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Digital economy drives the transformation and upgrading of manufacturing industry in Hebei Province

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ABSTRACT

In the context of digital economy, Hebei Province, as an important province in central China, has a huge manufacturing base and potential, and the development of digital economy has driven the transformation and upgrading of manufacturing industry to a certain extent. In order to better play the driving role of digital economy in the transformation and upgrading of manufacturing industry, this paper establishes an intermediary effect model based on three intermediary variables: enterprise resource allocation ability, enterprise cost and enterprise innovation ability, and conducts an empirical study on the panel data of 11 prefecture-level cities in Hebei Province from 2017 to 2022. The mechanism of digital economy driving manufacturing upgrading in Hebei Province was discussed. The results show that: (1) there is a significant positive correlation between the development of digital economy and the transformation and upgrading of manufacturing industry, which indicates that the development of digital economy has a direct driving effect on the transformation and upgrading of manufacturing industry; (2) There is also a positive correlation between the development of digital economy and the resource allocation ability and innovation ability of enterprises, indicating that the development of digital economy can improve the resource allocation ability and innovation ability of enterprises, and is conducive to the stable development of enterprises in the future; (3) Enterprise resource allocation ability and enterprise innovation ability play a significant intermediary role in the relationship between digital economy development and the transformation and upgrading of manufacturing industry, indicating that digital economy can indirectly accelerate the transformation of manufacturing enterprises' R & D achievements by improving enterprises' resource allocation ability and innovation ability, thus improving enterprises' market competitiveness and increasing enterprises'

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earnings. Drive the transformation and upgrading of the manufacturing industry. Based on this research conclusion, the government should give full play to the role of guidance and support, and introduce relevant policies to help the digital economy drive the transformation and upgrading of manufacturing enterprises. Manufacturing enterprises should seize the tide of the development of the digital economy, use digital technology to improve their resource allocation ability and innovation ability, enhance core competitiveness, and accelerate the transformation and upgrading of enterprises.

KEYWORDS

digital economy; transformation and upgrading; manufacturing industry; mediating effect; action mechanism

1. Introduction

Manufacturing industry is China's pillar industry, is the foundation of the country, the foundation of the strong country, but also the core of China's real economy, in the national economy plays a very important role. However, at present, China's traditional manufacturing industry still has the problems of weakening labor advantages, increasing land costs, and low production efficiency. At the same time, in the process of "re-industrialization" in Western countries, it may lead to the problem of overcapacity in China's manufacturing industry (Wang et al., 2022). In this context, it is crucial to promote the transformation and upgrading of China's manufacturing industry.

Digital economy is a new innovative economic form after agricultural economy and industrial economy, which brings new opportunities for the transformation and upgrading of the manufacturing industry, and the manufacturing industry has become the main battlefield of the digital wave (Wang et al., 2023). Since the second Tenth Party Congress was held, the digital economy has developed rapidly in recent years, and has penetrated into various industries such as agriculture, manufacturing and service industries (Yin and Zhao, 2023). Digital economy has been written into the government work report for six consecutive years, and in 2018, China proposed digital China construction for the first time. In 2019, it is proposed to strengthen the digital economy, and in 2020, it is proposed to comprehensively promote the "Internet plus" to create new advantages of the digital economy. To accelerate digital development and build a digital China in 2021; In 2022, it is proposed to accelerate the digital and intelligent transformation of traditional industries to promote the development of digital economy; In 2023, it is proposed to accelerate the digital transformation of traditional industries and small and medium-sized enterprises, vigorously develop the digital economy, and enhance the level of normal supervision (Matt et al., 2023). According to the "Digital China Development Report (2022)", the scale of China's digital economy will reach 5.02 billion yuan in 2022, and the total scale of China's digital economy has ranked second in the world for many consecutive years, and the digital economy has become an important engine for stable growth and transformation. General secretary Xi has also emphasized on many major occasions to accelerate the revitalization of the digital economy and help the digital and intelligent transformation and upgrading of China's manufacturing enterprises. Hebei Province, as the Beijing-Tianjin-Hebei coordinated development area, and as a large industrial province and manufacturing province, the digital economy has received full attention. In order to seize the opportunities of the new round of scientific and technological revolution and industrial transformation, and release the huge development potential provided by the coordinated development of Beijing-Tianjin-Hebei, the planning and construction of Xiongan New Area, and the preparation for the Beijing Winter Olympics, Hebei regards the digital economy construction project as the main breakthrough of the strong province. Hebei has achieved new breakthroughs in the development of digital industry, accelerated the pace of industrial digital development, and deepened the social digital transformation. However, there are still shortcomings such as the small scale of the core industries of the digital economy, the low level of digitalization of the manufacturing industry, and the weak ability of scientific and technological innovation (Hong et al., 2023). Based on this situation, the research on how to accelerate the integration of digital economy and traditional manufacturing industry in Hebei Province, how to drive the transformation and upgrading of the digital economy has become an urgent topic to be discussed. Therefore, by integrating the research status of digital economy and the transformation and upgrading of

manufacturing industry, this paper analyzes the core connotation of digital economy driving the transformation and upgrading of manufacturing industry, takes Hebei Province as the research object, and explores the mechanism and realization path of digital economy driving the transformation and upgrading of manufacturing industry in Hebei province based on the 2017-2022 panel data of 11 urban areas in Hebei Province.

The remaining research contents of this paper are as follows: in section 2, a literature review is conducted on digital economy driving the transformation and upgrading of manufacturing industry. Section 3 hypothesizes the mechanism of digital economy driving the transformation and upgrading of manufacturing industry from both direct and indirect effects. Section 4 establishes the research model of this paper. Section 5 analyzes the empirical results. Section 6 draws the relevant conclusions and enlightenment.

2. Literature review

2.1. The connotation of digital economy

As for the research on the connotation of digital economy, the term digital economy first appeared in the 1990s, and digital economy as a noun first appeared in Canadian scholar Don Tapscott's 1996 book "Digital Economy: In the "Prospects and Risks of the Era of Network Intelligence", he elaborated on the impact of digitalization on 12 fields such as government, business, and education, and was known as the "father of the digital economy". Since then, many scholars and institutions at home and abroad have also elaborated on the concept of digital economy, and domestic and foreign government departments have also made relevant explanations and definitions of the connotation of digital economy. In the cooperation agreement reached at the G20 Summit in 2016, the "digital economy" is defined as a series of economic activities that use digital knowledge and information as key production factors, modern information networks as an important carrier, and the effective use of information and communication technologies as an important driving force for efficiency improvement and economic structure optimization (Tang, 2018). The China Academy of Information and Communications Technology (2017) believes that the digital economy takes digital knowledge and information as the key production elements, digital technology innovation as the core driving force, modern information network as an important carrier, and continuously improves the digital and intelligent level of traditional industries through the deep integration of digital technology and the real economy. Accelerate the reconstruction of the new economic form of economic development and government governance model (Li, 2017). In the Statistical Classification of Digital Economy and Its Core Industries (2021) released by the National Bureau of Statistics in June 2021, the connotation, classification and measurement range of the digital economy are unified, and the digital economy industry is divided into five categories, of which the first four categories belong to the digital industrialization part and the fifth category belongs to the industrial digitalization part. Organizations represented by the Organization for Economic Cooperation and Development, the Bureau of Economic Analysis of the United States Department of Commerce, Statistics Canada, and the Department of Digital, Culture, Media and Sport of the United Kingdom focus on the understanding of the connotation of the digital economy at the level of "digital industrialization", and include e-commerce and other economic activities that are easy to calculate and integrate digital technology and traditional industries (Zhou and Chen, 2023). Most scholars believe that

digital economy is an economic form based on information technology. Pang and Zhu (2013) believe that digital economy is based on information and communication technology. Through the Internet, mobile communication network, Internet of Things, etc., digital economy can realize the digitalization of transactions, exchanges and cooperation, and promote the development and progress of economic society. Liao and Yang (2021) define digital economy as a series of economic activities that use digital knowledge and information as key production factors, modern information network as an important carrier, and effective use of information and communication technology as an important driving force for efficiency improvement and economic transformation and optimization. Xu et al (2023) believes that compared with the traditional economy, the digital economy is the manifestation of the industrialization and marketization of the information technology revolution, which has the unique advantages of improving the speed of information transmission, reducing the cost of data processing and transaction, and accurately allocating resources.

2.2 Research on the transformation and upgrading of manufacturing industry

As for the research on the transformation and upgrading of the manufacturing industry, scholars mainly study the connotation, influencing factors, internal mechanism and strategic path of the transformation and upgrading of the manufacturing industry. In terms of the connotation of the transformation and upgrading of the manufacturing industry, Zhang (2021) believes that the essence of the transformation and upgrading of the manufacturing industry is that the focus of the manufacturing industry is increasingly shifting from the resource industry and the raw material industry to the processing industry, and the structure of the processing industry itself is increasingly transforming from primary processing and simple processing to deep processing and complex processing, which makes the development of the manufacturing industry less dependent on resources. The dependence on science and technology and high-quality personnel is increasing. In terms of influencing factors and internal mechanism, most scholars believe that technological innovation is the core factor to promote the transformation and upgrading of manufacturing industry. Na and Li (2020) used the grey correlation analysis model to study the influencing factors of the transformation and upgrading of China's manufacturing industry. The results show that technological innovation and structural optimization have a significant impact on the transformation and upgrading of China's manufacturing industry, and scientific and technological innovation is the core driving force to promote the transformation and upgrading of China's manufacturing industry. Song and Zhang (2020) studied the impact of innovation drive on the industrial upgrading of the manufacturing industry and its mechanism based on the panel data of 26 sub-industries in Shaanxi Province from 2004 to 2017. It is found that innovation has a significant positive effect on the structural upgrading of the manufacturing industry, and the factors such as the degree of openness and the government act together constitute the driving mechanism of industrial upgrading. As for the research on the strategic path of the transformation and upgrading of the manufacturing industry, Huang (2015), after studying Germany's "Industry 4.0", drew a revelation: China's transformation and upgrading of the manufacturing industry needs to learn from the experience of Germany and implement policies such as vigorously promoting digital, networking and intelligent manufacturing. Na and Li (2020) pointed out that the transformation and upgrading of China's manufacturing industry can be further promoted by increasing support for technological innovation, accelerating the adjustment of industrial structure,

improving the constraint mechanism of resource conservation and environmental protection, creating a financing service platform for transformation and upgrading, and continuously optimizing the intellectual property environment.

In terms of measurement research on the transformation and upgrading of the manufacturing industry, most scholars first built a theoretical model, and then selected several factors with large weights as the measurement basis, and some scholars chose entropy weight method. Gao (2022) constructed the development indicator system for the transformation and upgrading of Suzhou manufacturing industry from the four dimensions of development momentum, innovation capability, digital transformation and green manufacturing, used the entropy weight method to measure and analyze the four dimensions of the transformation and upgrading of Suzhou manufacturing industry from 2016 to 2021, and calculated the evaluation index for the transformation and upgrading of Suzhou manufacturing industry. Pan et al (2019) constructed a comprehensive evaluation index system and comprehensive index for the transformation and upgrading of the manufacturing industry from four aspects: quality and efficiency, innovation capability, information technology and green development. The index weight was determined by entropy weight method, and the transformation and upgrading index of China's manufacturing industry was measured based on the panel data of 29 provinces and municipalities in China.

2.3 Study on the role of digital economy in the transformation and upgrading of manufacturing industry

The current research on the digital economy is partly about the connotation, development status, calculation and influencing factors of the digital economy, and partly about the promotion of high-quality economic development of the digital economy, and the research results in this area are relatively rich. Based on the logical relationship between digital economy, technological innovation and high-quality development, Song (2019) conducted an empirical analysis on the panel data of 31 provincial administrative regions in China for five consecutive years from 2014 to 2018. The results showed that digital economy had a positive promoting effect on high-quality economic development and technological innovation, and the promotion efficiency of direct effect was greater than that of indirect effect. Technological innovation plays a partial mediating role between the digital economy and high-quality development. Fan and Wu (2021), based on the provincial sample data from 2014-2017, constructed a digitalization index system from three dimensions: production digitalization, consumption digitalization and circulation digitalization. The DEA-Malmquist index method is used to calculate the total factor productivity index of each provincial administrative region to measure the development quality, and further decompose the technical efficiency change index and technological progress change index, and then explore the impact mechanism of digitalization on high-quality development. At present, there are few researches on the digital economy's effect on the transformation and upgrading of manufacturing industry, but some scholars have carried out relevant theoretical and empirical researches. In terms of theoretical research, Zhao (2017) believes that the internal mechanism of digital economy driving manufacturing transformation and upgrading is to solve the "pain points" in China's manufacturing transformation and upgrading by cracking the bottleneck of innovation chain, improving the quality of manufacturing chain, optimizing supply chain efficiency, and expanding service chain space. And then put forward the digital economy to drive the transformation and upgrading of China's manufacturing platform, ecological, software, sharing, denuclearization of the

realization of the path. Li (2020) and other scholars have studied the mechanism of digital economy driving the transformation and upgrading of manufacturing industry from the perspective of industry chain. Liu and Zhou (2023) studied the mechanism of digital economy driving the transformation and upgrading of manufacturing industry in Jiangsu Province, which was divided into digital change of physical form of manufacturing industry chain driven by data factors, linkage and coexistence of offline and online industrial clusters driven by data, and incubation of data-driven innovative technologies. The formation of industrial chain transformation and upgrading of the internal sustainable power of three aspects. Gu (2023) analyzed the impact mechanism of the digital economy on the traditional manufacturing industry from the aspects of information, research and development, production, sales, and organizational structure. In terms of empirical research, Liao and Yang (2021) analyzed the empowering path of the digital economy to the transformation and upgrading of the manufacturing industry in the Yangtze River Delta region based on the entropy method and the dynamic panel GMM model, and concluded that the digital economy promoted the transformation and upgrading of the manufacturing industry through three paths: resource allocation optimization effect, production cost reduction effect and innovation and development driving effect. Pan and Chen (2023) established the Cobb-Douglas production function and Panel Vector Auto Regression (PVAR) model based on the panel data of 16 prefecture-level cities in Anhui Province from 2006 to 2020. This paper empirically analyzes the impact of three dimensions of digital economy on the transformation and upgrading of manufacturing industry in Anhui province and puts forward corresponding suggestions.

In summary, in terms of research methods, there are relatively few studies on the mechanism of digital economy driving the transformation of manufacturing industry, and most of them focus on theoretical analysis, and the quantitative analysis of the mechanism is insufficient. In terms of research regions, some scholars choose China as a whole as the research region, and some scholars mostly choose southern regions such as Jiangsu, Zhejiang, Shanghai and Anhui Province as the research region, while few scholars take Hebei Province as the research region to study the mechanism of Hebei's digital economy on the transformation and upgrading of manufacturing industry. In terms of research content, most scholars separately study the development of digital economy and the transformation and upgrading of manufacturing enterprises, and few scholars study the mechanism of digital economy driving the transformation and upgrading of manufacturing. Therefore, this paper switches the research perspective to 11 prefecture-level cities in Hebei Province, which are closest to Beijing and Tianjin, and applies the intermediary effect model to study the mechanism of digital economy driving the transformation and upgrading of manufacturing industry in Hebei Province from three aspects: enterprise resource allocation ability, technological innovation ability and enterprise cost.

3. Action mechanism of digital economy driving the transformation and upgrading of manufacturing industry in Hebei Province

The driving effect of the digital economy on the transformation and upgrading of the manufacturing industry is mainly divided into direct and indirect effects. The direct effect is that the digital economy directly promotes the transformation and upgrading of the manufacturing industry by empowering all aspects of the manufacturing enterprise, improving the quality and efficiency of the manufacturing supply system. The indirect effect is that while the digital economy directly drives the transformation and upgrading of the manufacturing industry, it will also

indirectly promote the transformation and upgrading of the manufacturing industry by improving the resource allocation ability of manufacturing enterprises, improving the level of technological innovation, and reducing the cost of enterprises. This is shown in Figure 1.

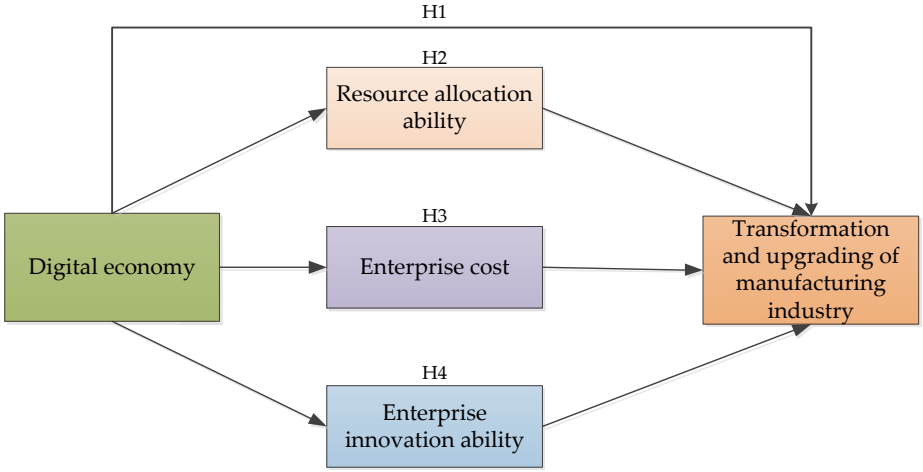

Figure 1. Model of the intermediary effect of the mechanism of digital economy driving the transformation and upgrading of manufacturing industry

3.1 The mechanism of digital economy directly driving the transformation and upgrading of manufacturing industry

The manufacturing industry plays a vital role in China's economic development. Facing the traditional production mode of high input, high energy consumption and high pollution, the transformation and upgrading of China's manufacturing industry is a must (Dong et al., 2022). Digital economy takes data as the core, and data is the fifth factor of production after land, labor, capital and technology. Secondly, the digital economy has high innovation, strong penetration and wide coverage, which is not only a new economic growth point, but also a fulcrum to enhance traditional industries. In this view, the development of the digital economy will directly promote the transformation and upgrading of the manufacturing industry. On the one hand, with advanced data elements as the core, the digital economy continues to integrate with traditional industries, enabling advanced manufacturing, making some new industries and new forms of business begin to emerge, and improving the quality and efficiency of traditional manufacturing (Yin et al., 2022). On the other hand, the digital economy enables all aspects of the manufacturing industry, improves the digital level of manufacturing enterprises in all aspects of the industrial chain such as research and development design, production and manufacturing, enterprise operation and maintenance, and product sales, extends and broadens the manufacturing industrial chain, promotes the manufacturing value chain to rise to the high-end, meets the personalized needs of consumers, and helps improve the quality and efficiency of the manufacturing supply system. Enhance competitive advantage (Yin et al., 2022). With the development of the digital economy, the driving role of the digital economy for the transformation and upgrading of the manufacturing industry is getting stronger and stronger, so the digital economy can directly enable the transformation and upgrading of the manufacturing industry.

H1: the mechanism of digital economy directly driving the transformation and upgrading of manufacturing industry.

3.2 Digital economy and resource allocation ability of manufacturing enterprises

Under the transformation and upgrading of the manufacturing industry, the most important factor is complete infrastructure, and the coordination level of production factors within the industry needs to rely on infrastructure construction. Digital technology and digital economy can promote the rapid flow of various resource factors, and digital transformation can improve the resource allocation ability of enterprises and further improve the business performance of manufacturing enterprises (Burmaoglu et al., 2023). Under the new industrial revolution, the digital economy is becoming more and more mature, and the digital economy can connect the original scattered equipment, technology, and market of the enterprise through intelligent production, precision marketing and other ways, so that the enterprise can realize the optimization of resource allocation in all aspects from production to sales, making it closer to the Pareto state (Shi et al., 2023). In the production link, firstly, the digital economy can rationally arrange production through intelligent analysis of digital technology, make the traditional production process more sophisticated, reduce the waste of production resources to a minimum, and improve the resource allocation efficiency of production resources. Secondly, the digital economy can accurately collect information such as the demand of the consumer market and the state of production factors through platforms such as the Internet, so as to obtain more abundant information available for production decisions, making production decisions more accurate (Colombari et al., 2023). In the marketing link, the digital economy transforms the traditional extensive marketing mode into precision marketing by collecting massive big data information, finds the most suitable marketing mode for its own enterprise, uses the lowest cost to obtain better marketing returns, and improves the efficiency of resource allocation in the marketing link. In terms of supply chain, the Internet platform in the digital economy can effectively integrate suppliers, producers, channel operators and the industrial chain, improve the flow efficiency of the whole industry chain, and reduce the waste of resources in the flow process (Dong et al., 2023). Therefore, hypothesis 2 is proposed in this paper.

H2: Digital economy drives the transformation and upgrading of manufacturing industry by improving the resource allocation ability of manufacturing enterprises.

3.3 Digital economy and manufacturing enterprise costs

With the development of digital technology, digital technology relying on the Internet thinking can reduce the production costs, marketing costs, transaction costs and other costs of manufacturing enterprises. From the perspective of product production, the application of digital technology to the production process of manufacturing enterprises can improve product quality, improve production efficiency, adopt a better production structure and mode, effectively reduce the waste of energy resources in the production process, achieve green production, and thus reduce energy consumption and production costs (Matthess et al., 2023). From the level of enterprise operation, the use of digital technology, enterprises can more convenient and fast access to internal information, for the internal enterprise, can effectively reduce the coordination and communication and management costs, improve the operation efficiency of enterprise

organizations. Not only that, but using digital technology, companies can enable on-demand hiring, reducing recruitment and labor costs. From the level of product sales, enterprises can use digital technology to accurately obtain the needs of consumers according to the big data information of the Internet, so as to push product information to relevant consumers, reduce the cost of information search, and greatly reduce the cost of sales and publicity. On the other hand, manufacturing enterprises can apply digital technology to achieve online and offline integration of sales, promote the deep integration of the digital economy and the real economy, broaden the business circle, expand the consumer group, and increase the sales revenue of enterprises. Therefore, hypothesis 3 is proposed in this paper.

H3: The digital economy promotes the transformation and upgrading of the manufacturing industry by reducing the cost of manufacturing enterprises.

3.4 Digital economy and innovation ability of manufacturing enterprises

The innovation ability of enterprises is the key link and main driving factor of the transformation and upgrading of China's manufacturing industry. The improvement of the innovation ability of the manufacturing industry by the digital economy can be seen from the internal and external environment of the enterprise. The digital economy affects the internal and external environment of the enterprise, and then affects the level of technological innovation (Yin and Li, 2018). At the level of the internal environment of enterprises, the digital economy mainly affects the level of technological innovation by affecting all aspects of the operation of enterprises. In product research and development, digital technology can not only accurately grasp the changes in market demand, use big data information to accurately analyze the potential needs of users, and develop personalized new products tailored to users, but also encourage users to participate in the innovation process, so that users can design novel products according to their own needs, and make users part of the enterprise innovation process. To collect ideas and improve the level of innovation (Yin et al., 2019). In the product production link, the digital economy development mainly relies on the physical level of sensors, networks, and other basic hardware, which can help rapid and high-quality production, improve production efficiency and product quality. In the product sales link, manufacturing enterprises rely on digital technology, collect big data information, form an Internet thinking centered on consumer demand, promote point-to-point consumption, and achieve sales innovation (Conti et al., 2023). Finally, in terms of enterprise internal management, the development of digital economy will promote enterprises to improve the internal management mode, strengthen the effective communication between various departments, realize the innovation of internal management and operation, and improve the operational efficiency of manufacturing enterprises (Yin et al., 2022). In terms of the external environment of enterprises, on the one hand, digital technology reduces the market information asymmetry of manufacturing enterprises, and in a fairer market competition environment, enterprises can only maintain their market position by improving their innovation ability. On the other hand, the development of digital economy can provide a broader platform for regional innovation and development and support the elements required for innovation, which is conducive to the improvement of regional innovation ability. This will drive the transformation and upgrading of traditional manufacturing industries (Zhou et al., 2022). Therefore, hypothesis 4 is proposed in this paper.

H4: The digital economy promotes the transformation and upgrading of the manufacturing industry by improving the innovation ability of manufacturing enterprises.

4. Research design

4.1 Data samples and data sources

In this paper, the panel data of 11 prefecture-level cities in Hebei province, including Shijiazhuang, Tangshan and Baoding, were selected from 2017-2022 for empirical research, and a total of 66 sample data were collected. The data studied in this paper are respectively from China Industrial Statistics Yearbook, Hebei Province Science and Technology Fund Investment Statistical Bulletin, China Economic and Social Big Data Research Platform, and the statistical yearbook and statistical bulletin of prefecture-level cities.

4.2 Model Construction

Based on the above theoretical analysis, first of all, this paper constructs a regression model to test the direct mechanism of action. The model formula is as follows:

$$MTU_{it} = \alpha_0 + \alpha_1 DE_{it} + \alpha_2 CV_{it} + \mu_i + \delta_t + \varepsilon_{it} \tag{4.1}$$

With the help of the intermediary effect model, this paper analyzes the impact of the development of digital economy on the transformation and upgrading of manufacturing industry by selecting enterprise resource allocation ability, enterprise cost and enterprise innovation ability as the intermediary variable M.Drawing on Wen et al's (2014) research on mediation effect, the following mediation effect model is constructed: The following model is designed and tested:

$$M_{it} = \beta_0 + \beta_1 DE_{it} + \beta_2 CV_{it} + \mu_i + \delta_t + \varepsilon_{it} \tag{4.2}$$

$$MTU_{it} = \gamma_0 + \gamma_1 DE_{it} + \gamma_2 M_{it} + \gamma_3 CV_{it} + \mu_i + \delta_t + \varepsilon_{it} \tag{4.3}$$

Where, i and t represent sample individuals and periods respectively; MTU_{it} is the upgrading level of manufacturing industry calculated according to the index system. DE_{it} is the calculated development level of digital economy; M_{it} stands for intermediate variable; CV_{it} represents control variable; μ_i and δ_t represent the region and time non-observed effects, and ε_{it} is the residual. Formula (4.1) is the linear regression equation of the relationship between the development level of digital economy (DE_{it}) and the transformation and upgrading of manufacturing industry (MTU_{it}) to test the direct impact of digital economy on the transformation and upgrading of manufacturing industry; Equation (4.2) is the linear regression

equation of the relationship between the development level of digital economy (DE_{it}) and the intermediary variable (M_{it}), and the influence of the development level of digital economy on each intermediary variable is tested. Formula (4.2) is the linear regression equation of the effect of the development level of digital economy (DE_{it}) and intermediary variable (M_{it}) on the transformation and upgrading of the manufacturing industry (MTU_{it}), and the impact of the development level of digital economy and each intermediary variable on the transformation and upgrading of the manufacturing industry is tested. The following analysis is carried out according to the steps of mediation effect test.

The first model (4.1) mainly examines the relationship between the independent variable digital economy development level (DE_{it}) and the dependent variable manufacturing transformation and upgrading (MTU_{it}), which is named model (1). Coefficient α_1 is the total effect. If α_1 is significant, the correlation between the development level of the digital economy and the transformation and upgrading of the manufacturing industry is significant, which conforms to the prerequisite of the method of sequential testing of regression coefficients, and the intermediate effect test can be continued. If α_1 is not significant, it means that the regression coefficient in equation (4.1) is not significant and does not meet the prerequisite for the generation of intermediary effect. The second model (4.2) mainly tests the correlation between the independent variable digital economy development level and the intermediary variable, which is named model (2). In this model, if β_1 is significant, it means that the regression coefficient in equation (4.2) is significant, and γ_2 can continue to test the significance of the coefficient. At this time, if β_1 is significant and greater than zero, it indicates that the independent variable digital economy development level has a positive induction effect on the intermediary variable. If β_1 is significant and less than zero, it indicates that the independent variable government R&D input has a negative crowding out effect on the intermediary variable enterprise R&D input. For the third model, whether the coefficient γ_2 in the main test formula (4.3) is significant, we named it model (3). In this model, if the coefficient γ_2 is significant, and the coefficient β_1 in the second model is also significant, we can conduct a full mediation effect test, that is, by judging the significance of γ_1 the coefficient, we can determine whether the influence of the independent variable DE on the dependent variable MTU is fully realized through the intermediary variable M.

4.3 Variable definition and measurement

4.3.1 Explained variables

Manufacturing transformation and Upgrading (MTU). In view of the availability of municipal data and the avoidance of arbitrary selection of indicators, the concept of manufacturing transformation and upgrading index is selected.

4.3.2 Core explanatory variables

Digital economy development level (DE). It is measured by the digital economy development index of each city measured by entropy value method.

4.3.3 Intermediary variables

Based on Liao et al (2021), enterprise resource allocation ability, enterprise cost and enterprise innovation ability are selected as intermediary variables. Among them, the enterprise resource allocation capacity (RPC) is expressed by the proportion of government fiscal expenditure to GDP. Enterprise cost (PC) is expressed as the main business cost of industrial enterprises above designated size; Enterprise innovation capability (IA) is expressed by the R&D expenditure of industrial enterprises above designated size in each region.

4.3.4 Control variables

(1) Level of foreign direct investment (FDI). Based on the research of Shi et al (2017), this paper uses the amount of foreign direct investment to represent the level of foreign direct investment.

(2) Economic development level (EDL). Based on the research of Shen et al (2020), this paper uses per capita GDP to represent the economic development level of each region.

(3) Industry scale (IS). Based on the research of Wang et al (2022), this paper uses the proportion of industrial added value in GDP to represent the scale of the industry. Table 1 describes the variables.

Table 1. Variable definitions and indicators

Variable	Target layer	Symbol	Index level
Explained variable	Manufacturing transformation and upgrading	MTU	Manufacturing transformation and upgrading index
Explanatory variable	Development level of digital economy	DE	Digital economy development level index
Intermediate variable	Enterprise resource allocation capability	RPC	Government expenditure as a share of GDP
	Enterprise cost	PC	The main business costs of industrial enterprises above designated size
	Enterprise innovation ability	IA	R&D funds for industrial enterprises above designated size

Control variable	Foreign direct investment	FDI	Amount of foreign direct investment
	Level of economic development	EDL	Per capita GDP
	Industry scale	IS	Industrial added value

4.4 Descriptive statistics and analysis

The descriptive statistical results of the variables are shown in Table 2. The standard deviation of the explained variable's transformation and upgrading of the manufacturing industry is the smallest, with a value of 0.07781, a maximum value of 0.5056, and a minimum value of 0.2042, indicating that there is still a significant imbalance in the transformation and upgrading level of the manufacturing industry in the cities of Hebei Province. The standard deviation of the explanatory variable digital economy development level is small, the value is 0.7782, the maximum value is 5.8443, and the minimum value is 5.4962, indicating that there is also a significant imbalance in the digital economy development level of cities in Hebei Province. From the perspective of intermediary variables, the standard deviation of enterprise innovation ability is the largest, the value is 1.0017, the maximum value is 5.2237, and the minimum value is 0.9933, indicating that there are great differences in the innovation ability of manufacturing enterprises in Hebei Province. The standard deviation of enterprise resource allocation ability is small, which is 0.0812, indicating that there is little difference in enterprise resource allocation ability among different regions in Hebei Province. From the perspective of control variables, the maximum value of industry scale is 8.4119, and the minimum value is 5.8844, indicating that there is a large gap between the scale of manufacturing enterprises in Hebei Province.

Table 2. Descriptive statistical results of variables

Name	Symbol	Sample size	Minimum value	Maximum value	Mean value	Standard deviation
Manufacturing transformation and upgrading	MTU	66	0.2042	0.5056	0.3290	0.07781
Development level of digital economy	DE	66	5.4962	5.8443	5.6577	0.07782
Enterprise resource allocation capability	RPC	66	0.0436	0.4019	0.2051	0.0812
Enterprise cost	PC	66	6.2307	9.3978	7.7728	0.7490
Enterprise innovation ability	IA	66	0.9933	5.2237	3.6018	1.0017
Foreign direct investment	FDI	66	7.8702	12.2370	11.1915	0.8827

Level of economic development	EDL	66	10.2576	11.6578	10.7675	0.3336
Industry scale	IS	66	5.8844	8.4119	6.8158	0.6655

5. Empirical analysis

5.1 Correlation analysis

The correlation coefficients of each variable are shown in Table 3.

Table 3. Correlation analysis

	MTU	DE	RPC	PC	IA	FDI	EDL	IS
MTU	1.0000							
DE	0.2412***	1.0000						
RPC	0.6191***	0.0991***	1.0000					
PC	0.6508	-0.0097***	-0.5614**	1.0000				
IA	0.3084***	0.2524***	-0.5337**	0.7617***	1.0000			
FDI	0.3375***	0.0022	-0.4669*	0.7077***	0.6808***	1.0000		
EDL	0.3953***	0.2786***	-0.5738**	0.5755***	0.5747***	0.4475*	1.0000	
IS	0.7099***	0.0485***	-0.6225	0.8918***	0.8264	0.6787**	0.6028***	1.0000

Note: *, ** and *** are significant at the level of 10%, 5% and 1% respectively.

As can be seen from the correlation test in Table 3: (1) The correlation coefficient between the transformation and upgrading of the manufacturing industry and the development level of the digital economy is 0.2412, which is significant at 1% level, indicating that the development level of the digital economy has a positive promoting effect on the transformation and upgrading of the manufacturing industry, verifying the correctness of hypothesis H1. (2) The correlation coefficient between the enterprise resource allocation ability and the development level of digital economy is 0.0991, and the 1% level test indicates that the development level of digital economy has a positive promoting effect on the enterprise resource allocation ability; The correlation coefficient between enterprise resource allocation ability and the transformation and upgrading of manufacturing industry is 0.6191, and the correlation coefficient is significant at 1% level, indicating that the improvement of enterprise resource allocation ability can promote the transformation and upgrading of manufacturing industry, which is consistent with hypothesis H2. (3) The correlation coefficient between enterprise cost and the development level of digital economy is -0.0097, and

the correlation coefficient is significant at 1% level, indicating that the development of digital economy will promote enterprises to reduce costs. The correlation coefficient between enterprise cost and the transformation and upgrading of manufacturing industry is 0.6508, which is not significant, so hypothesis H3 cannot be confirmed. (4) The correlation coefficient between the enterprise innovation ability and the development level of digital economy is 0.2524, and the correlation coefficient is significant at 1% level, indicating that the development of digital economy has a positive role in promoting the innovation ability of enterprises, and the development of digital economy can improve the innovation ability of enterprises; The correlation coefficient between the innovation capability of enterprises and the transformation and upgrading of the manufacturing industry is 0.3084, and the correlation coefficient is significant at 1% level, indicating that the improvement of the innovation capability of enterprises can promote the transformation and upgrading of the manufacturing industry, which is consistent with hypothesis H4.

5.2 Analysis of mediating effect

(1) Analysis of the empirical results of digital economy development and the transformation and upgrading of manufacturing industry

Based on Stata software, model (1) is used to explore the relationship between the development of digital economy and the transformation and upgrading of the manufacturing industry, and the estimated results of the development of digital economy on the transformation and upgrading of the manufacturing industry are obtained, as shown in Table 4. Through analysis, it can be seen that the estimated coefficient α_1 of the development level of digital economy is 0.3068, which is significant at 1% level, indicating that the total effect α_1 of the development level of digital economy on the financial performance of enterprises is 0.3068. Every 1% increase in the development level of digital economy, the transformation and upgrading level of manufacturing industry will increase by 0.3068%. The development level of the digital economy has a significant positive impact on the transformation and upgrading of the manufacturing industry, thus verifying hypothesis H1. From the perspective of control variables, foreign direct investment, economic development level, and industry scale are all conducive to promoting the transformation and upgrading of the manufacturing industry. The development level of the digital economy has a significant positive impact on the transformation and upgrading of the manufacturing industry, which conforms to the prerequisite of the method of sequential testing of regression coefficients, and the intermediate effect test can be continued.

(2) The intermediary effect analysis of enterprise resource allocation ability

As shown in Table 4, in model (2), the enterprise resource allocation ability is taken as the explained variable, and the development level of digital economy is taken as the explanatory variable, and the role of the explanatory variable digital economy development level on the intermediary variable enterprise resource allocation ability is explored. It is concluded that the regression coefficient β_1 is 0.2378, and it is significant at 5% level, indicating that the development level of digital economy has a positive induction effect on the resource allocation ability of enterprises. In model (3), the intermediary variable enterprise resource allocation ability

is added into the explanatory variable. The regression coefficient γ_1 of digital economy development level on the transformation and upgrading of manufacturing industry is 0.2463, and is significant at 1% level; the regression coefficient γ_2 of intermediary variable enterprise resource allocation ability on the transformation and upgrading of manufacturing industry is 0.2545, and is significant at 5% level. To sum up, both the development level of digital economy and the ability of enterprise resource allocation have significantly positive impacts on the transformation and upgrading of the manufacturing industry, so the intermediary effect is significant. Therefore, it indicates that the digital economy can indirectly promote the transformation and upgrading of the manufacturing industry by improving the ability of enterprise resource allocation (Zhang et al., 2023).

(3) Analysis of the intermediary effect of enterprise cost

As shown in Table 4, in model (4), enterprise cost is taken as the explained variable, and the development level of digital economy is taken as the explanatory variable, and the role of the explanatory variable digital economy development level on the intermediary variable enterprise cost is explored. It is concluded that the regression coefficient β_1 is -0.6372, which is not significant. Then, Sobel test is performed, and Z=-0.6811, P=0.5768>0.05 is still not significant. Therefore, it shows that the intermediary effect of digital economy development on the transformation and upgrading of manufacturing industry by reducing enterprise costs does not exist. Therefore, hypothesis H3 is negated.

(4) Analysis of the intermediary effect of enterprise innovation ability

As shown in Table 4, in model (6), the innovation capability of enterprises is taken as the explained variable, and the development level of digital economy is taken as the explanatory variable for regression analysis. It is concluded that the regression coefficient β_1 is 2.7659, and it is significant at 1% level, indicating that the development level of digital economy has a positive induction effect on the innovation ability of enterprises. In model (7), adding the intermediary variable enterprise innovation capability into the explanatory variable, the regression coefficient γ_1 of digital economy development level on the transformation and upgrading of the manufacturing industry is 0.1424, and is significant at 5% level; the regression coefficient γ_2 of intermediary variable enterprise innovation ability on the transformation and upgrading of the manufacturing industry is 0.0595, and is significant at 1% level. To sum up, both the development level of digital economy and the innovation ability of enterprises have significantly positive impacts on the transformation and upgrading of the manufacturing industry, so the intermediary effect is significant. Therefore, it indicates that the digital economy can indirectly promote the transformation and upgrading of the manufacturing industry by improving the innovation ability of enterprises. So let's say that H4 is true.

Table 4. Regression results of intermediary effects

Variable	(1) MTU	(2) RPC	(3) MTU	(4) PC	(5) MTU	(6) IA	(7) MTU
DE	0.3068*** (3.72)	0.2378** (2.38)	0.2463*** (2.98)	-0.6372 (-1.15)	0.2965*** (3.55)	2.7659*** (3.25)	0.1424** (2.00)
RPC			0.2545** (2.51)				
PC					0.0162 (0.84)		
IA							0.0595*** (6.02)
FDI	0.0257*** (2.73)	-0.0038 (-0.0266)	0.0266*** (2.94)	0.1534** (2.43)	-0.0282*** (-2.85)	0.2749*** (2.83)	-0.0093 (-1.17)
EDL	0.0202 (0.84)	-0.0970*** (-3.32)	0.0045 (0.18)	0.1675 (1.04)	0.0174 (0.71)	0.0646 (0.26)	0.0240 (1.25)
IS	0.1018*** (7.25)	-0.0446*** (-2.62)	0.0904*** (6.37)	0.8186*** (8.72)	0.0885*** (4.20)	0.9611*** (6.63)	0.1589*** (10.85)
Constant term	1.4414*** (3.18)	0.2503 (0.46)	1.5051*** (3.46)	2.2788 (0.75)	1.4045*** (3.08)	-22.3703*** (-4.79)	0.1115 (0.26)
N	66	66	66	66	66	66	66
R^2	0.6277	0.4980	0.6631	0.8201	0.6321	0.7604	0.7681

Note: The t value in parentheses is the same below.

6. Conclusion and enlightenment

6.1 Conclusion

Based on the 6-year panel data of 11 prefecture-level cities in Hebei Province from 2017 to 2022, this paper establishes a mediating effect model and empirically tests the mediating effect of enterprise resource allocation ability and innovation ability on the impact of digital economy on the transformation and upgrading of manufacturing industry by using the stepwise test method of mediating effect. The following conclusions are reached: (1) Through empirical research, it is found that there is a significant positive correlation between the development of digital economy and the transformation and upgrading of manufacturing industry, which indicates that the development of digital economy promotes the transformation and upgrading of manufacturing industry. (2) There is also a positive correlation between the development of digital economy and the resource allocation ability and innovation ability of enterprises, indicating that the development of digital economy can improve the resource allocation ability and innovation ability of enterprises, and is conducive to the benign and stable development of enterprises in the future. (3) Enterprise resource allocation ability and innovation ability play a significant intermediary role in the relationship between the development of digital economy and the transformation and upgrading

of manufacturing industry, indicating that the digital economy can accelerate the transformation of research and development achievements of manufacturing enterprises, and then improve the market competitiveness of enterprises and increase their profits. Based on the above empirical research results, this paper puts forward corresponding suggestions from the perspective of Hebei Provincial government and manufacturing enterprises, so as to provide reference for exploring the inner driving force of enterprises to enhance resource allocation ability and innovation ability under the background of digital economy and realize the transformation and upgrading of manufacturing industry.

6.2 Revelation

The transformation and upgrading of manufacturing industry driven by digital economy in Hebei Province has a long way to go, and the government should provide a solid foundation for it and increase policy support and guidance. First, the Hebei Provincial government should take the lead in building an industrial innovation platform adapted to the digital economy, vigorously promote the digital transformation of enterprises in Hebei province, realize resource information sharing through the industrial innovation platform of the digital economy, optimize the digital service environment, improve the efficiency of the digital economy industrial chain, and promote the upgrading of the digital industry. Second, the Hebei provincial government should increase its support and guidance for the transformation and upgrading of manufacturing enterprises, and give full play to its positive role in the transformation and upgrading of traditional manufacturing industry. On the one hand, the government should increase the provision of funds, technologies, policies and other aspects of convenience to help reduce the cost of digital transformation of enterprises, improve the ability of resource allocation of enterprises, and promote the smooth implementation of industrial transformation and upgrading. On the other hand, the government should further guide the direction of transformation and upgrading of manufacturing enterprises, establish benchmarking enterprises, and provide feasible development paths for the digital transformation and upgrading of manufacturing enterprises.

Manufacturing enterprises should actively respond to the background of the digital economy and promote their own transformation and upgrading. First of all, enterprises should cultivate digital thinking, build an information sharing platform within enterprises and between supply chain enterprises, improve the level of enterprise informatization, realize information sharing and collaboration within enterprises and between supply chain enterprises, improve the operational efficiency and competitiveness of enterprises and supply chain enterprises, establish a corporate culture adapted to the digital economy, and then promote the transformation and upgrading of enterprises. Second, manufacturing enterprises should give full play to the driving role of the digital economy in manufacturing enterprises, use information technology represented by artificial intelligence, big data and 5G, implement enterprise automated production and operation mode, reduce enterprise costs, improve enterprise resource allocation capabilities, and jointly create an information, digital and intelligent ecosystem for manufacturing. We will accelerate the development of digital transformation in the manufacturing industry. Third, manufacturing enterprises should use digital technology to improve their own innovation ability, the use of artificial intelligence and other technologies to improve the efficiency of scientific and technological innovation, at the same time, vigorously recruit and train scientific and technological talents, and strengthen their continuous training and learning, fully promote the gathering of

scientific and technological talents, promote the transformation and upgrading of manufacturing industry. Fourth, with the help of the Internet platform, while expanding sales channels, strengthen communication with retail enterprises and consumers, timely access to consumer data, real-time understanding of market demand changes, improve the ability of enterprises to respond to market changes, and quickly respond to market demand.

Author Contributions

Conceptualization: L.J.F. and Y.S.; methodology: T.M.; software, Y.S.; validation: L.J.F. and T.M.; writing—original draft preparation, Y.J.Y. and Y.S.; writing—review and editing, L.J.F. and Y.S. All authors agreed to the manuscript.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Conflicts of Interests

All the authors claim that the manuscript is completely original. The authors also declare no conflict of interest.

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