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Article

The coupling and coordination of digital economy and manufacturing transformation and upgrading for industry 5.0 in Hebei Province

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Abstract: In the context of the widespread application of digital technologies such as the Internet, big data, artificial intelligence, and cloud computing, digital transformation in the manufacturing sector has become an important engine to promote high-quality economic development in Hebei Province. This paper aims to objectively analyze the current situation of industrial integration between the Beijing-Tianjin-Hebei digital economy and the manufacturing industry and conduct level measurement so as to promote the in-depth integration and development of the digital economy and manufacturing industry in Hebei Province, so that the manufacturing enterprises in Hebei Province can rebuild their competitive advantages in future development, finally realize digital transformation, and promote the high-quality development of the manufacturing industry in Hebei Province. Therefore, it is very important to carry out empirical research on the integrated development of the digital economy and manufacturing industry in Hebei Province. First of all, this paper constructs the index evaluation system of the digital economy and manufacturing industry, respectively, takes the relevant data of the Beijing-Tianjin-Hebei region in the past five years as data samples, uses the entropy weight-TOPSIS method to measure the level of digital economy development and manufacturing industry transformation, and uses the coupling coordination degree model to measure the level of industrial integration of the two. The final results show that: (1) The development level of the digital economy in Hebei Province fluctuates greatly, and there is still a certain gap with Beijing and Tianjin, but the future development potential of the digital economy is huge. (2) The transformation level of manufacturing industry in Hebei Province shows a trend of fluctuation and rise on the whole, and the development trend is good, and the gap between Hebei Province and developed regions is gradually narrowing. (3) The integration of the digital economy and manufacturing industry in Hebei Province has a good development trend, but there is still a certain gap with Beijing and Tianjin, and there are problems of inadequate, unstable, and unbalanced industrial integration. Finally, based on the research conclusions, suggestions are put forward to promote the coordinated development of the Beijing-Tianjin-Hebei region, improve the level of digital economy and manufacturing integration of industrial convergence development, raise the level of digital infrastructure construction, and raise the level of science and technology innovation. This paper reveals the mechanism of the digital economy affecting the high-quality development of the manufacturing industry, studies the whole process of digitalization, information technology, and intelligence integration into the development of the manufacturing industry, and fully releases the positive effect of the digital economy driving the high-quality development of the manufacturing industry, which has important theoretical and practical significance for promoting the high-quality development of the manufacturing industry and formulating relevant industrial policies.

Keywords: manufacturing industry; digital economy; Hebei Province; entropy-topsis method; coupling coordination degree model

1. Introduction

In the Overall Planning and Layout for the Construction of Digital China issued by the Central Committee of the Communist Party of China and the State Council in 2023, it is emphasized that the construction of digital China is an important engine for promoting Chinese style modernization in the digital era, and it is necessary to make the digital economy bigger and stronger, cultivate and expand the core industries of the digital economy, and promote the integrated development of digital technology and the real economy [1]. At present, with the wide application of digital technologies such as the Internet, big data, artificial intelligence, and cloud computing, many domestic enterprises have begun to use big data analysis and artificial intelligence technology to carry out strategic formulation and decision-making [2]. Economic models characterized by digital technology have emerged and continue to develop. The development of digital technology and the digital economy has promoted the rapid flow of various resource elements in the market [3]. It will help all types of market entities update their organizational structure, change traditional production methods, and promote the country to build a modern and digital economic system [4]. The digital economy has become one of the important engines driving China's economic growth. The China Digital Economy Development Report (2022), released by the China Academy of Information and Communications Technology, pointed out that in eight years, China's digital economy development index increased by 4.61 times, and the compound annual growth rate reached 24.06%, significantly higher than the GDP index growth rate in the same period [5]. In the future, China's digital economy will be further developed.

At present, China is in a critical period of economic restructuring, upgrading, and transformation of traditional production modes. The integration of the digital economy and the real economy has become the backbone of promoting the construction of a modern economic system and strengthening China's international competitiveness [6]. China should make full use of the advantages of the digital economy and digital technology to update and transform traditional modes of production and build a modern economic system [7]. As a pillar industry of China's economic development, the manufacturing industry plays an important role in improving China's scientific and technological innovation ability and promoting the high-quality development of China's economy. However, at present, China's manufacturing industry is still in the low-end position of the global manufacturing value chain and plays a processing role in the global manufacturing value chain, so the transformation and upgrading of China's manufacturing industry are imminent [8]. In the era of the digital economy, the use of emerging digital technologies represented by the Internet, big data, artificial intelligence, cloud computing, etc., and the integrated development of the manufacturing industry have become the main driving force to promote the high-quality development of the manufacturing industry [9]. In recent years, China has introduced a series of policies to promote the digital development of the manufacturing industry, such as the "Made in China 2025" issued by the State Council, which pointed

out that it is necessary to improve the innovation capacity of the manufacturing industry, promote the deep integration of information technology and industrialization, and take intelligent manufacturing as the main direction of the integration of the two [10]. The Implementation Opinions on Promoting the Quality Improvement of Manufacturing Products and Services issued by the Ministry of Industry and Information Technology emphasize the need to strengthen the supporting role of digitalization, networking, intelligence, and other technologies in the manufacturing industry [11]. Under the guidance of these policies, the digital economy will enable the high-quality development of China's manufacturing industry, and the digital transformation of China's manufacturing industry will be further deepened, promote the digitalization [12], productization and service of manufacturing activities, accelerate the formation of new formats of China's manufacturing industry, and continuously emerge new models of intelligent, digital, and network coordination of manufacturing industry, promoting the high-quality development of China's economy [13].

Hebei Province has seized the opportunity of the development of the digital economy, vigorously implemented the "two-wheel drive" strategy of digital industrialization and industrial digitalization, and promoted the transformation and upgrading of Hebei's industrial structure. In 2022, the scale of Hebei's digital economy will reach 1.51 trillion yuan, accounting for 35.6% of Hebei's GDP [14]. However, at present, the digital application in Hebei Province is mainly concentrated in the service sector, while the digital transformation in the manufacturing sector is relatively small [15]. Moreover, there is still a large gap between the integration level of digital economy and manufacturing industry in Hebei Province compared with Beijing, Shandong and the developed areas along the eastern coast, and the competitive advantage of manufacturing enterprises in Hebei Province will continue to be weakened [16], if manufacturing enterprises in Hebei Province want to reshape their competitive advantages in the future development, they must be combined with digital technology to promote the integrated development of digital economy and manufacturing industry, and promote the digital transformation and upgrading of manufacturing enterprises to promote the high-quality development of manufacturing industry [17].

For Hebei Province, the digital transformation of the manufacturing industry has greater potential and space for economic growth. In order to give full play to the leading and supporting role of the digital economy in the high-quality economic development of Hebei Province, the most basic and primary problem is to estimate the current situation and development level of the integration of the digital economy and manufacturing industry in Hebei Province in order to better find the convergence point of the digital economy and manufacturing industry in Hebei Province through research on the integration and development of the digital economy and manufacturing industry. It is also easier to find the difficulties and pain points in the digital transformation of manufacturing enterprises and improve the integration efficiency of the digital economy and manufacturing industry in Hebei Province, which is particularly important for promoting the integration of the digital economy and real economy in Hebei Province, realizing the structural reform of the manufacturing industry, and promoting the high-quality development of China's economy. Therefore,

it is of great practical significance to study the current situation of the integrated development of digital economy and manufacturing industry in Hebei Province, reveal the dynamic mechanism of digital economy affecting the high-quality development of manufacturing industry, measure the level of integration of the two, and then integrate digitalization, information technology, and intelligence into the whole process of manufacturing industry development so as to promote the high-quality development of manufacturing industry in Hebei Province and formulate relevant policies by the government.

This paper will discuss the current situation and level of measurement of the integration of the digital economy and manufacturing industry and further study the current situation and mechanism of the integration of the digital economy and manufacturing industry in Beijing, Tianjin, and Hebei. The specific research objectives include the following: (1) enrich the theoretical research content of the digital economy and expand the research perspective on the industrial integration of the digital economy. (2) Provide diversified paths for the integrated development of the digital economy and manufacturing industry in Hebei Province and provide references for the statistical classification work of national government departments. (3) Based on the research theory and empirical research results, summarize and analyze the integration mechanisms of the digital economy and manufacturing industry, and provide policy suggestions for the integrated development of China's digital economy and manufacturing industry.

This paper summarizes the important references to the digital economy, the manufacturing industry, and the integrated development of the two industries. For the digital economy, the research content mainly focuses on the connotation, current situation, and related influencing factors [18]. Currently, the connotation of the digital economy is still continuously enriched, but the exact connotation has not been reached [19]. The relevant influencing factors of the digital economy mainly include digital infrastructure, digital technology development, digital industrialization, and industrial digitalization [20]. For the manufacturing industry, China's manufacturing industry is currently moving towards high-quality development and digital transformation. Therefore, the literature on these two aspects is reviewed and summarized. The key to high-quality development and digital transformation in the manufacturing industry lies in technological innovation, policy support, and market demand [21]. For the integrated development of the digital economy and manufacturing industry, a large number of scholars have analyzed the industrial integration of the two based on qualitative or quantitative analysis methods. A large number of research results show that the current trend of the integration of the digital economy and manufacturing industry is deepening, but there are still regional differences in industrial integration, and the internal problems of industrial integration between the two are insufficient and unbalanced [22].

Based on the annual data of the Beijing-Tianjin-Hebei region from 2017 to 2021, this paper uses the entropy weight topsis method to estimate the development level of the digital economy and the high-quality development level of the manufacturing industry, and then uses the coupling coordination degree model to measure the integration level. The main contents of this paper are as follows: First, this paper reviews and summarizes the relevant literature on the development of the digital

economy, the manufacturing industry, and their integration. Second, analyze the dynamic mechanisms of industrial integration. Thirdly, on the basis of dynamic mechanism analysis, the index evaluation system of the integration development of the digital economy and manufacturing industry is established, and on the basis of this system, the entropy weight topsis method and coupling coordination degree model are used to measure the industrial integration level of the two industries. Fourth, analyze the measurement results. Fifth, on the basis of the analysis, the present situation and level of integration of the digital economy and manufacturing industry in Hebei Province are studied. Sixth, summarize the conclusions and enlightenment to promote the better integrated development of the digital economy and manufacturing industry in Hebei Province.

The rest of this paper is as follows: Section 2 describes the relevant literature. Section 3 describes the dynamic mechanism and measurement method of industrial convergence. Section 4 is empirical research. Section 5 elaborates on the conclusion and enlightenment.

2. Literature review

2.1. Research on digital economy

With the rapid development of digital technology, the digital economy has come into being, and the related research on the digital economy has attracted the wide attention of many scholars. At present, scholars at home and abroad mainly carry out in-depth research on digital economy-related content from the following three aspects.

First, related research on the definition of the connotation of the the connotation of the digital economy. Li [23] analyzed the similarities and differences between the digital economy and other similar concepts by sorting out the origin and dissemination process of the concept of the digital economy, research results, and existing problems, and believed that the digital economy was essentially a new economic form of production in the form of digital technology. Bukht and Heeks seek a narrower definition for the digital economy by combing through the concept of intensive and widespread use of ICTs as the part of economic output derived entirely or mainly from digital technologies, whose business model is based on digital goods or services [24]. Chen et al. [25] sorted out the research process of "digital economy" and gave a relatively broad definition of the term "digital economy", holding that digital economy is a special new form of economic activity, its key resource is digital information, including data elements, the main information carrier is the Internet platform, and the new driving force is digital technology innovation. The digital economy includes three main features: data support, integration and innovation, and open sharing.

The second is research on the development status and level of the digital economy. Volkova et al. pointed out that the current trend of the digital economy is dominated by a few countries and relatively few companies. Although digitalization has potential benefits for the economic development of developing countries, it is very difficult to ensure their sustainable development under the current digital technology and policy model. Developing countries need to think outside the box and learn from the experience of developed countries. Produce more digital technology [26]. Batrancea et al., taking healthcare enterprises as the research object, adopted the two-

stage least squares method (2SLS) and the generalized moment (GMM) model to verify that the liquidity and solvency of corporate funds have a significant impact on corporate performance [27]. Wang et al. conducted a study on 285 prefecture-level cities in China and found that the development level of China's digital economy is rising steadily from the perspective of time and space, with the overall distribution pattern being higher in the east and lower in the west, and the distribution pattern being greater in the coastal areas than in the inland areas. They proposed the need to rationally coordinate the allocation of regional digital factors and narrow the differences in the level of the digital economy among regions [28]. Batrancea et al. [29] conducted data analysis on the determinants of economic growth in seven non-BCBS countries and found that national economic growth was mainly driven by bank capital and asset ratios.

The third is research on the relevant influencing factors of the digital economy. Zhang and Chen [30] pointed out that information technology progress and digital infrastructure construction are the main driving forces for the development of China's digital economy. Li and Liu [31] pointed out that factor input, technological progress, and institutional change are three important factors affecting the development of the digital economy. Batrancea and Tulai [32] study the energy sector, exploring the phenomenon of energy production and its main determinants in 37 European economies over the period 2011–2021, showing that energy production is largely dependent on energy productivity, primary energy consumption, and energy imports. Batrancea [33] takes panel data from SMES as the analysis object to study the determinants of economic growth in the EU and verifies that online import and export and import and export outside the EU have a significant impact on economic growth. Lv and Fan [34] studied the differences in the development level of the digital economy in different regions of China and pointed out that different driving factors at different times and regions have different influence levels on the development of the digital economy. Batrancea et al. [35] took 50 countries as research objects to discuss the sustainability of economic growth and proposed that more investment and green policies are needed to achieve the sustainability of national economic growth.

2.2. Research on manufacturing development

At present, scholars have carried out in-depth research mainly on two aspects: the high-quality development of the manufacturing industry and the digital transformation of the manufacturing industry.

On the one hand, in view of the high-quality development of the manufacturing industry, Li defined the connotation of high-quality development of the manufacturing industry as essentially a development paradigm that takes into account environmental benefits, social benefits, and economic benefits by meeting various needs and using various technical means [36]. Tian et al. explored new paths and methods to improve the high-quality development of China's manufacturing industry by studying the internal and external factors that affect China's business model innovation [37]. Wang and Shi analyzed the factors affecting the high-quality development of the manufacturing industry from both internal and external perspectives and pointed out that industry technology level, internal factor supply quality, opening to the outside

world, technological innovation, human capital, and producer services are important factors affecting the high-quality development of the manufacturing industry [38]. Wang and Liu [39] conducted a study on the factors affecting the high-quality development of the manufacturing industry based on the input-output method, and the results showed that the government, improving the investment environment, intellectual property protection, and other factors had a significant impact on the high-quality development of the manufacturing industry. Khin and Kee [40], based on a number of case studies on the manufacturing industry in Malaysia, pointed out the factors affecting the high-quality development of the manufacturing industry from three aspects: promotion, hindrance, and driving, among which the main driving factors are expected returns and market opportunities, the hindrance factors are lack of capital and knowledge, and the promotion factors are resources, skills, and support.

On the other hand, for the digital transformation of the manufacturing industry, Liere-Netheler et al. [41] identified 12 driving factors for the digital transformation of the manufacturing industry, including work environment improvement, vertical integration, and horizontal integration, through qualitative research methods. Liu uses a text mining algorithm to propose that digital investment, digital technology application, and business model transformation are the triple influencing mechanisms affecting manufacturing productivity, which has a significant impact on improving manufacturing productivity [42]. Wang and Wu point out that digital technology gives new connotation to traditional manufacturing industry through reshaping innovation, profit, production mode, service, and other modes of manufacturing industry and provides an important reference for the digital transformation and upgrading of China's manufacturing industry [43]. Liu and Yu analyzed the trend, current situation, and future development policies of China's digital transformation and proposed suggestions for manufacturing enterprises to improve their own digital transformation capabilities and give full play to the role of the market and government [44].

2.3. Research on the integration and development of the digital economy and manufacturing industry

At present, most domestic and foreign scholars have conducted in-depth research on the status quo, level, and existing problems of the integration of the digital economy and manufacturing industry based on qualitative and quantitative analysis methods.

In terms of quantitative analysis methods, Lv et al. [45] thought that there was a significant positive relationship between the basic industries of the digital economy and the manufacturing industry. Wang and Chen [46] used the Super-SBM-O-C method to estimate the high-quality development level of the manufacturing industry and the entropy method to estimate the development level of the digital economy and empirically verified that the digital economy has a significant positive impact on the high quality of the manufacturing industry. Batrancea et al. used the first-order differential generalized moment method (GMM) method and cross-section fixed effect to carry out data analysis, proving that export, import, FDI inflow, FDI outflow, social contribution, and wages have significant effects on economic growth [47]. Batrancea et al. analyzed the financing from 2005 to 2020 by combining the first difference generalized method of moment estimator and multiple time series analysis,

and the results showed that smes were mainly driven by interest rates, angel investment, bank support, and public support [48]. Zhou [49] uses the entropy weight method and the coupling coordination degree model to study the path of the digital economy, enabling high-quality development in the manufacturing industry. The results show that the digital economy can not only directly enable the high-quality development of the manufacturing industry but also indirectly promote the development of the manufacturing industry through the intermediary effect of industrial integration.

In terms of qualitative analysis methods, Li and Han conducted in-depth research on the connotation and characteristics of high-quality development in the manufacturing industry and the digital economy and put forward targeted suggestions for high-quality development in the manufacturing industry, such as scientific innovation, promoting industrial integration, and improving infrastructure [50]. Xue and Zhu analyzed the effect of manufacturing integration under the background of the digital economy from four aspects: cost constraint, organization optimization, market monopoly, and data fusion value-added, and the results showed that the integration of the digital economy and manufacturing industry is the general trend under the background of the digital economy [51]. Yin studied the blocking points, paths, and strategies of green innovation development in the manufacturing industry under the digital economy and put forward effective suggestions for the high-quality development of the manufacturing industry [52]. Some scholars combined qualitative and quantitative analysis methods to carry out research. Yin et al. [53] used the semantic integration method and comparative analysis method to define and classify the concept of digital economy, then used a complex network model to study the integration of manufacturing industry and digital economy and put forward targeted suggestions for promoting the integration of digital economy and manufacturing industry from the perspectives of enterprises themselves, the economy, and policies.

To sum up, a large number of scholars have conducted in-depth research on the development of the digital economy and the manufacturing industry. The relevant connotations, influencing factors, and research methods proposed by scholars have provided great references for this paper to study the integrated development of the digital economy and manufacturing industry. However, there are still three deficiencies in the existing research: First, there is a wide range of research objects. Scholars mostly conduct research on the digital economy and manufacturing based on national and other macroeconomic backgrounds and lack concentrated and targeted research on a certain province or region. Second, current research mainly focuses on the analysis of the integration degree of the digital economy and the real economy, with a lack of research on the status quo and level of manufacturing industry integration. There are relatively few achievements in in-depth analysis of the driving mechanism and measurement level of the digital economy to promote the high-quality development of the manufacturing industry. Third, the measurement of the integrated development of the digital economy and manufacturing industry mainly adopts a single index, which lacks pertinence and effectiveness. Therefore, this paper aims to determine a specific research object, take Hebei as the research object, and measure the development status of the digital economy and manufacturing industry and the integration level of the two by constructing an evaluation index system for the

development of the digital economy and the transformation of the manufacturing industry, and then put forward targeted suggestions to provide reference for the high-quality development of manufacturing enterprises in Hebei and the formulation of government policies.

3. Dynamic mechanism and measurement method of industrial integration

With the continuous development of the digital economy based on digital technology, the digital economy has begun to show a trend of integration with the real economy [54]. The integration of the digital economy with other industries has not only promoted the digital transformation of various industries but also helped various industries achieve industrial digitalization, and industrial integration has become an important engine to promote the development of the digital economy [55]. For China, the manufacturing industry is a pillar industry of the Chinese economy, so it should focus on promoting the integration of the digital economy and the manufacturing industry [56]. The degree of integration between the digital economy and the manufacturing industry mainly depends on the effect of the dynamic mechanism of the two, which is generally the result of the joint action of the external and internal dynamics of industrial integration [57].

3.1. Analysis of the dynamic mechanisms of industrial integration

3.1.1. Analysis of the integration of the digital economy and the manufacturing industry

Referring to the existing research on industrial integration, most scholars analyze the process of industrial integration, which roughly includes various forms of integration such as product integration, market integration, and factor integration. In the field of manufacturing, manufacturing enterprises have made use of emerging digital technologies such as the Internet, big data, and artificial intelligence to effectively promote the high-quality development of digitization, information technology, and service in the manufacturing industry. Combined with a large amount of literature and the actual situation, the integration of the digital economy and manufacturing industry mainly includes three aspects, namely technology integration, business integration, and product integration. The integration of the digital economy and manufacturing industry technology is mainly reflected in the application of relevant digital technologies to the production of different products and services by manufacturing enterprises. Technology integration mainly improves the technological innovation ability of manufacturing enterprises so as to enhance their productivity and finally reverse the competitive disadvantage of the manufacturing industry. Business integration is based on digital technology, the application of Internet technology, information technology, and other digital technologies to manufacturing enterprise product research and development, production design, operation management, and other processes. In addition to providing traditional manufacturing businesses, it is also important to provide new businesses formed by relying on relevant digital technologies so as to improve the business capabilities of manufacturing enterprises, extend the manufacturing industry chain, and update the manufacturing business

model. Product integration is mainly reflected in the new products produced by the integration of digital technology and traditional products in the manufacturing industry. Product integration promotes the transformation and upgrading of the product structure of the manufacturing industry, so that China's manufacturing industry can break through the bottleneck of low-end development and shift to the direction of service manufacturing and digital manufacturing.

3.1.2. Analysis of internal motivation mechanisms

The integrated development of the digital economy and manufacturing industry is the result of many factors. This paper analyzes the internal driving force from the perspective of supply and demand.

From the demand side, diversified user product demand and consumption upgrading requirements have driven the integrated development of the digital economy and the manufacturing industry. At present, China is in a critical period of consumption transformation and upgrading. Consumers are moving from the initial pursuit of low product prices to the pursuit of product quality. In this process, the traditional manufacturing industry has also put forward such things as rich product types, a shorter delivery period, accelerated speed of product replacement, and other requirements, so manufacturing enterprises must transform and upgrade their own products, technology, business, and other content. Inject the vitality of new production factors, integrate with the digital economy, and meet the needs of the consumer market.

From the supply side, the internal development requirements of manufacturing enterprises to improve production efficiency, save costs, and improve the level of innovation have driven the integrated development of the digital economy and the manufacturing industry. Digital technology innovation is the main driving force for the high-quality development of the manufacturing industry, and digital technology innovation is conducive to the integration and upgrading of traditional production factors in the manufacturing industry and improves the innovation ability and production capacity of manufacturing enterprises. Human capital provides a talent guarantee for the high-quality development of the manufacturing industry. High-level digital technical talents can effectively improve the production efficiency of enterprises and accelerate the level of digital development of enterprises. High-quality management talents can be sensitive to the problems existing in the development of enterprises, carry out effective management, and innovate the business development mode of manufacturing enterprises. Market capital is also one of the main driving forces behind promoting industrial integration. In the market competition, in order to ensure that they are in a favorable position and obtain advanced technology and data information, manufacturing enterprises often integrate with the digital economy through mergers and acquisitions, investment, and other forms, thereby reducing their financing costs and extending the manufacturing industry chain.

3.1.3. Analysis of extrinsic dynamic mechanisms

The economic environment and policy system are the two main factors that promote the integration of the digital economy and manufacturing industry. In terms of the economic environment, at present, China is in a critical period to promote high-quality economic development, and in the face of the current adverse environmental

situation, manufacturing enterprises, as a pillar industry of national economic development, need to assume the responsibility and obligation to promote high-quality economic development and protect environmental health. Based on the above background, manufacturing enterprises must actively transform and upgrade industrial structures. Integration with the digital economy industry involves the use of digital technology to promote the high-quality development of manufacturing. In terms of policies and systems, various departments in China have introduced many policies to encourage the high-quality development of manufacturing and digital transformation and upgrading. These policies can strengthen the guiding role of manufacturing enterprises and guide manufacturing enterprises to carry out digital technology innovation, so as to improve the competitiveness of manufacturing enterprises and break through the low-end position of Chinese manufacturing enterprises in the global value chain.

Based on the above analysis, this paper constructs the dynamic mechanism framework for the integration of the digital economy and manufacturing industry. It can be shown in **Figure 1**.

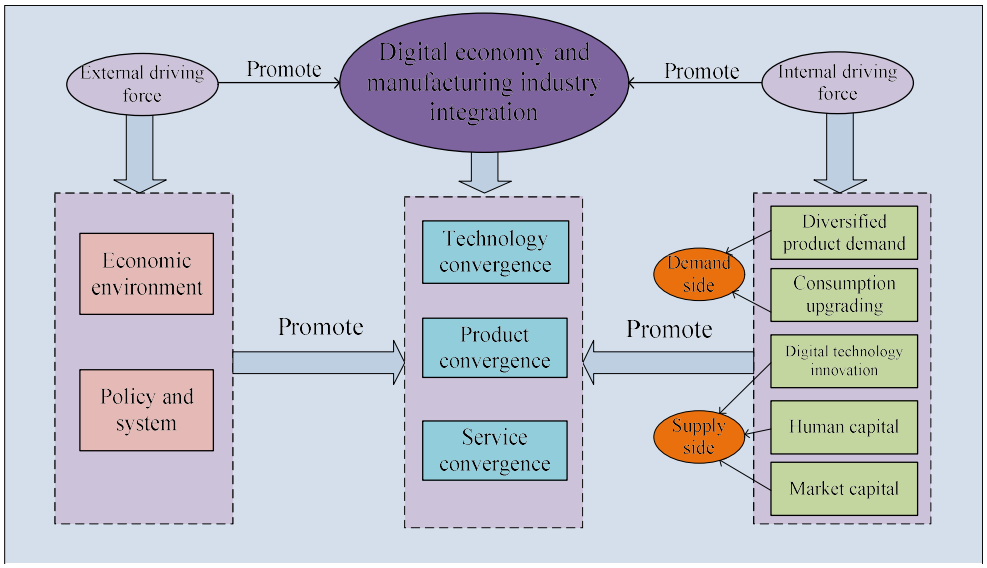

Figure 1. Dynamic mechanism framework of the integration of digital economy and manufacturing industry.

3.2. Analysis of industrial integration measurement methods

Through consulting relevant literature, the current domestic and foreign methods for measuring the development level of the digital economy and the transformation level of the manufacturing industry mainly include the input-output method, the value-added rate method, the establishment of an evaluation index system, and other methods. However, due to limited data acquisition and unstable data sources, it is difficult to use the input-output method and the value-added rate method to calculate the transformation level of the digital economy and manufacturing industry in Hebei Province. The establishment of a relevant evaluation index system has strong operability, more flexible index selection, and better data continuity. Therefore, this paper hopes to comprehensively evaluate the transformation level of the digital

economy and manufacturing industry in Hebei Province by constructing an evaluation index system for the digital economy and manufacturing industry. On this basis, based on the comprehensive scores of the two, the coupling coordination degree model is used to analyze the integrated development level of the digital economy and manufacturing industry, and specific suggestions are put forward for the integrated development of the digital economy and manufacturing industry in Hebei Province.

3.2.1. Digital economy and manufacturing index evaluation system construction

Most scholars have built a digital economy evaluation index system from the perspectives of digital infrastructure, digital technology applications, digital finance, and other aspects. Based on the reference to authoritative literature, this paper combines the connotational characteristics of digital economy with the development characteristics of digital economy in Hebei Province. The digital economy evaluation index system of Hebei Province was constructed from three aspects: digital infrastructure, digital technology innovation, and digital industrial foundation (**Table 1**).

Table 1. Digital economy index evaluation system of Hebei Province.

Primary index	Secondary index	Unit
Digital infrastructure(M1)	Internet penetration (X1)	%
	Mobile phone penetration (X2)	Department/Hundred People
	Number of Internet pages built (X3)	Ten thousand
Digital technology innovation(M2)	Number of patent applications (X4)	Piece
	Internal R & D expenditure for high-tech related industries (X5)	Ten thousand yuan
	Expenditures for new product development in high-tech related industries (X6)	Ten thousand yuan
	Technology market transaction volume (X7)	Billion
Digital industry foundation(M3)	E-commerce sales revenue (X8)	Billion
	Total postal and telecommunications services (X9)	Billion
	Software business revenue (X10)	Billion
	Employment in the digital industry (X11)	People

In addition, the measurement of the transformation level of the manufacturing industry in Hebei Province. Some scholars construct the evaluation index system from the perspective of input-output, while others mainly reflect the transformation level of the manufacturing industry by calculating the total output value and total proportion of the manufacturing industry from an overall perspective. With reference to the above research and comprehensive consideration of the actual development of the manufacturing industry in Hebei Province, this paper constructs the evaluation index system of the manufacturing industry in Hebei Province from the perspective of input-output (**Table 2**).

Table 2. Index evaluation system of Hebei manufacturing industry transformation level.

Primary index	Secondary index	Unit
Input index (N1)	Investment in technological transformation (Y1)	Billion
	Human capital input (Y2)	Ten thousand people
	Investment in fixed assets increased over the previous year (Y3)	%
Output index (N2)	Gross output value of manufacturing industry (Y4)	Billion
	Profit margin of manufacturing operating income (Y5)	%
	Gross manufacturing profits (Y6)	Billion
	Total energy production (Y7)	Tons of standard coal

3.2.2. Measurement methods and models

Entropy weight-topsis method:

Before calculating the level of digital economy development and manufacturing transformation, it is necessary to determine the weight of each index in the evaluation index system. There are two main methods to determine the weight of indicators, one is subjective weighting, such as the analytic hierarchy process, the Delphi method, and so on. The other is the objective weighting method, such as principal component analysis, entropy weight method, factor analysis, and so on. In order to enhance the objectivity of evaluation, this paper adopts the entropy weight method of objective weighting method to determine the weights of each index and adopts TOPSIS method to evaluate the comprehensive index of digital economy development and manufacturing transformation level of Hebei Province.

(1) Entropy weight method. Entropy weight method is a method that uses information entropy to determine the weight, effectively avoiding the interference of subjective factors, and its calculation steps are as follows:

1) Construct the initial data matrix of the evaluation system *X*:

$$X = \{x_{ij}\}_{m\times n} \tag{1}$$

In the formula, x_{ij} represents the value of the *j* evaluation index of the *i* sample.

2) Data standardization processing:

$$x'_{ij} = \begin{cases} \dfrac{x_{ij} - min\, x_{ij}}{max\, x_{ij} - min\, x_{ij}}, j\text{is a positive indicator} \\ \dfrac{max\, x_{ij} - x_{ij}}{max\, x_{ij} - min\, x_{ij}}, j\text{is a negative indicator} \end{cases} \tag{2}$$

In the formula, x'_{ij} is the standardized value, $min\ x_{ij}$ and $max\ x_{ij}$ are the minimum and maximum value of each index respectively, where $0 < i \le n, 0 < j \le m$.

3) Data standardization matrix:

$$y_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} (0 \le y_{ij} \le 1) \tag{3}$$

The data standardization matrix is obtained: $Y = \{y_{ij}\}_{m\times n}$.

4) Calculate the information entropy of item *j*:

$$e_j = -K \sum_{i=1}^{m} y_{ij}\, ln\, y_{ij} \tag{4}$$

where K is a constant, $K = \frac{1}{\ln m}, 0 \leq e \leq 1$.

5) Calculate the information utility value of each indicator:

$$d_j = 1 - e_j \tag{5}$$

6) Calculate the weight of each indicator w_j:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{6}$$

7) Calculate the overall score T_i:

$$T_i = \sum_{i=1}^{n} y_{ij} w_j \tag{7}$$

(2) TOPSIS method. The core of TOPSIS method is to determine the positive ideal solution and negative ideal solution of each index. By calculating the Euclidean distance between each evaluation subject and the positive ideal solution and the negative ideal solution, then calculating the relative proximity between each scheme and the ideal solution, ranking the pros and cons, and finally obtaining the comprehensive score.

1) Build a weighting matrix:

$$R = (r_{ij})_{m \times n}, \quad \mathrm{r_{ij}} = \mathrm{w_j} \times \mathrm{x_{ij}^{'}} \tag{8}$$

2) The positive and negative ideal solutions are determined according to the weighting matrix:

$$S_j^+ = max(r_{ij}); S_j^- = min(r_{ij}) \tag{9}$$

3) Calculate Euclidean distance:

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (S_j^+ - r_{ij})^2}; d_i^- = \sqrt{\sum_{j=1}^{m} (S_j^- - r_{ij})^2} \tag{10}$$

4) Calculate the relative proximity to the positive ideal solution:

$$C_i = \frac{d_i^-}{(d_i^+ + d_i^-)} \tag{11}$$

Coupling coordination degree model:

This paper adopts the coupling coordination degree model to measure the integration level of digital economy and manufacturing industry in Hebei Province, and accurately measure the integration development degree of the two. The calculation formula is as follows:

$$U = \sqrt{C \times \ （\alpha T_1 + \beta T_2} \tag{12}$$

$$C = \frac{(T_1 + T_2)}{(\frac{T_1 + T_2}{2})^2} \tag{13}$$

where: U is the integration level of digital economy and manufacturing industry in Hebei Province; T_1 is the comprehensive score of Hebei Province's digital economy development level; T_2 is the comprehensive score of Hebei Province's manufacturing industry transformation development; α, β is the undetermined parameter, indicating the importance of digital economy and manufacturing industry, where $\alpha + \beta = 1$, and $0 \leq \alpha$、$\beta \leq 1$, based on the actual situation of Hebei Province, $\alpha = \beta = 0.5$.

3.2.3. Data source

Considering the continuity of data acquisition, this paper selects the data of Beijing, Tianjin, and Hebei Province from 2017 to 2021 as the research unit. The data involved are mainly from the Statistical Report on the Development of China's Internet, the Statistical Yearbook of China's High-Tech Industry, the Statistical Yearbook of China's Electronic Information Industry, the Statistical Yearbook of China's Energy, the Statistical Yearbook of China, and the statistical yearbook of the three regions and provinces.

4. Empirical analysis

4.1. Digital economy development level measurement results

The entropy weight-TOPSIS method is used to calculate the weights of the digital economy development indicators of the three provinces and cities in Beijing, Tianjin, and Hebei, and the comprehensive scores and rankings of the digital economy development level of the three provinces and cities are given. The specific results are shown in **Table 3** and **Figure 2**.

Table 3. Weight of each evaluation index of the development level of digital economy in Beijing, Tianjin and Hebei.

	Hebei	Beijing	Tianjin
X1	0.2255	0.0695	0.0697
X2	0.0510	0.0940	0.0583
X3	0.0490	0.0883	0.0972
X4	0.0967	0.1266	0.1237
X5	0.0836	0.1064	0.1141
X6	0.1175	0.0530	0.0663
X7	0.0656	0.0786	0.0728
X8	0.1016	0.0989	0.1345
X9	0.0685	0.1125	0.1254
X10	0.0754	0.0752	0.0810
X11	0.0654	0.0970	0.0571

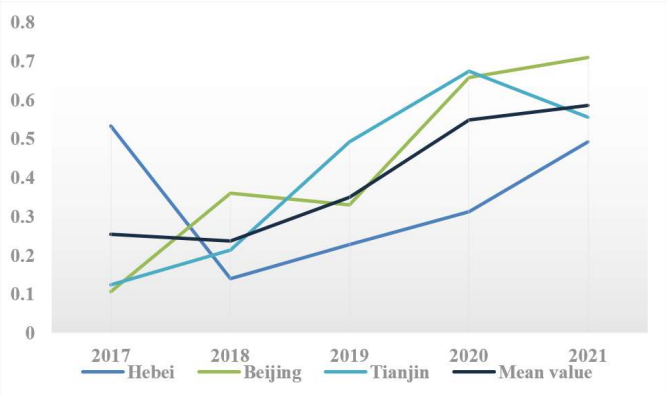

Figure 2. Comprehensive score of digital economy development level of Beijing, Tianjin, Hebei region from 2017 to 2021 based on entropy weight-TOPSIS method.

It can be seen from **Table 3** that there are obvious differences in the weights of 11 secondary indicators related to the digital economy in the three provinces and cities of Beijing, Tianjin, and Hebei. For Hebei Province, the top three indicators with greater weight are Internet penetration rate (0.2255), high-tech related industry new product development expenditure (0.1175), and the number of digital technology patent applications (0.0967), while the lowest weight is the number of Internet page construction (0.0490). In Beijing, the top three indicators with greater weight are the number of digital technology patent applications (0.1266), the total amount of postal and telecommunication services (0.1125), and the internal expenditure of high-tech related industry R & D funds (0.1064), and the least weight is the high-tech related industry new product development expenditure (0.0530). In Tianjin, the top three indicators with greater weight are e-commerce sales (0.1345), total postal and telecommunications business (0.1254), and the number of digital technology patent applications (0.1237), while the lowest weight is digital industry employment number (0.0571). It can be seen from comprehensive analysis that digital technology innovation has a significant impact on the development of the digital economy. Digital technology patent applications, new product development expenditure of high-tech related industries, and internal expenditure of R & D expenditure of high-tech related industries also play a large role in the development of the digital economy in various provinces and cities. The penetration rate of mobile phones, the number of web pages built, and the number of people employed in digital industries have less impact on the development of the digital economy than other indicators.

It can be seen from **Figure 2** the development of the digital economy in Beijing, Tianjin, and Hebei in the past five years. By 2021, the comprehensive scores of the three provinces and cities in terms of digital economy development level are Beijing, Tianjin, and Hebei respectively in order of magnitude. The highest score for Beijing is 0.7096, while the lowest score for Hebei is 0.4913. On the whole, the development level of the digital economy in Beijing and Tianjin showed a trend of fluctuation and rise from 2017 to 2021, while in Hebei Province, although the comprehensive score of the digital economy development level was high in 2017, it declined rapidly in 2018, although the level continued to rise after that. However, we can still find that the development level of the digital economy in Hebei Province has the problems of large fluctuations, unbalanced and unstable development, and there is still a certain gap between the development level of the digital economy in Beijing and Tianjin.

4.2. Manufacturing transformation level measurement results

By constructing the evaluation index system of the transformation level of the manufacturing industry, the comprehensive score and ranking of the transformation level of the manufacturing industry in the three provinces and cities of Beijing, Tianjin, and Hebei were measured by the entropy weight-TOPSIS method, and the specific results were shown in **Table 4** and **Figure 2**.

Table 4. Weights of each evaluation index of manufacturing transformation level in Beijing, Tianjin and Hebei Provinces.

	Hebei	Beijing	Tianjin
Y1	0.1048	0.0773	0.1351
Y2	0.1264	0.1556	0.0957
Y3	0.0778	0.1178	0.0809
Y4	0.1375	0.1201	0.2652
Y5	0.2261	0.0777	0.1214
Y6	0.2664	0.3717	0.1772
Y7	0.0610	0.0798	0.1244

As can be seen from **Table 4**, the largest weight index affecting the transformation level of Hebei's manufacturing industry is the total profit of the manufacturing industry, and the smallest weight index is the total energy production. The largest weight index affecting the transformation level of Beijing's manufacturing industry is the total profit of the manufacturing industry, and the smallest weight index is the investment in technological transformation and the total energy production. The largest weight index affecting the transformation level of Tianjin's manufacturing industry is the total output value of the manufacturing industry, and the smallest weight index is the proportion of fixed asset investment growth over the previous year. This shows that the total profit of the manufacturing industry and the total output value of the manufacturing industry have a significant impact on the transformation level of the manufacturing industry in a region, while the total amount of general energy production, the proportion of fixed assets investment growth over the previous year, and the investment in technological transformation have a small impact on the transformation level of the manufacturing industry in a region.

As can be seen from **Figure 3**, the average level of manufacturing transformation in the three provinces and cities of Beijing-Tianjin-Hebei from 2017 to 2021 is ranked as Tianjin, Beijing, and Hebei Province respectively. From the average of the transformation level of the manufacturing industry, it can be seen that the transformation level of the manufacturing industry in Hebei Province is still relatively backward. However, on the whole, the transformation level of the manufacturing industry in the Beijing-Tianjin-Hebei region shows a fluctuating upward trend, especially from 2020 to 2021, the transformation level of the manufacturing industry in the three provinces and cities will rise rapidly. From the growth rate, the average annual growth rate of the transformation level of the manufacturing industry in Hebei Province will reach 8.97%, indicating that the transformation speed of the manufacturing industry in Hebei Province will continue to accelerate. It is gradually narrowing the gap between Beijing and Tianjin in the level of manufacturing transformation.

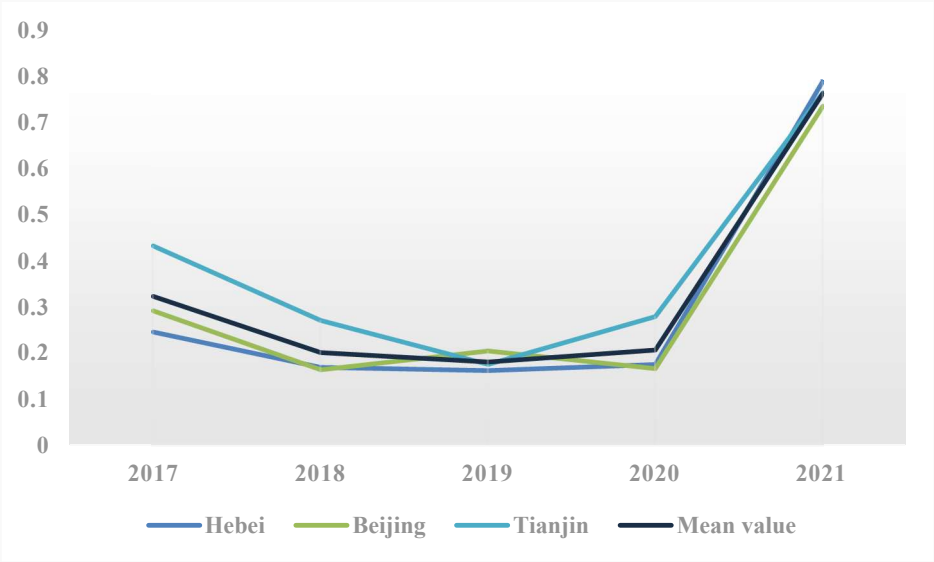

Figure 3. The comprehensive score of Beijing-Tianjin-Hebei manufacturing transformation level based on entropy weight-TOPSIS method from 2017 to 2021.

4.3. Digital economy and manufacturing integration development measurement results

According to the comprehensive scores of the development level of the digital economy and the transformation level of the manufacturing industry, the coupling coordination degree and coupling coordination degree of the integrated development of the digital economy and manufacturing industry in the three provinces of Beijing, Tianjin, and Hebei are calculated by using the coupling coordination degree model. The coupling level and coupling coordination degree classification standard of this paper is referred to by Yang [58]. The results are shown in **Tables 5** and **6**.

Table 5. 2017–2021 Coupling degree of integration and development of digital economy and manufacturing industry in Beijing, Tianjin, Hebei.

	Hebei	Coupling level	Beijing	Coupling level	Tianjin	Coupling level
2021	0.9727	Benign coupling	0.9998	Benign coupling	0.9874	Benign coupling
2020	0.9603	Benign coupling	0.8038	High level coupling	0.9106	Benign coupling
2019	0.9861	Benign coupling	0.9726	Benign coupling	0.8815	Benign coupling
2018	0.9951	Benign coupling	0.9286	Benign coupling	0.9928	Benign coupling
2017	0.9301	Benign coupling	0.8851	Benign coupling	0.8313	Benign coupling

As can be seen from **Table 5**, the coupling degree between the digital economy and manufacturing industry in the three provinces of Beijing, Tianjin, and Hebei in the past five years is greater than 0.8, basically in the benign coupling level, which indicates that there is a strong interaction between the dimensions of the digital economy and manufacturing industry in the three provinces of Beijing, Tianjin, and Hebei.

Table 6. 2017–2021 Beijing-Tianjin-Hebei digital economy and manufacturing integration development coupling degree coupling coordination degree.

	Hebei	Degree of coordination	Beijing	Degree of coordination	Tianjin	Degree of coordination
2021	0.7889	Moderate coordination	0.8497	Highly coordinated	0.8069	Highly coordinatedg
2020	0.4843	Primary coordination	0.5757	Moderate coordination	0.6587	Moderate coordination
2019	0.4388	Primary coordination	0.5101	Moderate coordination	0.5425	Moderate coordination
2018	0.3918	Primary coordination	0.4929	Primary coordination	0.4905	Primary coordination
2017	0.6015	Moderate coordination	0.4201	Primary coordination	0.4808	Primary coordination

As can be seen from **Table 6**, the coupling coordination degree between the digital economy and manufacturing industry is the highest in Beijing, with a value of 0.8497, followed by Tianjin, with a value of 0.8069, both of which are in the highly coordinated stage. The coupling coordination degree is the lowest in Hebei Province, with a value of 0.7889, in the moderate coordination stage. The low coupling coordination degree of integration and development of the digital economy and manufacturing industry in Hebei Province indicates that at present, the digital economy and manufacturing industry in Hebei Province have not formed a good driving mechanism. Although there is a strong interaction between the digital economy and the manufacturing industry in Hebei Province, the coordination level is moderate coordination, and the level of industrial integration and development of the two industries needs to be improved. From the perspective of the overall development trend, the integrated development level of the digital economy and manufacturing industry in Beijing and Tianjin has maintained a steady rise, gradually transitioning from primary coordination to advanced coordination, while the industrial integration development level of Hebei Province has experienced great fluctuations, falling from intermediate coordination to primary coordination, and then reaching intermediate coordination again. Although the growth level of the coupling coordination degree of the integration and development of the two industries in Hebei Province from 2020 to 2021 is 0.38, and the integration development level is growing rapidly, there are still problems of unstable development that need to be solved.

4.4. Discussion

4.4.1. Discussion on the development status of the digital economy in Hebei Province

According to the Hebei Provincial Department of Industry and Information Technology, by 2022, the scale of Hebei's digital economy will reach 1.51 trillion yuan, accounting for 35.6% of the province's GDP, which shows that the development level of Hebei's digital economy is constantly strengthening and gradually becoming an important driving force to promote the high-quality development of Hebei's economy.

However, comparing the above analysis results with developed regions, it can be found that there is still a certain gap between the development level of the digital economy in Hebei Province and developed regions, and the average annual growth rate is negative, and the development trend is not optimistic. By analyzing the measurement results of the development level of the digital economy and combining

them with the actual situation of Hebei Province, we find that there are many problems in the process of developing the digital economy in Hebei Province, mainly concentrated in the following three aspects. First of all, the speed of industrial digitalization and digital industrialization transformation in Hebei Province is slow, and the degree and scale of digital transformation in various industries are quite different. Generally speaking, the service industry has the highest degree of digital transformation, followed by industry and agriculture. Secondly, the digital technology innovation in Hebei Province is insufficient. According to the relevant data and empirical results, we find that the investment of capital, technology, and personnel in the digital economy in Hebei Province is small, and the investment degree is much lower than that of Beijing, Tianjin, and other developed regions. Finally, the overall development level of Hebei's digital economy lags behind that of developed regions. The proportion of Hebei's digital economy in GDP is 35.6%, lower than the national level of 41.5%. In 2021, Beijing's software business revenue and e-commerce sales are more than 10 times higher than Hebei's in the same period, indicating that Hebei's overall development level is relatively backward. There is still a big gap with developed areas.

4.4.2. Discussion on the current situation of transformation of the manufacturing industry in Hebei Province

The transformation level of Hebei Province's manufacturing industry reflects the scale and transformation degree reached in different years from 2017 to 2021. In the past five years, the transformation level of Hebei Province's manufacturing industry has shown a trend of fluctuation and rise on the whole. By 2021, the transformation level of Hebei Province's manufacturing industry has been greatly improved. The transformation level of Hebei's manufacturing industry increased from 0.2461 to 0.7884, with an average annual growth rate of 8.97%, indicating that Hebei's manufacturing industry is in a good situation of transformation and development, and is gradually narrowing the gap with developed regions. From the perspective of spatial dimension, Hebei Province is close to the two developed regions of Beijing and Tianjin. Hebei Province can make full use of its geographical advantages and the advantages of the Beijing, Tianjin, and Hebei coordinated development policy to effectively improve its own manufacturing development advantages.

However, at the same time, the transformation and development of the manufacturing industry in Hebei Province still have problems such as large fluctuations in development level and slow transformation and upgrading. Based on the empirical analysis, the main reasons are as follows. First, the industrial structure of the manufacturing industry in Hebei Province is too simple. The manufacturing industry in Hebei Province is mainly dominated by heavy industries such as steel, and the industrial structure is single, which cannot effectively promote the high-quality development of the manufacturing industry in Hebei Province. Second, Hebei's manufacturing technology innovation ability is insufficient. Compared with the innovation ability of developed areas such as Beijing and Tianjin, Hebei Province lacks professional technical personnel and sufficient financial support to promote the digital transformation and high-quality development of the manufacturing industry. Third, the manufacturing industry in Hebei Province is facing the problem of great

pressure on resources and the environment. When looking for indicator data, we found that the industrial waste emissions of the manufacturing industry in Hebei Province are the largest. Under the guidance of environmental protection policies such as "dual carbon" and low carbon policies, if the manufacturing industry in Hebei Province fails to carry out the transformation and upgrading of the manufacturing industry structure in time to promote the green development of the manufacturing industry, will face the increasing pressure of resources and environment.

4.4.3. Discussion on the development status of digital economy and manufacturing industry integration in Hebei Province

From 2017 to 2021, the integration development level of the digital economy and manufacturing industry in Hebei Province fluctuated from 0.6015 to 0.7889, indicating that both the digital economy and manufacturing industry in Hebei Province have achieved rapid development, and the two industries have carried out industrial integration in more and more fields. However, compared with developed areas such as Beijing and Tianjin, the integration level of the digital economy and manufacturing industry in Hebei Province is relatively backward, the driving mechanism of industrial integration of the two has not fully played a role, and the level of industrial integration still needs to be improved. The integration of the digital economy and manufacturing industry in Hebei Province is mainly reflected in the following three aspects.

First of all, the digital economy and manufacturing industry have obvious differences in the integration level of technology integration, product integration, and business integration. The automobile manufacturing industry and computer equipment manufacturing industry currently apply digital technology to a more mature and extensive degree, while some traditional manual manufacturing industries, limited by their own product characteristics and changes in market demand, still cannot carry out in-depth digital transformation. Secondly, the management level of related manufacturing enterprises is low. The integrated development of the manufacturing industry and digital economy requires excellent managers to carry out profound changes in the product production process, organizational structure, and business process within their companies, and carry out the digital transformation of the manufacturing industry in all aspects. However, at present, the various processes in the operation and management of manufacturing enterprises in Hebei Province have not been optimized, and the management level has not reached the stage of in-depth digital transformation. Finally, the digital foundation of manufacturing enterprises in Hebei Province is weak. According to the survey, most manufacturing enterprises in Hebei Province did not set up a special digital department, but usually dispersed to various departments to carry out relevant digital technology processing work, and did not form a professional business process, resulting in a low level of digital professionalism of manufacturing enterprises.

5. Conclusions and implications

5.1. Conclusions

This article takes the five-year data from 2017 to 2021 in the three provinces and cities of Beijing, Tianjin, and Hebei as samples. By constructing an evaluation system

for the development of the digital economy and manufacturing industry, the entropy weight-TOPSIS method is used to study the level of digital economy development and manufacturing industry transformation in Hebei Province. The coupling coordination degree is used to analyze the level of industrial integration development between the two. The specific conclusions are as follows:

First, in terms of the development level of the digital economy, the results show that from 2017 to 2021, the development level of the digital economy in Hebei Province fluctuated greatly, experiencing a process of first declining and then rising, and generally showing a trend of fluctuating and rising. In addition, the development level of the digital economy shows obvious regional differences, and there is still a certain gap between the development level of the digital economy in Beijing and Tianjin, but with the help of geographical advantages, Hebei Province has great potential for future digital economy development.

Second, in terms of the transformation level of the manufacturing industry, the results show that the transformation level of the manufacturing industry in Hebei Province shows a trend of fluctuation and rise during 2017–2021, and the transformation level of the manufacturing industry in Hebei Province also shows obvious regional differences. The average transformation level of the manufacturing industry in Beijing and Tianjin is higher than that of Hebei Province. However, in the past five years, the transformation and development level of Hebei's manufacturing industry has increased from 0.2461 to 0.7884, with an average annual growth rate of 8.97%, which also shows that Hebei's manufacturing industry is in a good situation of transformation and development, and is gradually narrowing the gap with developed regions.

Third, aiming at the integration development level of the digital economy and manufacturing industry, this paper studies and analyzes the integration level of the digital economy and manufacturing industry in Hebei Province by establishing the index evaluation system of the digital economy and manufacturing industry and using the coupling coordination degree model. The results show that there is a strong interaction between the three dimensions of the digital economy and the two dimensions of the manufacturing industry. The digital economy has been playing an increasingly important role in the development of manufacturing enterprises, but at the same time, the coupling coordination degree of digital economy and manufacturing industry integration and development in Hebei Province fluctuates greatly, and there are problems of inadequate, uncoordinated and unstable industrial integration and development.

5.2. Implications

5.2.1. Promote coordinated development of the Beijing-Tianjin-Hebei region

From the above analysis results, it can be clearly found that the development level of the digital economy, the transformation level of the manufacturing industry, and the development level of industrial integration of Hebei Province lag behind Beijing and Tianjin. Therefore, we should accelerate the coordinated development of the Beijing-Tianjin-Hebei region, make use of the geographical advantages of Xiongan New Area, gradually promote the in-depth cooperation between Beijing and Tianjin, promote the

coordinated development of digital economy elements such as digital infrastructure, digital technology innovation, and digital industrial foundation in Hebei Province, make up for the shortcomings of the integrated development of digital economy and manufacturing industry, and explore a new development model. At the same time, it has established a continuous and efficient communication mechanism with Beijing and Tianjin, advocated cross-regional and multi-department participation in the integrated development of the digital economy and manufacturing industry, promoted the integration of relevant resource elements, and improved the integrated development level of the digital economy and manufacturing industry in Hebei Province.

5.2.2. Improve the level of digital economy and manufacturing integration of industrial convergence development

At present, the integration of the digital economy and various manufacturing industries in Hebei Province is very different. From an external point of view, to promote the integration and development of various manufacturing industries and the digital economy, it is not only necessary to continue to improve the digital technology application level of high-tech manufacturing industries such as automobile manufacturing and computer equipment manufacturing but also to carry out in-depth digital transformation and upgrading of some traditional manufacturing industries. Get rid of traditional constraints and increase productivity. From the internal point of view, in order to improve the digitization degree of each operation and management process of manufacturing enterprises, managers should improve their professional ability, carry out profound digital changes in the company's internal product production process, business process, supply chain process, organizational structure, and other modules, establish professional digital technology departments, and form professional digital technology operation process. In order to improve the overall digital professional level within the manufacturing enterprise.

5.2.3. Raise the level of digital infrastructure construction

The level of digital infrastructure construction is related to the level of integrated development of the digital economy and manufacturing industry in Hebei Province, so it is very important to improve the level of digital infrastructure construction. On the one hand, digital infrastructure construction should be provided more effectively on the basis of scientific analysis and understanding of the specific needs of manufacturing enterprises in Hebei Province; on the other hand, digital infrastructure construction should be carried out according to local conditions, taking the overall pattern of various regions, the number of relevant enterprises and other relevant indicators into consideration, and digital infrastructure construction should be carried out according to the actual situation. Improve the use of digital infrastructure.

5.2.4. Raise the level of science and technology innovation

Scientific and technological innovation is the main driving force to promote the rapid development of the integration of the digital economy and manufacturing industry in Hebei Province, and it is necessary to increase scientific and technological innovation efforts to make up for the shortcomings of the two in the process of industrial integration so that the digital economy can deeply empower the

manufacturing industry, promote the digital transformation of the manufacturing industry and high-quality development. On the one hand, to improve the ability of scientific and technological innovation, the government should provide policy support for relevant enterprises, implement incentive mechanisms, and give relevant tax incentives and financial subsidies to benchmarking enterprises. On the other hand, it is necessary to strengthen the training of digital talents, encourage manufacturing enterprises to cooperate with relevant educational institutions to carry out vocational skills training on manufacturing digital technology and encourage colleges and universities to adjust and optimize the curriculum of relevant professional disciplines, and increase efforts to cultivate composite talents who understand both manufacturing knowledge and digital technology knowledge.

5.3. Deficiency and prospect

Subject to the influence of various factors, there are still many deficiencies in this paper to be further improved. On the one hand, the sample data selected in this paper is limited, which fails to carry out extensive and adequate research. In the future, more empirical studies are needed to put forward more targeted suggestions. On the other hand, there are some shortcomings in the construction of the evaluation index system of the digital economy and manufacturing industry in this paper, and the proposed rating index system needs to be fully tested and improved on the basis of in-depth research in the future.

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