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Industrial Digitalization in China: Literature Review and Research Prospects

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Abstract: *Facing the new development stage of the "14th Five-year Plan", high-quality development has become the theme of China's economic and social development, putting forward new requirements for industrial digitalization. However, the depth and systematicness of the existing literature on China's industrial digitalization research is insufficient. In view of this, this paper systematically combs the research results and context of China's industrial digitalization, and combines specific economic practice, in order to promote the deepening and systematization of research in this field, and provide reference for promoting China's industrial digital transformation. Firstly, the connotation and denotation of industrial digitalization are defined based on relevant domestic researches, and its characteristics are clarified. Secondly, combined with the changes of industrial structure, this paper summarizes the three driving modes of China's industrial digitalization: the backward-forcing mode dominated by social motivation, the integration mode dominated by technology motivation and the value-added service mode dominated by innovation motivation. Thirdly, the formation mechanism of the industry chain being reshaped by digitalization is summarized and interpreted; Finally, the future research is prospected to provide feasible directions and ideas for further expanding and deepening the research of industrial digitalization in China.*

Keywords: *Industrial Digitalization, China, Driving Modes, Industrial Chain Reshaping*

1. Introduction

Industry digitalization is the core of digital economy, both globally and in China.The latest data shows that in 2019, global industrial digitalization accounts for 84.3% of the digital economy, of which industrial digitalization in developed countries accounts for 86.3% of the digital economy and 51.3% of GDP[1].From 2005 to 2020, the proportion of China's industrial digitalization in the digital economy increased from 49.1% to 80.9%, and its proportion in GDP increased from 7% to 31.2%[2].It can be seen that although China's industrial digitalization is booming, there is still a certain gap between the current development level and that of developed countries. In the face of the international COVID-19 epidemic and the severe and complex global economic situation, it is urgent for China to accelerate the industrial digital transformation, give birth to new industrial models, innovate new industrial formats, create new industries, open up industrial cycles, and promote the basic capability and modernization level of the industrial chain, so as to cope with de-globalization and the reconstruction of the global value chain better and participate in the future global economic division of labor, export technical standards and develop service trade more efficiently. Therefore, exploring China's industrial digitalization has both important theoretical value and practical significance, not only enriching the theory of digital economy, but also a response to practical problems such as deepening supply-side structural reform, speeding up the construction of a new development pattern of "double cycle" and promoting the high-quality development of China's economy.

Accordingly, this paper reviews the literature on the concept and characteristics, development status, driving modes, industrial chain reshaping effects of China's industrial digitalization, and looks forward to the future research direction.The marginal contribution of this paper is mainly reflected in the following three aspects :(1) It systematically combs the representative research results of industrial digitalization in China, presents the knowledge context of industrial digitalization in China, and lays a literature foundation for the subsequent construction and improvement of theoretical analysis framework of industrial digitalization.(2)Combining changes of industrial structure, it summarizes three driving modes of China's industrial digitalization: the backward-forcing mode dominated by social motivation, the integration mode dominated by technology motivation and the value-added service mode dominated

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by innovation motivation, and then systematically illustrates the generation logic of China's industrial digitalization.(3)It points out that the key research directions of Industrial digitalization in China are the design and calculation of segmentation indicators, multiple effects and regional heterogeneity of Industrial digitalization, which can provide direction reference for subsequent research to a certain extent.

2. The Concept of Industrial Digitalization in China

2.1. The connotation and denotation of industrial digitalization in China

Domestic scholars' understanding of the connotation of industrial digitalization has gone from shallow to deep. Yu Yewen and Chen Gengxuan(2021)[3]believed that Industrial digitalization is a process in which traditional industries use digital technology to upgrade business and improve production quantity and efficiency.Yan Zichun et al.(2021)[4] believed that the connotation of industrial digitalization is that digital technology leads the integration of industries and the reform of industrial structure. Zhu Heliang and Wang Chunjuan(2021)[5] gave a more detailed explanation of the connotation of industrial digitization: Focus on business processes, combine cutting-edge technologies such as big data, cloud computing, artificial intelligence and the Internet of Things with production businesses, break down data barriers between different levels and industries, change the original business model, organizational structure, management model, decision-making model and supply chain collaboration model of industries, so as to achieve the coordinated development, transformation and upgrading of industries through flat industrial form, efficient business process, perfect customer experience, broad value creation and emerging industrial ecology.

The denotation of China's industrial digitalization is very broad, covering all-round changes of economic, social and other external environments required to support the industrial digital transformation. From the economic perspective, it mainly includes the comprehensive transformation of economic structure, innovation system, market competition mode and trade rules (Lu Yang and Wang Chaoxian, 2021[6];Wei Ying and Zong Xiaoyun, 2021[7];Sun Guoqiang et al., 2021[8];Tang Haodan and Jiang Dianchun, 2021[9]);From the social dimension, it mainly includes sustainable development issues such as social governance model, employment model and education system (Wu Jiebing and Cui Manfei, 2021[10];Sun Xuan and Wu Zhaoguang, 2021[11];Su Lanlan, Peng Yanling, 2021[12]).

2.2. The core characteristics of industrial digitalization in China

2.2.1 Data becomes the new factor of production

In the digital age, data is considered a factor of production alongside traditional factors such as land, labor, capital, and technology. As an information carrier, data is the core basis for business model innovation, business process optimization and business decision-making, and has become the core production factor for industrial digital transformation (Xiao Xu and Qi Yudong,2021[13]).The convergence and integration of data and industry promotes a new leap in productivity, and in the production process, data creates social value in collaboration with other production factors such as labor, land and capital(Li Haijian and Zhao Li,2021[14]).Big data technology is a tool for mining and processing information deposits, allowing people to further mine the commercial value of various data types and huge data volumes in addition to structured data, and realize the effective conversion of data into value creation, thus becoming an important source of business innovation, industrial upgrading and social change (He Daan,2021[15]).

2.2.2 Precise matching of supply and demand information becomes the driving force of business model innovation

The degree of digitalization of traditional industries is generally low. Driven by digital technologies such as cloud computing, artificial intelligence, and the Internet of Things, industrial digitalization drives the intelligent transformation of business models. Software function innovation driven by application needs has become an important starting point for digital transformation. The digital platform forms the information interconnection of manufacturers, intermediaries, and consumers, subverting the traditional product-driven business model, allowing production-end enterprises to directly contact consumer-end users, and consumer demand or experience has become a new driving force for enterprise production, prompting traditional industries to change in the direction of flexibility, customization and personalization (Cao Zhengyong,2018[16]). It is this precise matching of supply and demand information that provides new impetus for business model innovation.

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2.2.3 Industrial Internet becomes a booster for industrial revitalization

The Industrial Internet is based on the collection, aggregation, and analysis of massive data, and integrates and applies digital technologies such as cloud computing, big data, the Internet of Things, and artificial intelligence to build a production service system to support the ubiquitous connection, flexible and effective supply, and efficient and precise allocation of industrial resources, so as to realize the deep integration of the latest digital technology and modern technology and the ubiquitous link of all elements of the industry. As an important platform for resource aggregation and sharing, the industrial Internet platform enables the industry to realize comprehensive perception and dynamic transmission of data by building an intelligent production model and achieving a closed loop of interactive services, thereby improving the efficiency of resource allocation and becoming a booster for the revitalization of traditional industries (Du Huayong,2021[17]).

2.2.4 "Blockchain + supply chain" becomes the technical support for the large-scale coordinated development of the industry

The blockchain has the characteristics of decentralization, openness, sharing, transparency, privacy, etc. It breaks the traditional closed operation mode by providing blockchain-type data storage, data tamper-proof, and consensus-based transparent and trustworthy cooperation mechanism, creating a credible application environment, thereby effectively avoiding information distortion, helping enterprises to understand the status of goods in real time, not only optimizing production operations and management to meet the needs of supply chain management efficiency and benefits, but also forming an open and shared industrial ecology to meet the interests of alliance enterprises(Tian Yang et al.,2021[18]). Therefore, the blockchain plays an important role in the field of supply chain, providing reliable technical supports for solving the problem of large-scale industrial collaboration, and promoting the large-scale coordinated development of the industry.

3. The Driving Modes of Industrial Digitalization in China

The continuous change of the industrial structure is the driving force for the continuous development of an economy, and this process is endogenously determined by the change of the factor endowment structure. Only the industrial structure that is compatible with the factor endowment structure is the optimal industrial structure (Lin Yifu, 2011[19]). The social motives caused by the uncertain exogenous demand of consumption[20-22], the technological motives caused by the progress of endogenous information technology, and the innovation motives caused by the innovation of the business model of enterprises[23-26] are the three major factors that affect the evolution of the industrial structure. Based on this, three driving modes of China's industrial digitization can be concluded: the backward-forcing mode dominated by social motivation, the integration mode dominated by technology motivation and the value-added service mode dominated by innovation motivation. The last model is the one that best reflects the digital competitiveness of the industry [26].

3.1. The backward-forcing mode dominated by social motivation

The backward-forcing mode dominated by social motivation refers to the “uncertainty” driving innovation of digital products and services. From the perspective of information theory, Claude Shannon believed that "information is used to reduce random uncertainty, and the value of information is the increase of certainty" [27].

Uncertainty stems from the limited cognitive ability of people under the condition of information constraints. From the demand side, in the past, it was more based on relatively certain demand to achieve cost reduction and efficiency increase. Today, we are faced with more uncertainty, personalized customization, and fragmented needs, especially when those unusual events that are difficult to predict and usually cause negative chain reactions or even subversion occur in the market, we need to continue to innovate based on uncertain needs and enhance our "anti-fragile" capabilities. From the supply side, in the past, digital solutions and various software were closed technology systems for local, but today it is necessary to build a globally optimized open technology system (An Xiaopeng, 2019[28]). The solution is from a single product solution to a cloud, business middle office, data middle office and a value network solution that quickly adapts to customer needs. The software development business gradually transitions from process-oriented to role, scenario, and demand-oriented.

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3.2. The integration mode dominated by technology motivation

The integration mode dominated by technology motivation refers to the application of information technology in traditional industries, which promotes the efficiency improvement, digitalization and automation transformation of traditional industries, and then rebuilds the company based on the network and uses information technology to generate a large number of data assets and establish a platform ecosystem, so as to expand the space for survival and development in the new era (LiuZhou,2015[29]). New technologies can improve efficiency and promote the continuous transformation to new from old economic engines. The improvement in efficiency in turn accelerates the application of information technology to traditional industries, thereby promoting the integration between traditional industries and the digital economy, as shown in Figure 1.

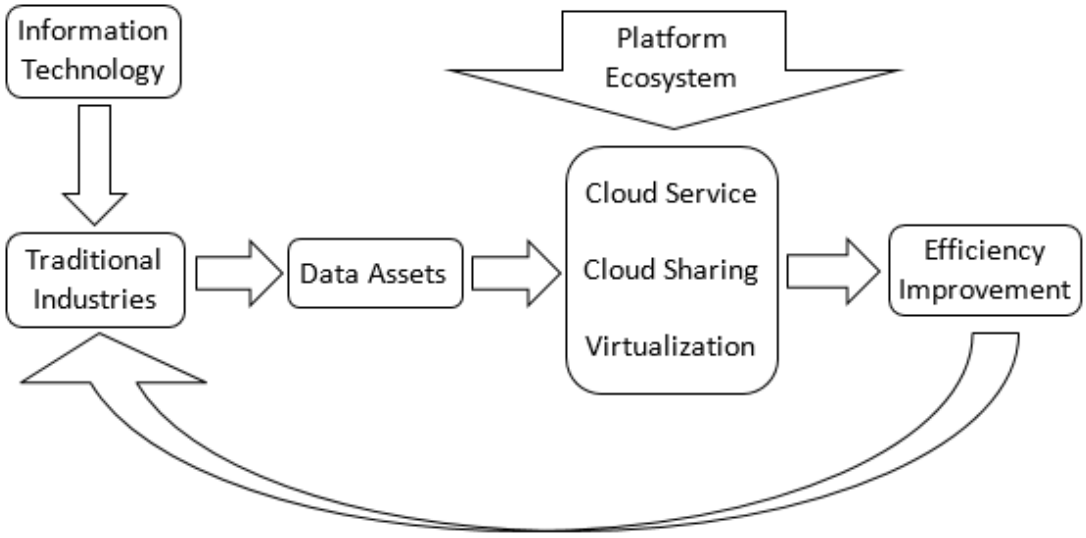

Figure 1: The integration mode dominated by technology motivation.

As the basic economic organization for coordinating and allocating resources in the digital economy era, the platform is the core of value creation and value aggregation, and it promotes the transformation of the industrial organization relationship from linear competition to ecological win-win. In the platform, value creation no longer emphasizes competition, but uses digital technology to integrate product and service providers, promotes transaction collaboration and moderate competition between them, and jointly creates value to cope with changes in the external environment (Tang Yaojia,2021[30]). Therefore, the platform is the core force of the industrial digital integration driving model.

3.3. The value-added service mode dominated by innovation motivation

The value-added service mode dominated by innovation motivation refers to the cost reduction and efficiency improvement of related industries driven by the business model innovation of the digital platform at the industrial end (Yang Zhuofan,2020[31]). In the era of industrial economy, the techno-economic paradigm is B2C, that is, a mode in which manufacturers are the center and demand is created and driven by the supply of commercial resources. The typical characteristics of B2C are standardized mass production, mass marketing, mass circulation, mass consumption, and mass finance (Yang Xiao, 2019[32]). The advent of the information economy has brought two significant changes to the business field: 1. On the demand side, consumers are first highly “empowered” by information, which leads to the transfer of power in each link of the value chain, and consumers are at the center of economic activities for the first time. As Prahalad wrote in " The Future of Competition: Co-Creating Unique Value with Customers": Consumers have changed from ignorant to well-informed, from scattered and isolated to widely connected, and from passive to active [33]; 2. On the supply side, the Internet has greatly improved the liquidity and penetration of information, reduced transaction costs, and greatly promoted large-scale social division of labor and collaboration. The mode of quickly gathering resources according to market demand and completing project tasks through online collaboration is prevalent. The C2B model originated from the change in the C-side caused by the empowerment of consumers by the Internet, which is an innovative business model in the era of digital economy, pioneered by Alibaba. The so-called "C2B" means that consumers put forward requirements, and manufacturers design consumer goods and

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equipment accordingly. This is a real revolution: an enterprise is no longer a single closed enterprise, but communicates flexibly with consumers at any time through the close connection between the Internet and the market (Han Yudong et al., 2016[34]). The typical performance of C2B on e-commerce platforms is shown in Figure 2.

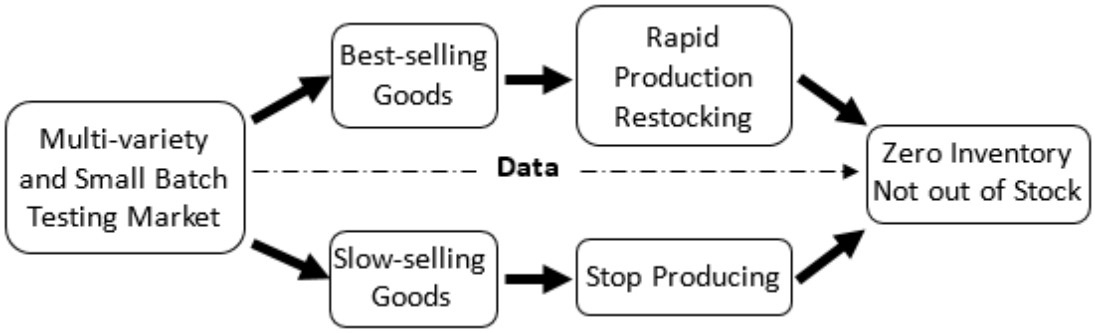

Figure 2: The typical performance of C2B on e-commerce platforms.

The retail side uses multiple varieties, small batches (low inventory), and fast delivery to capture market demand. The supply chain side conducts flexible production and continuous replenishment according to actual demand conditions such as best-selling, flat-selling, and slow-selling of different SKUs (stock keeping units). Even if the product is a hit, the merchant will continue to produce and replenish the product in multiple batches and small batches to ensure that the product will continue to be stocked throughout the life cycle, and there will be no excess inventory.

4. The Industrial Chain Reshaping Effect of Industrial Digitalization in China

Industrial digitalization reconstructs the organizational structure of enterprises and reinvents the process of the entire industrial chain through R&D reshaping, production reshaping, consumption reshaping, and collaboration reshaping.

4.1. R&D reshaping

The research and development of traditional industries is dominated by the company's own R&D team, which cannot directly understand consumers' need, so that the market research for consumers is limited and not timely. However, industrial digitization is able to directly conduct timely, in-depth and lasting two-way interaction with consumers through digital platforms, more accurately and quickly grasps market changes and users' pain points, and adjusts the direction and content of research and development at any time in a targeted manner. At the same time, consumers can directly participate in product R&D and design, bringing more sources of innovation to the industry, and promoting the transformation of R&D from closed self R&D to open crowdsourcing R&D in the past (Fan Zhuling and Liu Dewen,2018[35]). For example, Xiaomi mobile phone continuously optimizes and upgrades R&D programs through consumers' participation to enhances R&D capabilities.

4.2. Production reshaping

With the help of digital technologies such as cloud computing, big data analysis, and the Internet of Things, enterprises can not only locate user groups and needs more timely and accurately, realize intelligent allocation of production factors and dynamic management of production processes through relevant application software, so as to provide consumers with personalized and customized service(Wang Baicun et al., 2020[36]), but also dig out the deep value of a large amount of data information generated in the production process, reengineer the entire industry chain process of the enterprise, and finally realize intelligent, customized and flexible production (Wang Lei et al. , 2020[37]). For example, Haier Internet Factory, as a pioneer in the supply-side reform of traditional manufacturing in China, has become a model project for flexible manufacturing.

4.3. Consumption reshaping

Under the traditional consumption mode, enterprises usually rely on intermediate channels to find

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customers. This asymmetry of market information limits the expansion of the market and profits, and increases the time and economic costs of both parties of the transaction. Fortunately, digital technology has greatly weakened the asymmetry of information. Through online and offline multi-channel interaction, the precise and efficient connection between the supply and demand can be achieved, the traditional consumption format can be reconstructed, and omni-channel, interactive, and precise marketing can be realized (Gao Zhenjuan et al., 2021[38]). For example, e-commerce platforms represented by Alibaba and JD.com not only reduce the intermediate links of product sales, but also enhance the openness and transparency of the market.

4.4. Collaboration reshaping

Industrial digitalization not only facilitates the internal collaboration of enterprises and realizes the connection and integration of decentralized applications such as e-commerce, Internet finance, intelligent production, and mobile office, but also can connect different links of the industrial chain from the overall level to realize the collaborative linkage of upstream and downstream enterprises and create a more vital whole-industry ecosystem (Qi Yudong et al., 2020[39]). For example, the transaction information accumulated by the automobile industry through the digital platform plays a huge role in the research and development, trial production, sales and other links of the automobile industry chain, creating a synergistic and symbiotic ecosystem to achieve a win-win situation for all parties.

5. The Research Prospects of Industrial Digitalization in China

After more than ten years of development, China's industrial digitalization has formed many beneficial exploration results. The research content involves the concept, characteristics, development process, driving modes and industrial chain reshaping effects of industrial digitalization. However, compared with the classic topics of industrial economics such as industrial agglomeration and industrial integration, industrial digitalization is still a relatively new research field, and the analysis of many issues is not systematic and in-depth enough. The future research can be deepened from the following aspects:

The first is the design and calculation of China's industrial digital segmentation indicators. With the release of "Statistical Classification of Digital Economy and Its Core Industries (2021)", China's digital economy statistics work has entered the practical stage, and will face complex problems of classification data segmentation, especially the design and calculation of segmentation indicators. With the extensive penetration and integration of digital technology in various fields, the application traces of digital technology can be found in almost all economic activities. It is worth noting that the output increase and efficiency improvement brought by the application of digital technology in traditional industries have both digital and non-digital components. Taking online car-hailing as an example, it may cause great controversy if the traditional passenger services provided by drivers taking orders through the network are included in the scope of industrial digitalization accounting. If there is no scientific and reasonable division of the statistical scope of industrial digitalization, it is easy to fall into the dilemma of generalization, resulting in excessive statistics of the scale of the digital economy (Guan Huijuan et al.,2020[40]). Therefore, how to accurately strip digital components from statistical data is not only the focus of debate in the theoretical circles, but also the difficulty in the operation of practical departments. In addition, the manifestation and impact of industrial digitization will change with the development of digital technology, which means that the scope and classification of industrial digitization will face new challenges, and continuous research is required.

The second is the multiple effects of industrial digitalization in China. At present, researches on the effects of industrial digitalization in China mainly focus on industrial chain, industrial structure, industrial integration and other industry-related aspects, especially the reshaping effects of the industrial chain. However, as China entered the stage of high-quality development, the influence mechanism and effect of industrial digitalization on high-quality economic development has become one of the key points of future research (including ecological effects, social effects, economic effects, etc.),in order to provide a basis for industrial digital transformation to serve high-quality economic development.

The third is the regional heterogeneity of industrial digitalization in China. Existing studies have paid more attention to the differences in the time dimension of China's industrial digitalization, but not enough attention has been paid to the spatial dimension. Due to the objective differences in the initial conditions of economic development such as resource endowments and technological progress levels, coupled with the differences in the development environment of big data, China's industrial digitalization presents obvious spatial differences in structural characteristics. The heterogeneous level of industrial

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digitalization will have a differentiated influence on regional economic operation and industrial structure upgrading. The conclusions drawn only from the national macro-level research are difficult to apply to the practice of each region. Therefore, it is another important direction for further research to explore regional differences in the effects of industrial digitalization on economic growth and industrial structure.

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