ISSN: 2710-0170

Building a Secure and Resilient Digital Industrial Chain: Advantages, Challenges, and Governance Paths

Chengyan Zhou [a], Xiaohong Shi*

School of Economics, Anhui University of Finance and Economics, Bengbu, Anhui, China

[a]Zhouchengyan0502@126.com, *aufeshixiaohong@126.com

Abstract

Under the strategic guidance of coordinating development and security, building a secure and resilient digital industrial chain has become a core issue in promoting industrial modernization. Based on a theoretical analysis perspective, this paper systematically explains the dual roles of the digital economy in building industrial chain resilience. On the one hand, it analyzes the significant enabling advantages of the digital economy from three dimensions: information collaboration, intelligent decision - making, and ecological reconstruction. On the other hand, it identifies and discusses the real - world challenges faced in the current construction process, including risks of technological dependence, data security dilemmas, fragmented governance, and regional imbalances. Based on this, this paper proposes a systematic governance path for building a secure and resilient digital industrial chain from three levels: macro - institutional design, meso - industrial collaboration, and micro - enterprise capabilities, providing a theoretical reference for the implementation of the "coordinating development and security" strategy at the industrial level.

Keywords

Digital Economy; Industrial Chain Resilience; Secure Development; Collaborative Governance.

1. Introduction

In the context of the accelerating evolution of the once-in-a-century profound changes, coordinating development and security has become the core strategic guideline for China's economic and social development. The industrial chain and supply chain, as the backbone and blood of the national economy, their stability and resilience are directly related to economic security and national competitiveness. With the in - depth development of the new round of scientific and technological revolution and industrial transformation, the digital economy, with data as the key production factor, modern information networks as the main carrier, and the deep integration of digital technology and the real economy as the core feature, is reshaping the global industrial competition pattern and operation paradigm[1]. In this historical process, the digital economy shows great potential to inject new impetus for resilience into traditional industrial chains, but at the same time, it is also accompanied by unprecedented new risks and challenges. Therefore, systematically clarifying the internal logic and boundary of the digital economy's enabling of industrial chain resilience, analyzing the real obstacles in its evolution process, and constructing a governance system that matches it is not only a theoretical proposition that needs to be deepened urgently, but also a major practical issue related to long - term development.

ISSN: 2710-0170

2. Multi - dimensional Advantages of the Digital Economy in Enabling Industrial Chain Resilience

The rise of the digital economy is essentially another profound manifestation of the general-purpose technology paradigm in the information field. It lays a new technological and economic foundation for the industrial chain to shift from pursuing static efficiency optimization to achieving dynamic resilience adaptation by reducing information asymmetry, optimizing resource allocation, and reconstructing the production organization mode[2]. This enabling advantage is not a single-dimensional improvement, but a systematic enhancement that penetrates the entire process and multiple levels of the industrial chain operation.

2.1. Information Penetration and Global Perception Advantages

Traditional industrial chain management is often troubled by "information silos" and "data chimneys". The information transmission between various links is lagging and distorted, resulting in a "hazy" perception of potential risks, and the response actions are often lagging and passive. Relying on the Internet of Things, radio frequency identification, sensor networks, and industrial Internet platforms, the digital economy has built a "nerve ending" for real - time mapping between the physical world and the digital space[3]. This technological architecture enables the state data of the entire industrial chain, from raw material procurement, component production, product assembly to warehousing, logistics, and terminal sales, to be collected, aggregated, and analyzed in real - time. For example, through sensors installed on key equipment, its operating parameters can be monitored in real-time, and fault risks can beearly-warned in advance with the help of predictive maintenance algorithms to avoid supply chain disruptions caused by unplanned downtime. At the same time, combined with external data such as satellite remote sensing and automatic identification systems for port ships, enterprises can macroscopically grasp the potential impacts of global logistics dynamics, geopolitical events, and even climate anomalies on the supply chain network, thereby moving the risk management forward. This almost panoramic and transparent perception ability is the premise for building a full- cycle resilience management system of pre-warning, in-process response, and post-recovery, upgrading risk management from the traditional experience-driven and passive-response mode to a new data- driven and proactive-prediction mode[4].

2.2. Intelligent Decision - Making and Dynamic Adjustment Advantages

In the face of sudden shocks, the speed and scientific nature of decision-making directly determine the effectiveness of resilience recovery. Intelligent technologies represented by artificial intelligence, machine learning, and digital twins have greatly strengthened the decision-support and dynamic reorganization capabilities of the industrial chain. Digital twins allow managers to conduct "stress tests" and "pre-plan deductions" in the digital space by constructing a high-fidelity virtual mirror image of the physical industrial chain, evaluating the scope and transmission path of the impact of various interruption scenarios at low cost and high efficiency, and thus formulating and optimizing emergency pre-plans in advance[5]. When an actual interruption occurs, the intelligent scheduling system based on algorithms such as reinforcement learning can recalculate the optimal or satisfactory production plan, inventory allocation plan, and logistics route in a very short time according to the real-time updated production capacity, inventory, and transportation capacity data, realizing the multi-objective dynamic optimal allocation of resources[6]. For example, during the shutdown of a factory in a certain place due to the COVID-19 pandemic, some advanced manufacturing enterprises used the supply chain control tower and intelligent algorithms to quickly re-assign production tasks to other bases with idle production capacity and dynamically adjust the global logistics routes, significantly reducing the impact of the shock. This plug-and-play elastic scheduling ability

ISSN: 2710-0170

enables the industrial chain to quickly adapt to environmental changes like an organism when facing uncertainties and maintain the continuous operation of core functions.

2.3. Network Collaboration and Ecological Reconstruction Advantages

The vigorous development of industrial Internet platforms and industrial ecosystems is catalyzing a fundamental change in the organizational form of the industrial chain, from a chain-like structure centered on core enterprises with linear connections between upstream and downstream to a network ecosystem with equal connections among multiple subjects and open and shared capabilities[7]. This structural transformation itself is a deep-seated enhancement of resilience. In the networked ecosystem, the connections between enterprises are diverse and redundant. The platform reduces the technical threshold and transaction costs of collaboration between enterprises by providing standardized data interfaces, shared microservice components, and an open application development environment, promoting the online, modular, and platform- based sharing of design, production, service, and other capabilities[8]. When a node in the ecosystem fails due to an impact, its functions can be quickly taken over by other neighboring nodes or nodes with similar capabilities. For example, in an ecosystem based on a cloud manufacturing platform, an urgent component processing task can be completed collaboratively or competitively by multiple factories with different geographical distributions and similar processes on the platform, effectively avoiding the risk of a single supplier. This distributed and decentralized network structure has higher robustness and reconfigurability. It weakens the inherent "single - point failure" risk in the traditional chain-like structure, enabling the industrial chain to maintain the stable operation of the overall network through path reconstruction and function substitution when locally damaged[9].

2.4. Risk Diversification and Backup Capability Advantages

The new models and new business forms spawned by the digital economy objectively provide the industrial chain with more abundant risk-diversification tools and backup options. Supply chain financial technology uses big-data risk control and blockchain technology to more accurately evaluate the credit of small and medium-sized enterprises, alleviating their financing constraints, thereby stabilizing the large-scale but usually fragile small and medium-sized enterprise nodes in the supply chain network and enhancing the stability of the network foundation[10]. Flexible manufacturing systems and additive manufacturing technologies make it possible to produce in small batches, with multiple varieties, and quickly switch production, providing a strategic buffer for enterprises to cope with drastic fluctuations in market demand or the interruption of specific-model component supplies. More importantly, digital platforms have greatly expanded the scope and efficiency of enterprises' search for and integration of global innovation resources and production capacity resources. Enterprises can more easily find alternative suppliers, alternative technical solutions, or temporary cooperation production capacity, building a digital "virtual spare tire library" or "production capacity reservoir". This flexible backup capability based on digital connections means that the industrial chain no longer completely relies on high-cost physical backups established in advance, but can quickly activate and integrate potential resources through the digital market when needed, forming a dynamic and relatively low-cost backup capability, significantly improving the flexibility to cope with sudden and uncertain shocks.

3. Real - World Challenges in the Process of Building Resilience

3.1. Core Technology Dependence and New“Chokepoint”Risks

The deeper the digitalization of the industrial chain, the more its operation is based on a digital technology base composed of high-end chips, basic software, core algorithms, and advanced sensors. However, the global supply chain of this base shows highly concentrated and

ISSN: 2710-0170

geographically asymmetric characteristics. From chip design software to extreme ultraviolet lithography machines, from high-end server CPUs to precision industrial robot controllers, many key links are dominated by a very small number of countries and enterprises. This deep dependence exposes the digitalized industrial chain to a new type of strategicchokepointrisk. Once the supply of core digital technologies is interrupted due to political, trade, or technological reasons, its impact will be quickly transmitted and amplified along the digital network, possibly leading to a series of chain reactions from the shutdown of intelligent factories, the paralysis of data centers to the failure of logistics systems. Compared with the risk of a specific component supply interruption in traditional manufacturing, the supply interruption of the digital technology base has a wider impact range, greater repair difficulty, and a longer replacement cycle. It may instantly invalidate all resilience measures built at the physical level in the digital dimension. Therefore, ensuring the security and controllability of the digital technology supply chain has become the most basic and urgent issue for industrial chain resilience in the digital economy era.

3.2. Data Security, Sovereignty, and Compliance Dilemmas

Data, as the blood of the digital economy, its free and secure flow is the premise of value creation, but it also constitutes the main source of risk. First, the threat to data security is severe. The massive data generated in the operation of the industrial chain, including core production process parameters, supply chain maps, customer information, and trade secrets, has become the main target of cyberattacks, ransomware, and industrial espionage. A successful data attack may not only lead to the leakage of intellectual property rights and production interruption, but may also be used to manipulate the production process, causing physical damage. Second, the issue of data sovereignty is prominent. As the data of the global industrial chain converges to a few multinational cloud platforms and industrial Internet platforms, a governance contradiction between cross-border data flow and local storage has emerged. The outflow of key industrial data may face the risk of improper access and utilization, threatening national industrial security and economic security. Finally, the fragmentationof global data governance rules brings high compliance costs. The EU's General Data Protection Regulation, the US's Clarifying Lawful Overseas Use of Data Act, and China's Data Security Law and Personal Information Protection Law have many differences and even conflicts in aspects such as cross-border data transmission, personal information protection, and law-enforcement data retrieval. When multinational enterprises operate the global industrial chain, they have to invest a huge amount of resources to meet complex compliance requirements, which virtually increases the institutional transaction costs and may hinder the optimal allocation of data, forming a "paradox of data flow".

3.3. Fragmented Governance Framework and Lack of Standard System

Currently, digital economy governance shows significant "fragmentation" characteristics at the global, regional, and national levels, and a unified and mutually recognized technical standard and industrial rule system has not been fully established. This situation seriously restricts the network collaboration effect of the industrial chain. On the one hand, technical standards are incompatible. The industrial Internet platform architectures, data communication protocols, and device interface standards introduced by different countries and different industry alliances are different, resulting in difficulties in device interconnection and forming new "digital silos".

ISSN: 2710-0170

4. Governance Paths for Building a Secure and Resilient Digital Industrial Chain

4.1. Macro - Level: Strengthening Strategic Planning and Institutional Design

The government should play a leading role in formulating a long-term development strategy for the digital industrial chain, guiding the overall direction of industrial development through policies, regulations, and standards. It is necessary to clarify the strategic positioning, development goals, and key tasks of the digital industrial chain, and promote the coordinated development of various industries. At the same time, it is necessary to improve the legal and regulatory system related to the digital economy, strengthen the protection of intellectual property rights, data security, and privacy, and create a good legal environment for the development of the digital industrial chain.

4.2. Meso-Level: Promoting Industrial Collaboration and Ecosystem Construction

Industry associations and platforms should play a bridging role, promoting in-depth cooperation between enterprises in the industrial chain, sharing resources, and jointly exploring new business models. Encourage the construction of industrial Internet platforms, promote the digital transformation and upgrading of small and medium- sized enterprises, and improve the overall competitiveness of the industrial chain. At the same time, it is necessary to strengthen the construction of the industrial ecosystem, promote the coordinated development of upstream and downstream industries, and form a virtuous cycle of mutual promotion.

4.3. Micro - Level: Enhancing Enterprise Resilience and Innovation Capability

Enterprises are the main body of the digital industrial chain. They should strengthen their awareness of risk prevention, improve their digital transformation capabilities, and build a flexible and resilient production and operation system. In terms of technology strategy, it is necessary to increase R&D investment in basic and key digital technologies or make layouts through investment, alliances, etc., to reduce deep dependence on a single technology source. Actively adopt open-source technology routes, while enjoying the innovation dividends of the community, cultivate their own technology understanding and control capabilities. In terms of supply chain management, it is necessary to make full use of digital tools to comprehensively sort out and visualize the multi - level supply network, accurately identify bottleneck links and single-source risks. Based on this, actively promote the diversified, near-shore, or friendly-shore layout of suppliers, and establish strategic reserves of key materials or sign production capacity backup agreements with suppliers. In addition, talent and culture are the foundation of resilience. Enterprises need to focus on cultivating and introducing composite talents who understand both digital technology and business processes and have a sense of risk. At the same time, through training, drills, and incentive mechanisms, a "resilience culture" should be cultivated throughout the company, encouraging employees to actively identify risks and participate in pre-plan formulation, making resilience everyone's responsibility and behavioral consciousness.

4.4. Linkage Level: Building a Governance Mechanism of Multi-Party Co-Governance and Dynamic Iteration

The construction of a secure and resilient digital industrial chain is a long - term process of continuous evolution and dynamic adjustment, which requires the establishment of an efficient multi-party linkage and feedback iteration mechanism. A regular dialogue and cooperation platform jointly participated by the government, enterprises, industry associations, scientific research institutions, and professional think-tanks should be built to conduct regular risk assessments, policy consultations, and joint drills. A three -level linkage security risk

ISSN: 2710-0170

monitoring and early - warning network covering key industrial chains, namely "national-level, industry - level, and enterprise-level", should be constructed. Using big-data and artificial intelligence technologies, multi-source information such as macro-economy, geopolitics, natural disasters, cyber threats, and public opinions should be integrated to achieve early identification, intelligent analysis, and accurate early-warning of industrial chain risks, and a standardized risk information notification and sharing mechanism should be established to improve the efficiency of collaborative response. It is crucial to establish a "reverse feedback" channel from micro - practice to macro-governance. Through the establishment of an enterprise resilience construction case library, the evaluation of policy implementation effects, the establishment of an entrepreneur advisory committee, etc., the technical problems, standard requirements, and policy obstacles encountered by front-line enterprises in the process of building digital resilience should be timely feedback to policy - makers and standard-setting institutions, promoting the continuous optimization and iteration of relevant laws, regulations, technical standards, and industrial policies, and forming a benign governance closed-loop of "practice exploration-policy feedback-rule improvement-better practice"[11].

5. Conclusion

The in-depth integration of the digital economy and industrial chain resilience is a profound change related to the dominance of future development, and its strategic significance is no less than any revolutionary leap in industrial organization since industrialization. On the one hand, this integration eliminates the blind spots between supply and demand through information penetration, improves the accuracy and speed of resource allocation through intelligent decision-making, realizes instant linkage across subjects and regions through network collaboration, and builds a reconfigurable and substitutable production capacity through flexible backup, thus injecting unprecedented revolutionary potential into the industrial chain to resist external shocks, digest internal frictions, and achieve dynamic balance. On the other hand, it also faces the risk of global turmoil caused by a single-point failure due to the systematic dependence on the technical base, the compound challenges of privacy leakage, algorithmic bias, and sovereign jurisdiction due to the deep penetration of data elements, the institutional frictions of standard fragmentation and regulatory arbitrage due to the fragmentation of governance rules, and the widening of the resilience gap between leading enterprises and small, medium, and micro-enterprises due to the uneven distribution of digital capabilities. This distinct "double-edged sword" effect deeply reveals that digital enabling does not automatically and necessarily translate into industrial chain resilience. The conversion efficiency and final effectiveness between them highly depend on a systematic governance framework that can handle technical complexity, balance diverse interest demands, and achieve incentive compatibility. Without this framework, advanced technical equipment may become a tool to strengthen the existing monopoly pattern, a large amount of data resources may give rise to new types of dependency relationships, and the overall resilience of the industry may be quietly eroded under the appearance of local high-agility.

Acknowledgments

This work is supported by Anhui Province Social Science Planning Project, “Research on Mechanism Innovation and Path Optimization of Urban Rural Integration in the New Development Stage” (Number: AHSKY2022D092).

ISSN: 2710-0170

References

[1] Xiao, J. H., Hu, Y. S., & Wu, Y. (2020). Growth products: A case study of data-driven interactive innovation between enterprises and users. Management World, 36(3), 183–205.

[2] Bresnahan, T. F., & Trajtenberg, M. (1995). General purpose technologies: Engines of growth? Journal of Econometrics, 65(1), 83–108. https://doi.org/10.1016/0304-4076(94)01594-T

[3] Zhao, C. J., Li, J., & Feng, X. (2021). Research on the development strategy of smart agriculture towards 2035. China Engineering Science, 23(4), 1–9.

[4] Ivanov, D., & Dolgui, A. (2021). A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0. Production Planning & Control, 32(9), 775–788. https://doi.org/10.1080/09537287.2020.1820260

[5] Ren, B. P., & Cao, Z. Y. (2025). The mechanism and path of the digital ecosystem promoting the deep integration of the real economy and the digital economy. Journal of Humanities, (8), 113–122.

[6] Huang, Y. P., & Huang, Z. (2018). The development of digital finance in China: Present and future. China Economic Quarterly, 17(4), 1489–1502.

[7] Guo, X. M., & Lv, Z. F. (2024). The connotation, characteristics, development blockages, and practical paths of the new-quality productivity in agriculture. Academic Journal of Zhongzhou, (8), 38–45.

[8] Gawer, A., & Cusumano, M. A. (2014). Industry platforms and ecosystem innovation. Journal of Product Innovation Management, 31(3), 417–433. https://doi.org/10.1111/jpim.12105

[9] Yao, Y. C., & Zhang, J. S. (2023). A political-economic analysis of the digital economy enabling urban-rural integration development. Inner Mongolia Social Sciences, 44(2), 117–125, 213.

[10] Xie, Y. X., & He, S. Q. Digital product import, enterprise innovation, and export competitiveness. Commercial Research, 1–16.

[11] Wu, J. H., & Guo, Y. X. (2024). The digital economy boosts the development of new-type urbanization: An analysis based on the spatial Durbin model and threshold model. Resource Development & Market, 40(9), 1350–1361.