industries (units)	Positive	0.0765
High-quality developm ent of manufact uring industry	Innovation development	Expenditure on science and technology in local general budget expenditure (%)	Positive	0.0812
		Intensity of R&D investment (%)	Positive	0.0519
		Number of effective invention patents (pieces)	Positive	0.1102
	Structural optimization	Proportion of industrial added value to regional GDP (%)	Positive	0.0618
		Proportion of output value of high-tech industries in total industrial output value above designated size (%)	Positive	0.1148
		Sales revenue of new products (yuan)	Positive	0.0708
	Economic efficiency	Growth rate of output value (%)	Positive	0.0809
		Sales profit margin (%)	Positive	0.1142
		Sales rate of new products (%)	Positive	0.0648
	Green development	Energy consumption per unit of industrial added value (standard coal, t/million yuan)	Negative	0.0776
		Energy consumption per unit of industrial added value (standard coal, t/million yuan) Negative 0.0776 Industrial wastewater emissions per unit of income (10,000 t/billion yuan)	Negative	0.1073
		Industrial sulfur dioxide emissions per unit of income (t/billion yuan)	Negative	0.0645

3. EMPIRICAL ANALYSIS

Analysis of the comprehensive level of Lianyungang digital economy: In 2011-2021, the level of digital economic development in Lianyungang City is continuously optimized, showing a good upward trend (Table 2). In 2013, Lianyungang City built a national innovative city, developed a high-tech zone economy, guided by preferential support policies, created four national industrial bases of new pharmaceuticals, silicon materials, high-performance fibers and composites, and equipment manufacturing, and promoted the fusion of innovation and industry to speed up the the pace of digital industrialization. 2014-2019 growth is relatively flat. Lianyungang City has gradually improved new measures for the digital economy, and with the further acceleration of the development of "Internet +", the postal courier and information and communication industry has shown obvious positive changes. With the widespread application of digital technology and digital elements in various fields, it promotes the accelerated development of digital industrialization and industrial digitization process, and gradually leads the direction of digital economic growth. 2021 digital economic

development level growth is more significant, on the one hand, the Lianyungang government actively promotes the process of digital services, digitalization is implemented in the areas of education, health care, civil affairs, human resources and social services, and housing, etc., and promotes the development of governmental affairs. service innovation; on the other hand, the digital economy gradually promotes technological diversification, facilitates the construction of new digital infrastructure, promotes the deep integration of basic industries and digital infrastructure, stimulates new industrial kinetic energy, drives the development of the digital economy, and contributes to the high-quality development of Lianyungang's economy. Lianyungang City is actively integrating into the global digital economy development trend, and steadily promoting the continuous development of digital economy in various fields.

Analysis of the comprehensive level of high-quality development of the manufacturing industry in Lianyungang City: The comprehensive score of Lianyungang City's manufacturing high-quality development level showed a fluctuating rise in 2011-2019; the new crown epidemic in 2020-2021 had an impact on the production and operation of manufacturing enterprises, and there was a brief decline in the manufacturing high-quality development score. 2019 had the highest comprehensive score of the manufacturing high-quality development level (Table 2). 2019 Lianyungang was selected as one of the top fifty cities of China's Advanced Manufacturing City Development Index" top 50, located in the third echelon of China's advanced manufacturing industry, its manufacturing industry has a better foundation and high potential for future development. Enterprises in Lianyungang have continuously increased their investment in R&D, forming advanced manufacturing clusters represented by new pharmaceuticals, new materials, new energy and high-end equipment manufacturing. Pharmaceutical manufacturing is a pillar industry in Lianyungang, the local pharmaceutical enterprises to accelerate the intelligent manufacturing upgrade, promote the realization of the "Internet +pharmaceutical industry". 2019 Lianyungang City, pharmaceutical manufacturing industry to achieve 20.1% of the operating income, the industry plays a significant role in leading the way. 2020-2021, by the new crown epidemic to the impact and the global industry chain Restructuring, Lianyungang City manufacturing enterprises exports are hindered, the amount of traditional processing trade in the manufacturing industry declined. 2021 Lianyungang manufacturing enterprises to accelerate the deep integration with the industrial interconnection, and actively adapt to the new market changes, to encourage enterprises to adapt to the market high-quality, segmented market demand, the manufacturing industry high-quality development of the comprehensive score compared to 2020 to improve.

Lianyungang digital economy and manufacturing high-quality development coupling coordination degree: According to the coupling coordination model measured the degree of coupling coordination between the digital economy and the high-quality development of the manufacturing industry in Lianyungang City in 2011-2021, as shown in Table 2.

2011-2021, Lianyungang City, digital economy and high-end manufacturing industry Lianyungang City, digital economy and high-end manufacturing industry linkage coordination degree of upward trend, the degree of linkage coordination reached 0.2734 of 0.8197, from moderate imbalance to good coordination, digital economy and high-end manufacturing industry deepening integration of the two interact with each other, to achieve high-quality coordination still have differences.2011-2012, the digital economy industry has just emerged, the development of the manufacturing industry has less impact, the industry's digital transformation and application is still in its infancy, presenting a lower level of coupling. 2013 coupling degree reached 0.6046, indicating that Lianyungang City to promote the process of digital industrialization of the process of industrial structure optimization, to promote the aggregation of high-tech industry development, high-tech Manufacturing enterprises absorbed and drew on the innovations of emerging digital technologies, accelerating the pace of digital transformation. 2014-2020 coupling growth rate slowed down, the later by the impact of the epidemic, the degree of coordination declined, the epidemic made the development of the manufacturing industry affected, but the overall also reached a high degree of coupling and coordination state. As a typical advanced manufacturing developing city, Lianyungang enterprises continuously increase R&D investment, a number of influential high-tech enterprises successfully "promoted" national high-tech enterprises, regional innovation-driven capacity is constantly

Table 2. Lianyungang digital economy and manufacturing high-quality development coupling and coordination results

year	Level of development of the digital economy	Level of high-quality development of the manufacturing sector	degree of coupling coordination	Degree of coupling coordination	categorization
2011	0.0254	0.2200	0.2734	moderate disorder	Low coupling coordination
2012	0.0631	0.3940	0.3971	mild disorder	Moderate coupling coordination
2013	0.2961	0.4513	0.6046	Primary coordination	Highly coupled coordination
2014	0.1375	0.5116	0.5150	sue for harmonization	
2015	0.1651	0.6115	0.5637	sue for harmonization	
2016	0.2255	0.7053	0.6315	Primary coordination	
2017	0.2823	0.6799	0.6619	Primary coordination	
2018	0.3085	0.5313	0.6363	Primary coordination	
2019	0.3672	0.7150	0.7158	Intermediate level coordination	
2020	0.4200	0.5000	0.6769	Primary coordination	
2021	0.7820	0.5774	0.8197	good coordination	Extreme coupling coordination

improving, the high-quality development of the manufacturing industry makes the amount of investment in the digital economy increase, and promotes the digitization of the manufacturing industry and the development of intelligence. In 2021, the degree of coupling coordination reached 0.8197, reaching a good state of coordination, thanks to the rapid popularization and development of the digital economy, Lianyungang digital infrastructure support continues to be strengthened, the development of digital industrialization continues to promote the digital transformation of industries continues to accelerate, the value of data elements continue to release, accelerating the transformation and upgrading of Lianyungang City's manufacturing industry and the pace of quality enhancement.Setting the level of harmonization and delineation of the two systems.

4. COUNTERMEASURES AND RECOMMENDATIONS

Driving digital transformation in manufacturing: The digital economy has become an important engine for promoting the high-quality development of the manufacturing industry. Accelerating the deep integration of the digital economy and manufacturing industry provides a source of power for the development of manufacturing to digitalization and intelligence. Lianyungang copes with the traditional manufacturing industry to accelerate the transformation and upgrading, comprehensively promotes intelligent intelligent manufacturing, and promotes the development of the deep integration of new digital technologies such as big data, blockchain and artificial intelligence with traditional manufacturing in the whole process of design, production, management, service and other manufacturing activities. Realize the digital transformation and upgrading of the manufacturing industry, improve industrial competitiveness, upgrade the quality of traditional manufacturing products, increase the added value of products, and help create local high-end brands. Lianyungang with the help of high-tech industrial development zones, gathering local high-tech enterprises, benchmarking enterprises, high-end talent, the implementation of a number of key enterprises intelligent manufacturing key transformation projects, combined efforts to enhance the city's enterprise automation and intelligent manufacturing level, play the role of the reform of the test field. At the same time, high-tech industrial development zones should actively build public service platforms, share manufacturing digital transformation mode, promote small and medium-sized enterprises to join the digital, intelligent transformation, drive the city as a whole to promote the whole industry chain to achieve digital transformation.

Accelerating the construction and improvement of digital infrastructure: “In the global competitive landscape of recent years, digital infrastructure has become a key area of competition among countries. Countries around the world have implemented a series of policy initiatives aimed at accelerating the pace of their digital infrastructure construction. Digital infrastructure covers multiple dimensions such as hardware, software and network facilities, and its importance as the foundation for the development of digital economy is increasing day by day. Lianyungang needs to accelerate the digital transformation of its traditional infrastructure to meet the needs of the digital era, and also needs to further strengthen the overall layout of its digital infrastructure. This involves the systematic advancement of multiple aspects of network infrastructure, arithmetic infrastructure, and application infrastructure to achieve systematic development and scale deployment of digital infrastructure” (Don Tapscott, 1996) [1]. The Lianyungang government and enterprises have strengthened cooperation, improved relevant supporting systems, accelerated scientific and technological research and development, and given full play to the support of digital infrastructure for the high-quality development of the manufacturing industry.

Accelerate the construction and improve the talent cultivation system: Talent is the core driving force to promote the manufacturing industry to realize digitalization and intelligent development. In response to the urgent need for the development of the manufacturing industry, it is necessary to broaden the channels for the introduction of talents and implement the strategy of precise talent attraction, especially to increase the introduction of professional and skilled talents related to the digital economy and manufacturing industry. First of all, the government and colleges and universities to build a perfect talent cultivation mechanism, through the establishment of close cooperation between colleges and universities and enterprises to cultivate a number of excellent talents with manufacturing digital composite ability. In

addition, the optimization of talent service guarantee measures is also crucial, the government should introduce targeted talent policy, to provide stable employment security for the talent and for them to explore the field of digital innovation in the manufacturing industry to provide a relaxed environment and conditions [16]. Finally, we must adhere to the principle of scientific use of talent, to ensure that each position can realize the best use of people, maximize the effect of talent, for the digital transformation of the manufacturing industry and intelligent development to provide strong intellectual support.

5. RESULTS AND DISCUSSION

Based on the data of Lianyungang City in 2011-2021, this paper uses the entropy value method and the coupling coordination model to measure the degree of coupling coordination between the digital economy and the high-quality development of the manufacturing industry, analyzes its time evolution characteristics, and draws the following conclusions: the degree of coupling coordination between Lianyungang City's digital economy and the high-quality development of the manufacturing industry has been increasing. As a whole, Lianyungang digital economy and manufacturing industry show an extreme coupling and coordination development trend in terms of time evolution characteristics. The limitation of this paper is that the study selection is representative but not comprehensive due to the availability of data.

6. CONCLUSION

It is concluded that this study provides a certain reference for the promotion of coupled and coordinated development of digital economy and manufacturing industry in Lianyungang City in the future. In order to deepen the high-quality integration of the digital economy and manufacturing industry in Lianyungang, it is necessary to accelerate the in-depth integration of the digital economy and manufacturing industry, accelerate the digital transformation of the traditional infrastructure, and increase the introduction of professional and skilled talents related to the digital economy and manufacturing industry, so as to provide a strong support for the digital transformation of the manufacturing industry and intelligent development.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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