

The Impact and Strategic Responses of Digital Economy Development on China's Manufacturing Industry

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Abstract. The rapid expansion of China's digital economy has significantly transformed the manufacturing sector, enhancing production efficiency and supply chain optimization through technologies such as IoT, AI, and blockchain. However, this digital transition is accompanied by substantial challenges, including a persistent digital divide between large enterprises and SMEs, regional disparities, and growing cybersecurity risks. Based on a descriptive case analysis and review of existing policies and enterprise practices, this paper examines the impact of digitalization—highlighting its potential for operational improvement and innovation, while also addressing structural barriers that hinder inclusive and secure adoption. The study proposes a dual strategy to mitigate these issues: first, through collaborative skill-development initiatives such as regional Digital Skills Hubs and tripartite cooperation among government, academia, and industry; second, via a multi-layered cybersecurity framework incorporating security-by-design, shared Security Operations Centers, and continuous staff training. These recommendations aim to support the construction of a resilient, inclusive, and innovative digital manufacturing ecosystem in China. The findings provide a strategic framework for policymakers and industry leaders to navigate the complexities of digital industrialization.

Keywords: Digital Economy; Manufacturing; Digital Divide; Cybersecurity; Tripartite Collaboration.

1. Introduction

The digital economy's expansion represents a significant shift in global industrial development during the 21st century. This shift is particularly visible in China. Official statistics indicate that China's digital economy exceeded 50 trillion RMB in scale in 2022. This scale constitutes over 40 percent of the country's Gross Domestic Product [1]. The manufacturing sector forms a core component of the national economy. The manufacturing sector contributes approximately 30 percent to China's GDP. It also supports the employment of over 100 million workers. This situation makes the sector's digital transformation a matter of strategic importance [1].

Technological innovation serves as a primary driver of this industrial change. A group of key technologies enables new capabilities. These technologies include artificial intelligence, the Internet of Things, and big data analytics. Blockchain and cloud computing are also part of this group. These technologies allow manufacturing enterprises to handle information on a larger scale. Research indicates that the application of these technologies leads to higher operational efficiency. They also allow for greater production flexibility and customization [2]. Specific data exists regarding their impact. Production systems that utilize the Internet of Things can increase productivity by 20 to 30 percent. Those same systems can reduce operational costs by 15 to 25 percent [3]. Another technology, the digital twin, facilitates process optimization without interrupting actual production [3].

Supply chain management is one area experiencing major changes from digitalization. The use of blockchain technology creates records that are difficult to alter. This characteristic improves the traceability of goods. It also lowers the risk of counterfeit products entering the supply chain [4]. Artificial intelligence contributes through forecasting models. These models make inventory management more refined. Cloud computing platforms allow different participants in a supply chain to coordinate their activities in real time [5]. Evidence from Chinese companies shows measurable

outcomes. Companies that use digital supply chain solutions achieve gains in logistics efficiency. These companies also demonstrate reductions in inventory costs [6].

The pathway of digitalization, however, encounters substantial structural barriers. A significant challenge is the difference in capability between large firms and small and medium-sized enterprises. This difference is known as the digital divide. Small and medium-sized enterprises often lack sufficient financial resources for digital investment. They also frequently lack the necessary technical knowledge. Organizational readiness for sophisticated digital systems is another common shortcoming [7]. Regional differences within China present another layer of complexity. Manufacturing hubs in coastal provinces generally possess more advanced digital infrastructure. Interior provinces tend to have less developed infrastructure and innovation ecosystems [8]. A survey by the China Academy of Information and Communications Technology provides a specific figure. Over 60 percent of small and medium-sized enterprises report major difficulties in hiring digital talent [8]. This shortage slows down the pace of technology adoption.

Cybersecurity concerns present further complications. The increased connectivity of manufacturing systems introduces new vulnerabilities. These systems face threats such as ransomware attacks and data breaches. Theft of intellectual property is another significant risk [9]. A specific incident from 2017 illustrates the potential impact. A cyber-attack targeted a major automobile manufacturer. The attack forced the company to stop its production operations for a period of three weeks. The estimated financial losses from this event exceeded 20 million U.S. dollars [10]. This case shows the serious vulnerabilities present in connected industrial environments. Regulatory frameworks exist to address these risks. China's Cybersecurity Law is one example. The Multi-Level Protection Scheme is another. These frameworks provide important safeguards. Yet, they often struggle to keep pace with the speed of technological change. They also frequently offer insufficient protection for smaller enterprises [11].

The combination of opportunities and challenges creates a complex situation. Technological advances offer clear potential for efficiency gains and innovation. Structural barriers, however, risk limiting the distribution of these benefits. Much of the existing research has focused on the positive technological and economic outcomes. There has been less examination of practical strategies to overcome the systemic obstacles. The specific situation of small and medium enterprises has received limited investigation. These enterprises form the base of China's industrial system. Understanding their effective transition is important.

This investigation aims to conduct a comprehensive analysis. The analysis focuses on the impact of the digital economy on China's manufacturing industry. It will consider both the positive influences and the critical challenges. The research will examine policy frameworks and the practices of enterprises. It will also include a detailed assessment of the existing problems. The goal is to contribute useful insights. These insights may support the building of a more inclusive, secure, and innovative manufacturing ecosystem.

2. Case Description

China's manufacturing sector provides a clear example for studying industrial modernization driven by technology. Government policy has played a decisive role in shaping this development. A key policy initiative, named Made in China 2025, was launched in 2015. This initiative places a clear emphasis on smart manufacturing and industrial upgrading. It actively promotes the adoption of new technologies [12]. These technologies include artificial intelligence, robotics, and cloud computing. A subsequent policy, the 14th Five-Year Plan, continued this direction. It set ambitious goals for the development of industrial internet platforms. It also focused on creating advanced manufacturing clusters and intelligent supply chain systems [13]. These policy frameworks provide strategic direction for the entire sector. They also offer tangible financial incentives to companies. These incentives include direct subsidies for technology adoption. Tax benefits for research and development activities are also available. There is also support for leading national champion

companies. These measures encourage companies to view digitalization as a path to enhancing their global competitiveness.

The practical application of digital transformation is observable at the level of individual enterprises. Several prominent cases exist. The Haier Group developed an industrial internet platform called COSMOPlat. This platform functions by connecting consumers, suppliers, and manufacturers into a single network. A key feature is its enablement of mass customization. It achieves this by incorporating real-time consumer feedback directly into production planning and processes. This integration shortens product development cycles. It allows for the production of tailored solutions on a large scale [14]. Another example is the technology company Huawei. Huawei has constructed fully connected factories. These factories utilize digital twin technology to create virtual models of physical operations. They also employ predictive maintenance systems to anticipate equipment failures. This approach demonstrates how expertise from the telecommunications sector can be transferred to manufacturing [15]. In the automotive industry, SAIC Motor provides a further case. The company has implemented production lines that are driven by artificial intelligence. It has also installed monitoring systems based on the Internet of Things. These implementations have led to safer operational environments. They have also provided better visibility across the company's extensive supply chain [16]. These cases illustrate that digital technologies do more than improve efficiency. They can also enable the creation of completely new business models.

Conversely, many small and medium enterprises face a different situation. Manufacturers located in inland provinces also encounter significant challenges. The obstacles to adopting digital solutions are significant. The primary barriers are limited financial capacity and a pronounced shortage of technical talent. There is also the issue of less developed digital infrastructure outside the major coastal hubs. These enterprises typically have less access to venture capital funding. They also have fewer technology firms and research institutions in their immediate vicinity. This relative isolation hinders their ability to acquire knowledge and form partnerships necessary for digital upgrading [7, 11]. The result is a clear division within the sector. This division exists between large, technologically advanced firms and smaller, less digitalized ones. It also exists between the developed coastal regions and the less developed interior provinces [8]. This divergence risks slowing the overall advancement of the entire manufacturing sector. It also has the potential to make regional economic inequalities more severe. Therefore, the main objective is to catalyze a broad, inclusive, and sector-wide modernization. In contrast, the alternative is a future characterized by a divided industrial landscape.

3. Analysis of the Problem

3.1. Positive Impact of Development of Digital Economy on China's Manufacturing Industry

3.1.1 Promoting the efficiency of Production

The rapid growth of the digital economy, including the Internet of Things (IoT), artificial intelligence (AI), and big data analytics, has triggered a critical transformation in China's manufacturing industry. For instance, the application of smart manufacturing systems allows enterprises to monitor, correct, or optimize the performance of operations in a timely manner. This can efficiently reduce the downtime of equipment, capital expenditure, and maintenance costs. In dangerous and repetitive tasks, industrial computers and automated manufacturing lines have largely displaced manual labor, improving working conditions and maintaining consistent product quality. To ensure daily maintenance and reduce unanticipated production interruptions, AI-powered predictive maintenance systems analyze technology device data to forecast potential problems before they occur. According to research, IoT-based automation systems have led to productivity increases of 20 to 30 % and operational cost savings of between 15 % and 25 % [2]. In addition, by using digital twin technology, the virtual replicas of actual assets can be generated, which enables manufacturers to simulate testing and marketing without practical production. Such technological advancements can remarkably enhance the overall equipment effectiveness (OEE) and flexibility of operation [3]. In

essence, this series of technologies facilitates a transition of decision-making from an experience-based style to a data-driven approach, thus optimizing the entire production lifecycle. Digital development also promotes productive methods and alleviates the effects of climate change by utilizing the smart grid and real-time monitoring systems.

3.1.2 Optimization of supply chain management

As a result of the popularization of the digital economy, the strategies of supply chain management in China's manufacturing industry witness significant shifts. The blockchain technology, which ensures product provenance tracking throughout the whole supply chain, can be seen as an effective way of addressing the issue of widespread fakes and raising consumer confidence. In practice, all supply chain individuals ought to have access to a single source of truth by using distributed ledger technology, which reduces conflicts and enhances operational efficiency [4]. Thus, the link between parties based on mutual trust can shift to a system reliant on encrypted verification and distributed consensus, substantially reducing the cost of transactions and communication. Artificial intelligence algorithms, which can collect traditional sales data, market trend patterns, and externalities such as seasonal or economic indices, play a crucial role in forecasting public needs, thus strengthening the effectiveness of stock management. The supply chain cloud-based platform, correspondingly, provides a transparent and efficient system through real-time information sharing among all sectors within the whole chain. For instance, such a method helps Chinese manufacturing companies achieve a 25% to 30% increase in logistics efficiency and a 30% to 40% decline in the costs of goods, inventory, and management [5]. Additionally, Internet of Things devices, integrated with global positioning systems and radio frequency identification, make real-time monitoring of goods while in transit possible, offering more precise and timely updates of goods' status. Such digital transformation helps manufacturers build more flexible and resilient supply chains, which better adapt to condition changes and unexpected events, thus enhancing their competitiveness in the global context [6]. Besides, the blockchain system can automate the payment procedures, handle sophisticated tasks, and reduce the transaction costs, further improving the entire performance of the supply chain.

3.2. Problem Analysis

Given the fact that the development of the digital economy can be conducive to China's manufacturing industry to a large extent, challenges that may potentially hinder overall performance and exacerbate existing problems cannot be neglected.

3.2.1 Digital divide and skill gaps

Even with the ambition of following the pace of digital transformation, some companies still struggle due to skill deficiencies and the digital divide. In terms of digital resources and capabilities, a huge gap exists between large enterprises and small or medium-sized enterprises (SMEs). Large companies with abundant financial budgets can bet heavily on cutting-edge technologies like business Internet of Things, artificial intelligence, or cloud-based platforms. They can also hire talented professionals who are highly skilled or well-educated and provide professional and comprehensive employee training programs. These approaches help large enterprises grow increasingly fast. In contrast, SMEs suffer from limited financial resources and technical knowledge, making them struggle to implement and maintain the practical digital systems [7]. The shortage of skilled workers who can build, maintain, and operate online techniques even makes the situation worse. Most traditional manufacturing workers lack the specialized skills and technical knowledge required to operate the digital technology. In contrast, the recent graduates often have insufficient practical experience. According to reports, about 60 % of developing SMEs have trouble attracting and keeping employees with sufficient online skills, which significantly slows their digital adoption and development [8]. Regional differences can exacerbate the issue. More specifically, modern manufacturing enterprises prefer to stick together in a sea area and grow rapidly; the inland companies, however, are left behind, finding it hard to have access to up-to-date information. Consequently, the

high cost of digital adoption limits the talent available to SMEs, further constraining their capability for research and development.

3.2.2 Harm to data security and privacy risks

The wide-range adoption of modern technology in manufacturing can lead to important and complex data and privacy issues. These issues further expanded the scope of cybersecurity challenges, as manufacturing technologies are increasingly connected to the Internet and integrated with the information technology networks of enterprises. Ransomware, data breaches, and intellectual property theft are now possibilities for industrial control systems (ICS) and supervisory control and data acquisition (SCADA) systems, which were previously isolated. Such problems have a wide range of negative effects, from manufacturing downtime and quality concerns to health situations and significant financial losses [9]. Take a Chinese automaker as an example, in 2022, it was one of the victims of a ransomware attack, resulting in a suspension of production for three weeks, with an estimated loss of over 20 million U.S. dollars, and massive leakage of core design files [10]. This event highlights the serious vulnerabilities in highly digitized but inadequately protected manufacturing operations, indicating that cybersecurity is no longer merely an IT issue but a core operational risk, leaving critical infrastructure exposed. There are also forms of external threats and internal risks, such as employee errors, inadequate access control, and the lack of data protection measures. Although basic guidance directions have been provided, the current regulatory frameworks, such as China's "Cybersecurity Law" and the Multi-Layered Protection Scheme (MLPS), often struggle to keep up with the rapid changes in threats in the commercial environment. Some businesses, especially SMEs, are prone to problems because they lack the knowledge and tools to implement complete security procedures [11]. Also, large amounts of administrative data are collected and processed, which raises privacy issues, particularly when it comes to personal information. To ensure the safety and resilience of modern manufacturing ecosystems, stronger protective measures, industry-specific standards, and improved collaboration between manufacturers, technology providers, and regulatory bodies are required in this difficult landscape of security challenges. Normal safety assessments and the incorporation of security-by-design principles into digital transformation projects are necessary components of a complete cybersecurity technique.

4. Suggestion

The challenges posed by the digital divide and data security risks are significant, yet they can be effectively mitigated through targeted, collaborative strategies. The following solutions focus on creating sustainable frameworks for skill development and robust cybersecurity protocols, ensuring that the digital transformation of China's manufacturing sector is both inclusive and secure.

4.1. Bridging the Digital Divide through Collaborative Skill Development

A multi-stakeholder method involving government, educational institutions, and industry is necessary to address the serious shortage of online talent and the major differences between big enterprises and SMEs. Regional Digital Skills Hubs, which are co-funded by local governments and private companies, are a tempting type, and empirical evidence suggests that higher education quality indeed strengthens the positive effect of the digital economy on manufacturing competitiveness [17]. These centers may provide standard instruction on practical, industry-relevant knowledge like IoT repair, data analytics, and AI-assisted manufacturing procedures. For instance, a hub could offer a certified short-course on "Data-Driven Predictive Maintenance for CNC Machining", which combines online theoretical modules with hands-on workshops conducted in a partner factory. This method creates a common education standard while lowering individual SMEs' financial burdens.

Additionally, recent graduates' ability to bridge the theory-practice space can be effectively bridged by incorporating work-study programs into higher knowledge and technical training methods [18]. For instance, colleges in manufacturing-intensive regions should collaborate with local businesses to offer alternating periods of scientific study and hands-on apprenticeships. Students gain

practical experience as a result of this and maintain a regular skill pipeline for SMEs battling with enrollment.

For SMEs that enroll employees in qualified mentoring programs, the government does encourage participation through tax breaks or subsidies. According to research from pilot projects in Zhejiang Province, coordinated efforts can increase digital talent retention by up to 40 % in SMEs in two years. Ultimately, moving away from isolated business training to shared, open skill development facilities that benefit the whole production industry is necessary to create a tenacious skills ecosystem.

4.2. Building a Resilient and Multi-Layered Cybersecurity Framework

A responsive approach to data protection is inadequate given the more sophisticated digital threats. Manufacturers ought to adopt a strategic, integrated approach incorporating corporate culture-building, technological advancement, and regulation compliance. Manufacturers go beyond basic needs, even though compliance with national systems like the MLPS (Multi-Level Protection Scheme) is required. In all projects involving digital transformation, security-by-design principles must be implemented, as highlighted in systematic reviews of industrial control systems security that emphasize integrating safeguards at the design stage [19]. This implies that security is immediately integrated into the infrastructure of business IoT and fog systems. For instance, strict exposure settings based on the principle of least privilege and data encryption at rest and in transit can drastically lower internal and external risks.

Second, unresolved IT security challenges remain a major barrier to Industry 4.0 adoption in manufacturing SMEs. Shared SOC's could therefore provide the collective resources and expertise necessary to overcome these limitations and ensure more secure digital transformation [20]. By combining resources and expertise that are unmatched by a single small firm, these centers would offer affordable, real-time threat monitoring and incident response services to several SMEs. This social protection model's security position significantly improves the supply chain's most resilient players.

Lastly, employees receive ongoing training in digital hygiene, such as how to identify phishing efforts and adhere to secure information handling practices. Even though human-made errors remain the main reason for data leaks, building a safety culture is equally significant as investing in technological advancements. To mitigate the problems, staff can be trained for potential attacks using regular simulations and drills. The industry can create the necessary, reliable, and secure online environment by adopting a layered approach, which combines compliance, technical resilience achieved through design, collaborative defense mechanisms for small and medium-sized enterprises, and continuous human training.

5. Conclusion

China's industrial framework is currently experiencing a profound restructuring, a process deeply intertwined with the implementation of intelligent manufacturing principles. Observers note a transition in operational methodologies, where managerial staff increasingly depend on integrated data platforms for the oversight of production assets. This approach is augmented by assembly systems capable of predictive self-analysis, thereby forestalling operational halts through preemptive maintenance alerts. The overall outcome of these technological shifts shows a clear improvement in financial resources and a steady drop in excess material throughout production sequences. An obvious divide, however, marks the spread of these industrial changes. Large production centers, mostly located in coastal economic zones, gain from the funds needed to apply modern robotic and data-analytic solutions, in addition to attracting trained engineering workers. This situation contrasts strongly with the work setting of smaller productive groups, often based in inland regions. For these groups, the initial financial cost for upgrades, combined with a limited labor market for digital skills, creates a serious barrier to innovation. The related economic weaknesses often make upgrade plans unrealistic. This gap is forming a technological divide with clear social effects. Regions that serve as

hosts to updated industrial work usually show economic strength and growth. On the other hand, areas whose economic bases depend on traditional production methods face major problems in sustaining growth. So, strategic plans must

focus on bridging this technological gap with scalable automation tools, specialized technical training programs, and new financial products designed for smaller groups. Second, securing manufacturers' digital information and intelligent systems calls for a layered cybersecurity model that combines security-by-design practices, real-time threat detection through shared Security Operations Centres, and continuous staff training in digital hygiene. Both strategies are designed to create an inclusive and resilient digital manufacturing ecosystem. This study contributes to business and society in two ways. Practically, it offers a solution pathway for Chinese manufacturers--especially SMEs--to bridge their structural constraints and join the digital economy. Policy-wise, it highlights the need for an inclusive digital infrastructure and targeted human resource development to achieve balanced regional digitalization. Socially, it calls for reducing inequality by narrowing the digital gap and building a secure and innovation-ready digital ecosystem that benefits all. Despite its implications, this study is not without limitations. This research is based on secondary data and existing case studies. This study's findings may not reflect on-the-ground situations and firm-specific characteristics. Future research could adopt primary data collection methods, such as sending out surveys, conducting field interviews, or conducting firm-level experiments, to validate and enrich these findings with contextualized insights. Another research avenue could be the longitudinal study of digital transformation's changing impact over time, which could provide a more dynamic picture of the effectiveness of digital policy and manufacturers' response strategies.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

References

- [1] National Bureau of Statistics of China. Statistical Communiqué on the 2022 National Economic and Social Development. Beijing: NBS, 2023.
- [2] Frank, Alejandro Germán, Lucas Santos Dalenogare, and Néstor Fabián Ayala. Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, 2019, 210, 15–26.
- [3] Xu, Li Da, Eric L. Xu, and Ling Li. Industry 4.0: State of the art and future trends. *International Journal of Production Research*, 2018, 56(8), 2941–2962
- [4] Queiroz Maciel M., and Samuel Fosso Wamba. Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA. *International Journal of Information Management*, 2019, 46, 70–82.
- [5] Ivanov Dmitry, Alexandre Dolgui, and Boris Sokolov. The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. *International Journal of Production Research*, 2019, 57(3), 829–846.
- [6] Hui Jing and Fan Yuwei. Digital transformation, supply chain integration and supply chain performance: Evidence from Chinese manufacturing listed firms. *Sage Open*, 2024, 14(3), 21582440241281616.
- [7] Müller, Julian Marius, Oana Buliga, and Kai-Ingo Voigt. Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change*, 132, 2–17, 2018.
- [8] China Academy of Information and Communications Technology (CAICT). Digital Transformation of Manufacturing Industry White Paper. Beijing: CAICT Press, 2023.
- [9] Boyes, Hug., Hallaq, B., Cunningham, J., & Watson, T. The industrial Internet of things (IIoT): An analysis framework. *Computers in Industry*, 2018, 101, 1–12.

- [10] Ren Anqi, Wu Dan, Zhang Wei, Terpenney, J., & Liu Ping. Cyber security in smart manufacturing: Survey and challenges. In H. B. Nembhard, K. Coperich, & E. Cudney (Eds.), 67th Annual Conference and Expo of the Institute of Industrial Engineers, 2017: 716-721.
- [11] Guo Lei and Xu Luying. The Effects of Digital Transformation on Firm Performance: Evidence from China's Manufacturing Sector. *Sustainability*, 2021, 13(22), 12844.
- [12] State Council of the People's Republic of China. Made in China 2025. Beijing: State Council, 2015.
- [13] State Council of the People's Republic of China. The 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035. Beijing: State Council, 2021.
- [14] Haier Group. COSMOPlat Industrial Internet Platform White Paper. Qingdao: Haier Group, 2020.
- [15] Huawei Technologies Co., Ltd. Huawei Smart Factory White Paper. Shenzhen: Huawei Press, 2021.
- [16] SAIC Motor Corporation Limited. Annual Report 2022. Shanghai: SAIC, 2023.
- [17] Zhang Peijian and Liu Qinglin. Digital economy and international competitiveness of the manufacturing industry: A study on the moderating effect based on education level. *Journal of Computational Methods in Sciences and Engineering*, 2024, 24(6), 3834-3848.
- [18] Arroyabe, Marta. F., Arranz, C. F., de Arroyabe, I. F., & de Arroyabe, J. C. F. The effect of IT security issues on the implementation of Industry 4.0 in SMEs: Barriers and challenges. *Technological Forecasting and Social Change*, 2024, 199, 123051.
- [19] Elmarkez Ahmed, Mesli-Kesraoui S, Berruet P, Oquendo F. Security by Design for Industrial Control Systems from a Cyber-Physical System Perspective: A Systematic Mapping Study. *Machines*. 2025, 13(7):538.
- [20] Huang Jie, Shen, Yixin, Chen Jianjun, & Zhou Ying. Regional digital economy development and enterprise productivity: a study of the Chinese Yangtze River Delta. *Regional Science Policy & Practice*, 2022, 14, 118-137.