International Journal of Research in Engineering, Science and Management
Volume 7, Issue 10, October 2024
https://www.ijresm.com | ISSN (Online): 2581-5792

Unraveling the Nexus of Industrial Intelligent Transformation: Exploring the Dual Regulatory Impact of Digital Affordances and Resource Sharing in the Era of Digitalization

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***Abstract*: This study meticulously examines the industrial Internet's influence on smart transformation, emphasizing digital affordances and resource sharing as pivotal empowerment mechanisms. It integrates technological affordance theory to elucidate the industrial Internet's comprehensive value in smart transformation. Findings indicate positive impacts of big data capabilities, competitive environments, and government support on industrial Internet use, which subsequently fosters intelligent transformation and business model innovation. The paper underscores building digital affordances and resource sharing capabilities as essential for leveraging the industrial Internet's transformative potential, offering strategic recommendations for enhancing smart manufacturing within Industry 4.0.**

***Keywords*: Industrial Intelligent Transformation, Digital Affordances, Resource Sharing, Dual Regulatory.**

1. Introduction

The global manufacturing sector has undergone significant changes, progressing from the steam-powered era of Industry 1.0 to the intelligence stage of Industry 4.0. Utilizing smart sensors and secure transmission networks across the entire product lifecycle, substantial volumes of time series data can be swiftly generated (Fichman et al., 2014; Côrte-Real et al., 2019; Simetinger and Zhang, 2020). In this fourth industrial revolution wave, centered on digital innovation, data emerges as a fundamental element driving progress in industries and enterprises (Liu et al., 2020). Meanwhile, the Industrial Internet, as an emerging enabling technology, unveils its value during utilization (Ma et al., 2020). The concept of empowerment accentuates the stimulation of subject capabilities to attain novel value creation (Leong et al., 2015), offering fresh insights into comprehending the Industrial Internet's role in enterprises' intelligent transformation.

Businesses are increasingly acknowledging the pivotal role played by big data in augmenting business management and recognizing its inherent untapped value. This new paradigm of smart manufacturing, often denoted as the New Industrial Revolution, leverages the Internet's potential to deliver advanced computing, sophisticated analytics, cost-efficient sensing technologies, and heightened global industrial systems connectivity.

To expedite economic recovery and capitalize on the opportunities presented by this revolution, both developed and developing nations have devised targeted stimulus policies centered around manufacturing. These policies aim to propel the industrial revolution alongside a more robust network revolution (Tambe, 2014). For instance, Germany has introduced the Industry 4.0 plan, intending to transition traditional manufacturing into smart industries by integrating cyber-physical systems (CPS). Similarly, the United States initiated the Industrial Internet and Advanced Manufacturing Partnership (AMP) to revolutionize manufacturing processes. Concurrently, China has outlined the "Made in China (2025) Plan" aimed at elevating the intelligence level within its manufacturing sector. Simultaneously, a growing body of research endeavors is underway to comprehend the transformative impact of digital technologies on traditional manufacturing practices.

In the new economic era, big data stands out as a pivotal production resource, distinguished by its abundance and reusability. While ushering in significant transformations in corporate practices, it concurrently opens up vast realms for the evolution of management theory. The Technology Affordances Theory, amalgamating perspectives from technological determinism and social constructivism (Leonardi & Barley, 2010; Robey, 2012), has gained prominence in research within the realms of information systems (IS) and organizational management. A growing cohort of international scholars is dedicated to investigating the support offered by information technology to individuals, groups, and organizations, as well as the overall process of informatization (Liu& Wang, 2019).

To achieve this objective, this paper systematically reviews prevalent research on technology affordance theory. It introduces the digital affordance as a regulatory variable to illustrate the combined value of the industrial Internet and digital affordances in the process of intelligent transformation and application. While scholars have explored factors

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influencing the willingness to use the Industrial Internet (Zhu, Sun & Zhu, 2020), its role in promoting enterprise business model innovation (Kiel, Arnold & Voigt, 2017; Shang & Jiang, 2021), and the construction of business ecosystems (Sun, Zhang & Wang, 2022) has been widely acknowledged, empirical studies in this domain are still limited, with existing research primarily adopting a technological and organizational adoption perspective (Wang, Deng, He & Zhou, 2023). The discussions mainly focus on the "what" and "whether to use" the Industrial Internet, leaving a gap in understanding the mechanisms through which enterprises can effectively utilize the Industrial Internet to transform into intelligent enterprises—a key focus of this article. The concept of dual empowerment through digital affordances and resource sharing underscores the activation of subject capabilities and the realization of new value creation, providing a fresh perspective for comprehending the role of the industrial Internet in the intelligent transformation of enterprises.

The subsequent sections of this article are structured as follows. Section 2 will delineate key concepts, interlinking them with the existing knowledge framework. It will outline the salient points and innovations of this study while proposing six hypotheses to be tested within its scope. Section 3 will expound upon the research methodology, encompassing data sources and details regarding collection and analysis. Section 4 will employ sample data gathered from small and medium-sized industrial enterprises in Wuhu City, Anhui Province, to assess the predictive model. Finally, Section 5 will present the primary conclusions drawn from this study, along with an exploration of the limitations of this article and suggestions for future research directions.

2. Conceptual Background

For close to 15 years, the Internet revolution has redefined industries in the business-to-consumer (B2C) realm, such as media, retail, and financial services. Looking ahead, the IoT revolution is poised to profoundly transform various industrial sectors—manufacturing, energy, agriculture, transportation, among others—that collectively contribute to nearly two-thirds of the global gross domestic product (GDP). This transformative wave will fundamentally alter the dynamics of human-machine interaction (O'Halloran and Kvochko, 2015). Termed the Industrial Internet or Internet of Things (IoT), this latest technological wave presents unprecedented opportunities and accompanying risks for both business and society. It merges worldwide internet connectivity with novel capabilities to directly control the physical realm. As society progresses towards an integrated digital-human workforce, the Industrial Internet will redefine the nature of work and shape the emergence of new job categories (O'Halloran and Kvochko, 2015).

Despite encountering certain obstacles, the adoption of the Industrial Internet is rapidly gaining momentum. Reports indicate a substantial surge in sensor usage, with numbers escalating from 4.2 billion to 23.6 billion between 2012 and 2014—a more than fivefold increase. This surge has captured the attention of key industry players like Cisco, General Electric, and Huawei, along with government initiatives such as Germany's Industry 4.0 (Elfrink, 2014). The second IoT World Forum, hosted by Cisco, exhibited over 250 practical deployment instances, illustrating how businesses and municipalities worldwide are leveraging the Industrial Internet to enhance efficiency, generate new revenue streams, and augment the quality of life concerning citizenship and consumption (O'Halloran and Kvochko, 2015).

The concept of the Industrial Internet is currently in its nascent stage of development. Within the industry, there is keen anticipation regarding both short-term and long-term trajectories for its evolution, as illustrated in Figure 1, showcasing the adoption and impact pathways of the Industrial Internet (O'Halloran and Kvochko, 2015). The depicted figure delineates two distinct stages in the development of the Industrial Internet: the phase of enhancing operational efficiency and the subsequent phase focusing on the provision of new products and services. In the short term, the applications of the industrial Internet predominantly concentrate on predictive maintenance and remote asset management, aimed at augmenting production efficiency and curbing costs. Looking ahead in the long term, the evolution of the industrial Internet will progress towards stages characterized by a results-driven economy and an intelligent pull economy.

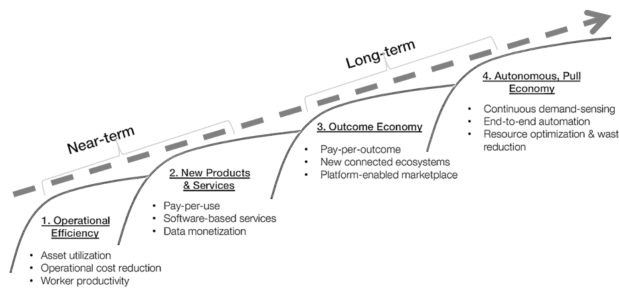

Fig. 1. The adoption and impact path of the industrial internet (O'halloran and Kvochko, 2015)

Nevertheless, the current progress of the Industrial Internet has fallen short of respondents' expectations (Ma et al., 2020). Several factors contribute to this divergence. These include the expenses associated with digitalization, barriers stemming from the intersection of knowledge across industries, and challenges in safeguarding trade secrets (Ma et al., 2020). These factors collectively impede the Industrial Internet's ability to fully leverage economies of scale and scope.

Previous research has formulated an Industrial Internet empowerment pyramid grounded in enterprise capability theory, establishing the theoretical framework of "industrial Internet use-core capabilities-intelligent transformation," illustrated in Figure 2. According to Wang et al. (2023), the foundation of industrial Internet empowerment resides in nine pivotal technical pillars representative of the Industry 4.0 era. These pillars encompass the Internet of Things, cloud computing, additive manufacturing, big data analysis, advanced manufacturing solutions, network security, simulation, as well as horizontal and vertical integration, among other enabling technologies (Büchi et al., 2020).

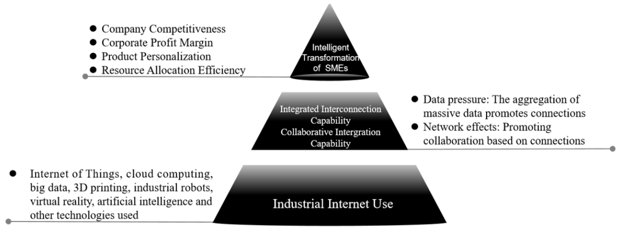

Fig. 2. Industrial IOT empowerment logical architecture (Wang et al, 2023)

Through the integration of interconnection capabilities and collaborative fusion capabilities, enterprises enhance their capacity to collect, preprocess, extract value from data, culminating in the formation of integrated interconnection capabilities and collaborative fusion capabilities. Integrated interconnection capabilities dismantle information silos by establishing connections among extensive data points, thereby facilitating data interoperability and aiding enterprises in optimizing resource allocation. Meanwhile, collaborative integration capabilities foster enhanced data acquisition through expanded collaborative networks. This, in turn, expedites the integration process for small and medium-sized manufacturing enterprises, fostering collaboration across the industrial chain's upstream and downstream segments (Büchi et al., 2020).

The essence of the Industrial Internet's value lies in propelling enterprises toward intelligent transformation, fostering efficiency in resource allocation, facilitating personalized product customization, and cultivating competitive advantages (Wang et al., 2023).

A. Drivers of Industrial Internet Use

1) Big Data Capability

Goes (2014) provides a definition of big data as an extensive collection of diverse observational data used for various decision-making purposes. Meanwhile, Schroeck et al. (2012) emphasize a broader spectrum of information, encompassing real-time data, unconventional media forms, technology-driven data, substantial datasets, trending terms, and data derived from social media platforms.

An enterprise's prowess in handling big data pertains to its capacity to discern, accumulate, retain, and scrutinize extensive and varied data streams at a high velocity, aiding the attainment of strategic and operational objectives (Lin & Kunnathur, 2019). Current research dissects the facets of big data capabilities through the lens of resource-based theory, defining them as a blend of tangible, intangible, and human resources encompassing technical expertise, managerial acumen, and talent proficiency (Gupta & George, 2016; Akter et al., 2016; Zhang et al., 2021). However, these studies exhibit two limitations: firstly, a lack of explicit elucidation concerning the inertia and overreliance on resource systems and access methods that enterprises might encounter (Gupta & George, 2016; Gilbert, 2005); secondly, regarding the restricted benefits of big data capabilities, predominant research predominantly concentrates on factors such as technology, talent, and infrastructure, overlooking a distinct explanation of constructing big data capabilities at the strategic decision-making echelon (Lin & Kunnathur, 2019). Advancing research endeavors introduce the concept of building big data capabilities based on dynamic capability theory, elucidating how enterprises amass and preserve big data resources, leverage big data technology and infrastructure for data analysis, and make data-driven strategic decisions, thus formulating a systematic approach to big data practices (Lin & Kunnathur, 2019; Ciampi et al., 2021). Unlike the resource-based theory-based big data management and analysis capabilities, dynamic capability theory not only encapsulates the evolving traits of capabilities but also showcases their constituents and their synchronization and synergy with other organizational resources and capabilities (Zhang et al., 2021).

The Industrial Internet amalgamates various information technologies and data elements, serving as a crucial asset in enterprises' innovation processes and a fundamental technical foundation for leveraging the Industrial Internet (Wang et al., 2023). Consequently, digital capabilities play a pivotal role, significantly influencing the extent and breadth of enterprises' utilization of the Industrial Internet (Wang et al., 2023). Cognitively, companies equipped with robust digital capabilities demonstrate heightened awareness of emerging technological trends and possess a more receptive attitude toward innovation, experiencing fewer barriers to embracing novel technologies, especially evident among small and medium-sized manufacturing firms that boast advanced digital capacities, displaying more enthusiasm for adopting emerging tech and integrating with the Industrial Internet. From a behavioral standpoint, digitalization is a critical enabler compelling companies to integrate with the Industrial Internet (Ma, Li & Pan, 2020). Given the intricate systems and substantial data generated by the Industrial Internet, enterprises necessitate specific big data capabilities for proficient data storage, processing, and management. Research suggests that small and medium-sized manufacturing companies equipped with strong digital capabilities possess foundational technical expertise and accumulated knowledge, enhancing their data management proficiency (Dholakia & Kshetri, 2004). Conversely, enterprises lacking robust digital capabilities encounter formidable challenges in digital data collection and management. Substandard data quality can trigger a domino effect within organizations, impeding their further integration with the Industrial Internet (Ghadimi et al., 2022). Hence, this study posits the following hypothesis:

H1: Big data capabilities have a significantly positive impact on Industrial Internet Use.

2) Competitive Environment

In the realm of business operations, organizations must conscientiously consider the ambient environmental factors, encompassing interactions with competitors and governmental entities. Within the domain of the industrial Internet, the interconnected entities are multifaceted, spanning individuals, machinery, inanimate objects, systems, as well as the entire industry and value chains. This diversity and intricacy impart a level of professionalism and challenge to the implementation of industrial Internet solutions. Consequently, throughout the endeavor to promote the adoption of industrial Internet technologies, the pivotal roles of competitive environmental pressures within the industry and robust governmental support emerge as indispensable components (Wang et al., 2023; Oliveira, Thomas & Espadanal, 2014).

Environmental competitiveness is indicative of the number of external competitors and the range of competitive domains (Matusik & Hill, 1998). Within a competitive landscape, companies contend with factors such as the density of industry peers and the pace of technological advancements. On one hand, intense competition compels firms to embrace novel technologies to meet their developmental requirements (Li, Yang & Jin, 2012; Wang et al., 2023). In highly competitive environments characterized by an expanding competitor base, the limitations of traditional innovation methodologies become apparent, necessitating the adoption of more transformative approaches to fortify competitive advantages (Peng, Li, Yang & Yu, 2020; Chen & Liu, 2017). In the pursuit of augmented market share, small and medium-sized enterprises may leverage industrial Internet solutions to enhance production efficiency and innovation capabilities, thereby gaining a competitive edge (Dholakia & Kshetri, 2004).

Conversely, in environments marked by excessive competition, the proliferation of competitors and high homogeneity levels diminish the availability of exploratory innovation resources (Zahra, 1996; Chen & Liu, 2017; Zhang, Shang & Chen, 2021). Establishing a favorable market position through the cultivation of heterogeneous characteristics becomes challenging. Notably, the innovative behaviors of small and medium-sized enterprises, operating as market followers, are influenced by the actions of market leaders (Zhang, Shang & Chen, 2021). Within fiercely competitive market scenarios, Companies at the forefront of industrial Internet adoption for transformation and upgrade often trigger a potent "herd effect." Meanwhile, smaller enterprises, grappling with the dilemma of "advance or retreat," may emulate leading firms to avoid market elimination. This emulation of innovative practices by industry leaders serves to accelerate the adoption of the Industrial Internet among smaller players (Estensoro, Larrea, Müller & Sisti, 2022). Therefore, this article posits the following hypotheses:

H2: Competitive Environment have a significantly positive impact on Industrial Internet Use.

3) Government Support

Government support constitutes a significant institutional backdrop for the development of enterprises. According to the World Economic Forum (2018), numerous governments globally are incentivizing companies to invest in Industry 4.0 technologies and engage in experimental initiatives through pilot programs. While this governmental initiative has reduced the entry barrier for companies transitioning to Industry 4.0, it is crucial to note that financial support cannot be sustained indefinitely (Ghadimi, Donnelly, Sar, Wang & Azadnia, 2022). Governmental backing, on one hand, can augment the resource base of small and medium-sized enterprises to a certain extent, fostering a conducive environment for innovative endeavors (Wang, Deng, He & Zhou, 2023). Favorable fiscal and financial policies can alleviate financial burdens on small and medium-sized manufacturing enterprises and diminish the costs associated with the adoption of industrial Internet technologies (Ghadimi, Donnelly, Sar, Wang & Azadnia, 2022). Consequently, this facilitates the realization of the "cloud and platform" paradigm for small and medium-sized enterprises.

On the other hand, government support contributes to the creation of a favorable external collaborative environment (Wang, Deng, He & Zhou, 2023). Leveraging the full potential of the Industrial Internet is challenging for a singular enterprise, necessitating interaction and collaboration among diverse entities to establish a novel industrial ecosystem (Won & Park, 2020). Government support expands the possibilities for such collaboration by integrating multiple forces, including platform companies, incubators, industry associations, and regional government departments, to assist small and medium-sized enterprises in utilizing the industrial Internet (Wang, Deng, He & Zhou, 2023). Therefore, the following hypothesis is posited:

H3: Government Support have a significantly positive impact on Industrial Internet Use.

B. The Mechanism of Enablement in the Industrial Internet

1) Industrial Internet Use and Enterprise Intelligent Transformation

The rapid advancement of next-generation information technology, coupled with the accelerated integration of advanced manufacturing technologies, has given rise to intelligent manufacturing (Huang, 2022). Serving as a form of human-machine integrated intelligent system (Baroroh et al., 2021), intelligent manufacturing facilitates various intelligent activities throughout the manufacturing process, including analysis, reasoning, judgment, conception, and decision-making. It extends beyond traditional manufacturing paradigms of automation, informatization, and digitization to incorporate a higher degree of intelligence (Wang et al., 2021). However, research by Matt & Rauch (2020) suggests that the transition toward intelligence is still in its nascent stages, posing risks and challenges, particularly for small and medium-sized manufacturing enterprises. The Industrial Internet use has emerged as a viable direction for these enterprises to overcome challenges, with its core objective being the substitution of human mental and physical labor by data capital, resulting in a profound transformation in the social mode of production (Kolade & Owoseni, 2022). This transformation not only entails the restructuring of production and manufacturing processes but also underscores the integration of information software, emerging technologies, and various data resources into the manufacturing industry, propelling the entire sector towards intelligent transformation (Wu & Li, 2023). Hence, the Industrial Internet use holds significant strategic importance for the transformation and upgrading of the manufacturing industry.

As a burgeoning enabling technology, the value of the Industrial Internet becomes evident through its practical application (Malik et al., 2021). This enabling characteristic emphasizes the stimulation of organizational capabilities, the attainment of new value creation, and fresh insights into the role of the Industrial Internet use in the intelligent transformation of enterprises (Allioui & Mourdi, 2023). According to the theory of organizational capabilities, widespread adoption of the Industrial Internet allows enterprises to closely integrate it with their organizational structure and business strategies (Leminen et al., 2021). This integration facilitates the continuous creation and accumulation of specialized resources, leading to the development of unique competitive advantages. By employing the Industrial Internet in internal operations, production processes, and product development, enterprises can effectively enhance business responsiveness, facilitate internal resource integration and efficient utilization, thereby improving the efficiency of resource allocation. Concurrently, in collaborating with external partners and maintaining customer relationships, leveraging the Industrial Internet use can assist enterprises in better predicting market demands, enhancing research and development innovation, and achieving full-process interaction and lifecycle maintenance (Wu & Li, 2023). This can lead to the creation of new profit growth points by extending service capabilities. Serving as the foundational infrastructure for the deep integration of the new generation of information and communication technologies with industrial economics, the Industrial Internet use contributes to driving the intelligent transformation of small and medium-sized enterprises (Zheng, Sun & Yin, 2022). Based on the aforementioned background, the following hypothesis is proposed.

H4: Industrial Internet Use have a significantly positive impact on Intelligent Transformation.

2) Moderating Effects of Digital Affordances

The Industrial Internet represents the convergence of traditional industrial production with modern information technology, utilizing Internet technology and concepts to establish efficient, intelligent, and interconnected processes among equipment, systems, and enterprises (Lampropoulos, 2019). This transformation requires real-time data collection during production processes, processed through the connection of various devices and sensors. Technological affordances, rooted in affordance theory within ecological psychology, combine perspectives from technological decision-making theory and social constructivism. Widely applied in information systems and organizational management, this theory analyzes various management phenomena such as organizational socialization, change, knowledge sharing, and virtual reality (Liu & Wang, 2019; Robey, Anderson & Raymond, 2013; Chemero, 2018; Shin, 2017). Autio et al. (2018) introduced the concept of digital affordances, referring to technological affordances shaped by digital technologies and infrastructures. In the context of the current Industry 4.0 and Made in China 2025 era (Liu & Wang, 2019), the transformation of traditional manufacturing industries presents both challenges and opportunities.

The integration of intelligent embedded terminal systems and devices, such as sensors and controllers, is accelerating. The interconnection between individuals in the Internet era has evolved into the interconnection of entities, including people, machines, and equipment, in the Internet of Things era (Liu & Wang, 2019). In the industrial field, smart equipment continuously generates real-time data throughout processes like design, debugging, operation, maintenance, recycling, and others, covering the entire product life cycle (Liu & Wang, 2019).

The Industrial Internet provides a wealth of real-time data, and digital affordances enable businesses to make more informed decisions based on this data (Sisinni, 2018). The surge in data production in the process of intelligent transformation and upgrading in the industrial field has elevated massive data to the status of the most critical production factor (Liu & Wang, 2019). The Industrial Internet realizes intelligent monitoring and management of the production process through data analysis, artificial intelligence, and other technologies. Digital affordances allow companies to better understand and utilize the output of these intelligent systems, achieving smarter decisions (Khan et al., 2021).

Digital affordances emerge from the interaction process between material subjects and behavioral subjects, requiring the new generation of information technology infrastructure and its users as necessary prerequisites. In conjunction with the use of the industrial Internet, cultivating employees' industrial big data application capabilities in business processes is crucial. Transforming managers' decision-making models and establishing a data-driven decision-making model are essential for improving digital operations and management capabilities (Kempers, 2023). Furthermore, digital representation achieves the automation and visualization of business processes. Intelligent equipment, integrating multiple sensors, accurately identifies workpieces. The intelligent monitoring system forms a digital mirror, achieving virtual and real integration. Automated production and scene visualization remotely monitor the production site, coordinate internal processes, and improve efficiency, saving time and costs (Rane, 2023; Liu & Wang, 2019).

Digital affordance prompts enterprises to update infrastructure and form new digital capabilities. By continuously approaching strategic goals and building a dynamic feedback loop, the enterprise ultimately realizes multi-level development in digital business practices. Finally, the Industrial Internet provides digital tools and platforms for enterprises, and digital affordances are a key factor for enterprises to effectively use these tools for digital transformation (Chwiłkowska-Kubala, 2023). On the one hand, the Industrial Internet provides a platform for enterprises to efficiently maintain competition and achieve intelligent transformation. On the other hand, digital affordances establish a means to build a digital foundation, enhance organizational culture, and cultivate digital technical talents, providing a solid basis for enterprises to achieve intelligent transformation. Therefore, the relationship between digital affordances and intelligent transformation is mutually reinforcing and supportive (Ostrovska et al., 2023). Based on the above, the following hypotheses are put forward.

H5: Digital Affordances positively moderate Industrial Internet Use and Intelligent Transformation

3) Moderating Effects of Resource Sharing

Intelligent transformation represents the prevailing developmental trajectory for the manufacturing industry, particularly for small and medium-sized manufacturing companies, which encounter risks and challenges (Wang, Deng, He & Zhou, 2023). The application of the industrial Internet can assist enterprises in enhancing response speed, integrating resources, predicting market demand, and creating new avenues for profit growth through R&D innovation and service extension. Widespread and frequent applications of the industrial Internet can help establish unique competitive advantages for enterprises and serve as a crucial catalyst in promoting the intelligent transformation of small and medium-sized manufacturing enterprises (Wang, Deng, He & Zhou, 2023). Khan et al. (2020) highlighted that the Industrial Internet facilitates the collection and sharing of substantial data in the production process by connecting and integrating equipment, sensors, and systems, empowering enterprises to gain deeper insights into the production environment, ultimately optimizing processes and enhancing efficiency and quality.

Resource sharing encompasses various dimensions, including data, technology, and talent. Data sharing enables companies to comprehensively comprehend the market, customer needs, and production processes, forming the foundational support for intelligent decision-making (Zhang et al., 2022). Specifically in manufacturing enterprises, resource sharing manifests through integrated interconnection capabilities and collaborative intergration capabilities. Enterprises leverage these capabilities to efficiently integrate various data resources, fostering interconnectedness among humans, machines, and things (Wang, Deng, He & Zhou, 2023). Collaborative integration capabilities, on the other hand, pertain to an enterprise's collaborative prowess with entities across the industry chain, integrating external technology with enterprise business processes (Wang, Deng, He & Zhou, 2023). Both integrated interconnection capabilities and collaborative integration capabilities support the establishment of digital twin models for enterprises and the creation of virtual production environments (Jiang et al., 2021). Within this virtual domain, resource sharing can be simulated and optimized, offering guidance for actual production and facilitating digital resource sharing practices.

Through the collaborative sharing of equipment and production resources, the Industrial Internet maximizes equipment utilization, fosters information exchange, and encourages resource sharing practices, thereby aiding in avoiding production bottlenecks and reducing waste. Integrated connectivity capabilities ensure the seamless flow of real-time data across the production chain, encompassing production plans, equipment status, and inventory information (Rane, 2023). Real-time information flow contributes to optimizing production processes, enhancing production efficiency, and laying the groundwork for intelligent transformation. Collaborative integration capabilities facilitate teamwork across different departments, promoting information and resource sharing, and significantly contributing to overall efficiency. They stand as an indispensable factor in the journey of intelligent transformation. Collaborative integration capabilities further encourage innovative collaboration, not only in technology but also in business processes and management models. Shared innovation propels intelligent development forward. The harmonious interplay of resource sharing, integrated interconnection capabilities, and collaborative integration capabilities propels enterprises towards intelligent transformation. These capabilities empower enterprises to respond more agilely to market changes, improve production efficiency, and bolster innovation capabilities, thereby ensuring competitiveness in the intense market landscape (Hou et al., 2022). Based on the above, the following hypotheses are posited.

H6: Resource Sharing positively moderate Industrial Internet Use and Intelligent Transformation

Drawing upon the pertinent literature and the aforementioned hypothesis analysis, Figure 3 illustrates the theoretical model for this article.

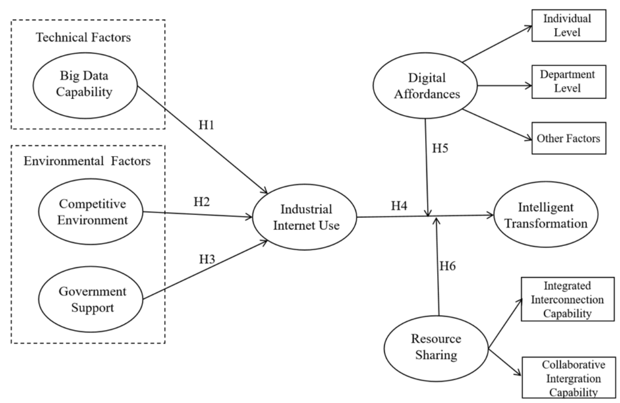

Fig. 3. Theoretical model

3. Research Methodology

A. Samples

All measurement items employed in this study were drawn from pre-existing literature and tailored to align with the specific context of industrial intelligent transformation analysis. The focus of this research is on small and medium-sized manufacturing enterprises, with the survey period spanning from January 2024 to February 2024. Utilizing the Questionnaire Star platform, surveys were meticulously administered to small and medium-sized manufacturing enterprises situated in Wuhu, Anhui Province, with the aim of acquiring pertinent data. To ensure the quality and research significance of the data collected, the survey was exclusively targeted at basic, middle, and senior managers, as well as technical personnel within the enterprises. Screening questions were incorporated to ascertain whether companies are actively utilizing the industrial Internet. Only small and medium-sized manufacturing companies engaged in industrial Internet utilization were included in the research sample. Data screening adhered to the following criteria: firstly, exclusion of research samples displaying excessively high repetition in answer options; secondly, removal of research samples with overly brief response times. Ultimately, a total of 483 valid questionnaires were obtained, yielding a questionnaire validity rate of 91.1%. Table 1 provides a breakdown of the demographic characteristics and fundamental details pertaining

Table 1
Demographic characteristics of the sample

Items	Categories	Sample Size (N=483)	Percent (%)
Gender	Male	246	50.93
	Female	237	49.07
Educational Qualifications	College degree and below	156	32.3
	Bachelor degree	139	28.78
	Master degree and above	188	38.92
Occupation	Upper-level executives	123	25.47
	Intermediate-level managers	124	25.67
	Frontline managers	110	22.77
	Technical personnel	126	26.09
Enterprise Age	＜9	123	25.47
	9~19	127	26.29
	20~30	100	20.7
	>30	133	27.54
Enterprise Scale	Publicly-owned enterprises	156	32.3
	Privately-owned enterprises	151	31.26
	Others (including collectives, foreign-funded enterprises, joint ventures, etc.)	176	36.44
Industry	Automobile and parts industry	86	17.81
	Home appliance industry	77	15.94
	New material research and development and production	85	17.6
	Artificial intelligence industry	87	18.01
	New energy and energy-saving and environmental protection technology	80	16.56
	Others (including pharmaceutical manufacturing, high-end equipment manufacturing (modern agricultural machinery), aerospace (low-altitude economy) R&D and manufacturing, and digital creativity (online economy), etc.)	68	14.08
Service life in the context of the Industrial Internet	＜3	165	34.16
	3~6	158	32.71
	>6	160	33.13
Total		483	100

to the valid sample.

B. Measurements

This article employs Likert's 5-point measurement method to formulate a measurement questionnaire comprising 39 core items. To ensure the accuracy and scientific rigor of the questionnaire, the study draws upon mature research scales from both domestic and international sources, making appropriate modifications based on actual circumstances and expert opinions.

Big data capability is assessed using the measurement scale developed by Lin & Kunnathur and Zhang, Shang & Chen, which encompasses 5 items. Competitive Environment primarily relies on the measurement methods of Van Den Bosch & Volberda and Zhang, Shang & Chen, each consisting of 4 items. The government support measurement scale, inclusive of 5 items, is informed by the research findings of Li and Zhang, Shang & Chen. The measurement of industrial Internet use, featuring 4 items, references the research outcomes of Ifinedo and Wang, Deng, He & Zhou. Digital affordances measurement, comprising 5 items, is based on the measurement scale developed by Liu & Wang and Dremel, Herterich, Wulf & Vom Brocke. Resource sharing measurement, with 6 items, follows the methods outlined by Meng & Zhao and Wang, Deng, He & Zhou. Intelligent transformation measurement, including 3 items, predominantly draws on the research results of Meng & Song and Wang, Deng, He & Zhou.Additionally, this study, considering the influence of factors such as company age, company size, and company type, incorporates these variables as control variables, aligning with the approaches of Zhang, Shang & Chen (2021) and Mikalef, Boura, Lekakos & Krogstie (2019).

4. Result Analysis

In this research, SPSS 25.0 and SmartPLS 3.0 software were chosen as the tools for statistical testing. Prior to hypothesis testing, a comparative analysis between models was performed through confirmatory factor analysis to ascertain satisfactory discriminant validity of the latent variables. Subsequently, descriptive statistics and correlation analysis were conducted to elucidate the fundamental characteristics of the variables and ensure their consistency for subsequent model testing. Ultimately, the hypothesis was validated by constructing an equation model.

A. Reliability and Validity Analysis

This research employed Cronbach's Alpha to assess the internal reliability of the questionnaire. A higher coefficient in Cronbach's Alpha measurement indicates greater internal consistency of the questionnaire. The internal consistency of the questionnaire was evaluated by testing the reliability of each segment of the scale individually. The outcomes of these tests are presented in Table 2. In this instance, confirmatory factor analysis (CFA) was conducted on a total of seven factors and 31 analysis items.

As evident from the table, the Average Variance Extracted (AVE) values corresponding to all seven factors exceed 0.5, while the Composite Reliability (CR) values surpass 0.7. This signifies that the analyzed data in this study exhibits commendable convergent validity. Concerning measurement relationships, for each such relationship, the absolute values of the standardized loadings are greater than 0.6 and exhibit statistical significance, indicating robust measurement relationships.

Table 2
Reliability and convergent validity

Factor	Items	Loading	Cronbach's Alpha	rho_A	CR	AVE
BDC	BDC1	0.816	0.851	0.855	0.894	0.627
	BDC2	0.823				
	BDC3	0.789				
	BDC4	0.776				
	BDC5	0.752				
CE	CE1	0.798	0.823	0.825	0.882	0.653
	CE2	0.795				
	CE3	0.84				
	CE4	0.798				
GS	GS1	0.805	0.829	0.832	0.886	0.66
	GS2	0.811				
	GS3	0.83				
	GS4	0.804				
IIU	IIU1	0.853	0.865	0.868	0.908	0.711
	IIU2	0.839				
	IIU3	0.832				
	IIU4	0.849				
IT	IT1	0.849	0.812	0.813	0.888	0.726
	IT2	0.861				
	IT3	0.847				
DA	DA1	0.765	0.842	0.855	0.887	0.611
	DA2	0.784				
	DA3	0.834				
	DA4	0.762				
	DA5	0.761				
RS	RS1	0.752	0.856	0.871	0.89	0.574
	RS2	0.777				
	RS3	0.795				
	RS4	0.769				
	RS5	0.749				
	RS6	0.700				

Note: (1) N=483; (2) BDC=Big Data Capability; CE=Competitive Environment; GS=Government Support; IIU=Industrial Internet Use; DA=Digital Affordances; RS=Resource Sharing; IT=Intelligent Transformation

Moreover, the Cronbach's Alpha coefficients for the scale surpass 0.7, suggesting a relatively high internal consistency of the questionnaire. Consequently, the questionnaire can be deemed a suitable research instrument for this study.

This study employed Harman's single-factor analysis method to examine the potential presence of common method bias in the present investigation. The explained variation of the first factor prior to rotation was determined to be 20.42%, falling below the critical value of 40%. Examination of the table reveals that the commonality values associated with all research items exceed 0.4, indicating effective extraction of information from the research items. The Kaiser-Meyer-Olkin (KMO) measure is 0.870, surpassing the threshold of 0.6, affirming the data's efficacy in extracting information.

Furthermore, an analysis of factor extraction patterns and the amount of information derived from the factors was conducted. The factor analysis yielded a total of 7 factors, all with characteristic root values exceeding 1. The variance explanation rates of these 7 factors after rotation were as follows: 11.353%, 10.485%, 9.998%, 9.370%, 8.778%, 8.656%, and 6.354%. The cumulative variance explanation rate after rotation reached 64.994%, surpassing the 50% threshold. This indicates effective extraction of information from the research items.

In the assessment of discriminant validity, the square root of the Average Variance Extracted (AVE) for BDC is 0.792, surpassing the maximum absolute value of the inter-factor correlation coefficient (0.419). This discrepancy underscores the robust discriminant validity of BDC. Similarly, for CE, the AVE square root value stands at 0.808, exceeding the maximum absolute value of the inter-factor correlation coefficient (0.419), affirming its substantial discriminant validity.

Table 3
Discriminant validity

	BDC	CE	GS	IIU	IT	Z1_DA	Z2_RS
BDC	**0.792**						
CE	0.292	**0.808**					
GS	0.247	0.226	**0.813**				
IIU	0.253	0.28	0.263	**0.843**			
IT	0.419	0.419	0.417	0.422	**0.852**		
Z1_DA	0.098	0.158	0.127	0.048	0.119	**0.782**	
Z2_RS	0.051	0.001	-0.007	0.039	0.148	0.211	**0.757**

Note: (1) N=483; (2) BDC=Big Data Capability; CE=Competitive Environment; GS=Government Support; IIU=Industrial Internet Use; IT=Intelligent Transformation；Z1_DA=Industrial Internet Use*Digital Affordances; Z2_RS=Industrial Internet Use*Resource Sharing.

GS exhibits a square root of AVE value of 0.813, surpassing the maximum absolute value of the inter-factor correlation coefficient (0.422), indicating robust discriminant validity. Likewise, IIU demonstrates a square root of AVE value of 0.843, exceeding the maximum absolute value of the correlation coefficient between factors (0.422), attesting to its robust discriminant validity.

The AVE square root value for IT is 0.852, surpassing the maximum absolute value of the inter-factor correlation coefficient (0.422), reinforcing its strong discriminant validity. DA, with an AVE square root value of 0.782, surpasses the maximum absolute value of the correlation coefficient between factors (0.158), affirming its robust discriminant validity. Lastly, RS, with an AVE square root value of 0.757, exceeds the maximum absolute value of the inter-factor correlation coefficient (0.211), confirming its substantial discriminant validity.

B. Structural Model

Utilizing SmartPLS 3.0 software and employing the maximum likelihood method, a path model was formulated. The outcomes of the normalized path model diagram are depicted below.

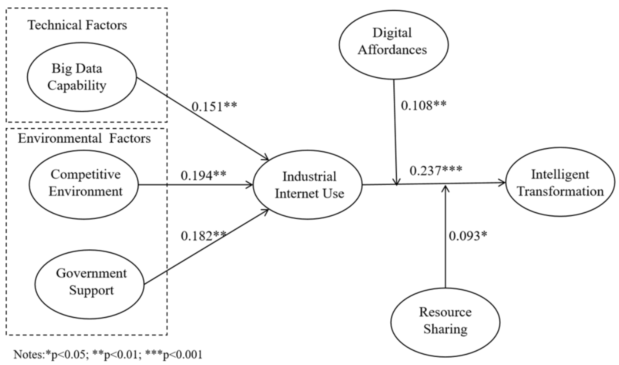

Fig. 4. Model effect test

Table 4 illustrates that, in the context of BDC influencing IIU, the path coefficient is 0.151, signifying a statistically significant impact at the 0.01 level (T=2.959, p=0.003<0.01). This underscores the significant positive influence of BDC on IIU, thereby confirming Hypothesis 1. For the relationship between CE and IIU, the path coefficient is 0.194, with the sub-path exhibiting significance at the 0.001 level (T=4.057, p=0.000<0.001). This result substantiates the substantial positive impact of CE on IIU, thereby validating Hypothesis 2.

Similarly, in the case of GS affecting IIU, the path coefficient is 0.182, with the sub-path demonstrating significance at the 0.001 level (T=3.721, p=0.000<0.001). This affirms the significant positive impact of GS on IIU, supporting the validation of Hypothesis 3. Examining the influence of IIU on IT, the path coefficient is 0.237, exhibiting statistical significance at the 0.001 level (T=5.858, p=0.000<0.001). This result affirms the substantial positive impact of IIU on IT, providing empirical support for Hypothesis 4.

Moreover, the correlation coefficient of the moderating effect path coefficient for Digital Affordances, along with the associated P value, demonstrated significant significance (T=2.712, p=0.007<0.01). This implies that, in the context of Industrial Internet Use influencing Intelligent Transformation, the moderating variable Digital Affordances exhibits noteworthy variations at different levels of impact. This discernment is further elucidated through the graphical representation in Figure 5, supporting Hypothesis 5.

Similarly, the correlation coefficient between the path coefficient of the moderating effect of Resource Sharing and its P value also indicated significant significance (T=2.712, p=0.007<0.01). This indicates that, in the scenario where Industrial Internet Use influences Intelligent Transformation, the moderating variable Resource Sharing manifests notable variations in the degree of influence across different levels. This observation is further explicated by referencing the simple slope in Figure 6, thereby confirming the validation of Hypothesis 6.

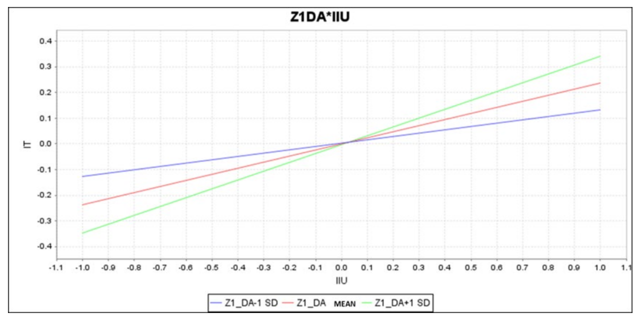

Fig. 5. Slope plot

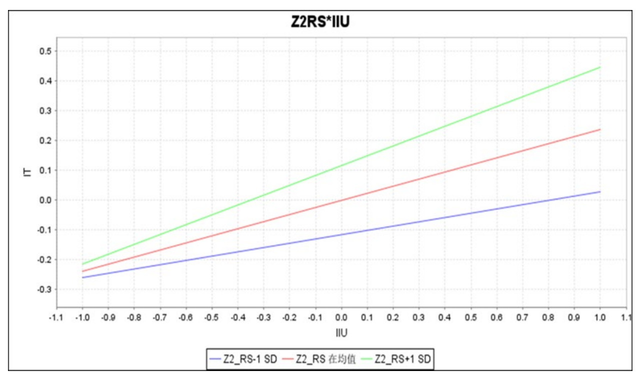

Fig. 6. Slope plot

Table 4
Path analysis

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	2.50%	97.50%	Conclusion
BDC -> IIU	0.151	0.154	0.051	2.959	0.003	0.054	0.252	Supported
CE -> IIU	0.194	0.196	0.048	4.057	0.000	0.101	0.293	Supported
GS -> IIU	0.182	0.182	0.049	3.721	0.000	0.08	0.274	Supported
IIU -> IT	0.237	0.237	0.041	5.858	0.000	0.158	0.315	Supported
Z1DA*IIU -> IT	0.108	0.103	0.04	2.712	0.007	0.023	0.179	Supported
Z1_DA -> IT	-0.004	0.004	0.035	0.1	0.920	-0.062	0.073	
Z2RS*IIU -> IT	0.093	0.088	0.04	2.347	0.019	0.009	0.166	Supported
Z2_RS -> IT	0.116	0.121	0.032	3.63	0.000	0.06	0.182	

Note: (1) N=483; (2) BDC=Big Data Capability; CE=Competitive Environment; GS=Government Support; IIU=Industrial Internet Use; DA=Digital Affordances; RS=Resource Sharing; IT=Intelligent Transformation; (3) 2.50% refers to the lower limit of the 95% interval of Bootstrap sampling, and 97.50% refers to the upper limit of the 95% interval of Bootstrap sampling.

Table 5
Model fit

	Saturated Model	Estimated Model
SRMR	0.044	0.045
d_ULS	0.981	0.99
d_G	0.325	0.324
Chi-Square	934.544	932.296
NFI	0.855	0.856
rms Theta	0.107	

Table 5 presents the model fit assessment. The SRMR fitting value for this study stands at 0.042, significantly below the threshold of 0.08. The NFI surpasses 0.85 and approaches 0.9. Additionally, the rms Theta is 0.09, meeting the established criterion of 0.12. Consequently, the overall model fit is deemed satisfactory and exhibits a commendable level of fit.

5. Discussion

A. Conclusion

Within the context of China's manufacturing industry transformation and upgrading, this study delves into the mechanism of the industrial Internet in small and medium-sized manufacturing industries in Anhui Wuhu concerning the intelligent transformation of enterprises based on the theory of technology affordances. The research results reveal that : 1) Big Data Capability, Competitive Environment, and Government Support positively impact Industrial Internet Use (intermediary variable), and Industrial Internet Use positively influences Intelligent Transformation (result variable). 2) The use of the industrial Internet positively influences Intelligent Transformation. 3) The dual regulatory effect of Digital Affordances and Resource Sharing is significant. As Digital Affordances continue to rise, the use of the industrial Internet accelerates intelligent transformation, while resource-sharing capabilities (Integrated Interconnection Capability, Collaborative Integration Capability) continue to increase, and the use of the industrial Internet can also expedite intelligent transformation. All six hypotheses posited in this study have been substantiated, and the detailed results are outlined as follows:

1) Crucial driving factors influencing the utilization of the industrial Internet encompass big data capabilities, environmental competitiveness, and government support. Technical and environmental factors serve as prerequisites for small and medium-sized manufacturing enterprises to leverage the Industrial Internet effectively. The Industrial Internet predominantly relies on elements of "invisible data" to empower enterprises, necessitating timely responses based on digital affordances and resource-sharing capabilities. Big data capabilities constitute the technical foundation for small and medium-sized manufacturing enterprises to engage with the industrial Internet. The systematic approach involves the accumulation and preservation of big data resources, employing big data technology and infrastructure for data analysis, and making strategic decisions driven by data. Environmental competitiveness reflects the inherent needs of small and medium-sized manufacturing enterprises to utilize the industrial Internet for gaining competitive advantages. Government support acts as a guarantor for small and medium-sized manufacturing enterprises, alleviating financial burdens and reducing costs related to Industrial Internet technology adoption (Ghadimi, Donnelly, Sar, Wang & Azadnia, 2022), compensating for shortcomings in resources and capabilities.
2) The Industrial Internet empowers enterprises to undergo transformation and upgrade by constructing two core capabilities. The utilization of the Industrial Internet exerts a substantial enabling influence on the intelligent transformation of small and medium-sized manufacturing enterprises, presenting novel solutions for the manufacturing industry's transformation and upgrade. This involves harnessing the power of third-party entities to empower and propel industry transformation and upgrade. Digital affordances enable enterprises to make informed decisions based on real-time data generated continuously by smart devices throughout various stages such as design, commissioning, operation, maintenance, and recycling (Sisinni, 2018). Integrating interconnection capabilities within resource sharing achieves intelligent transformation by fostering connectivity within enterprises. These capabilities efficiently integrate diverse data resources and facilitate interconnection between people, machines, and things (Wang, Deng, He, and Zhou, 2023). Collaborative integration capabilities encompass the collaborative capabilities of enterprises and entities across the industry chain, integrating external technologies with enterprise business processes (Wang, Deng, He & Zhou, 2023). Small and medium-sized enterprises, grappling with low resource capabilities and high knowledge barriers, find it challenging to achieve intelligent transformation independently. The Industrial Internet acts as a gathering point for various value participants from different industries or fields, strengthening collaboration among entities in the industrial chain. Leveraging resource sharing on the industrial Internet platform, enterprises can achieve deep integration of new-generation information technology with all facets of industrial production, thereby providing fresh impetus for transformation and upgrading.

B. Theoretical Contributions

1) Delve into a more comprehensive examination of the driving factors influencing the utilization of the industrial Internet in small and medium-sized enterprises. Previous research predominantly focused on technological and organizational adoption perspectives, addressing questions related to "what is" and "whether to use" the Industrial Internet. It identified factors influencing the willingness to

adopt the Industrial Internet but did not explore how enterprises leverage it for intelligent transformation. Building on the theories of enterprise capabilities and technology affordances, this article elucidates the impact of technology and environment-related factors on the utilization of the industrial Internet. It offers a theoretical reference for small and medium-sized manufacturing enterprises seeking to employ the Industrial Internet.

2) Further unveil the "black box" of the mechanism by which the Industrial Internet contributes to the intelligent transformation of enterprises. Prior research suggested that the industrial Internet adds value to enterprises from the perspective of organizational adoption but did not thoroughly analyze the impact mechanism on enterprise transformation. By investigating the two core enabling capabilities of the Industrial Internet, this study uncovers the facilitating role of digital affordances and resource sharing (integrated interconnection capabilities, collaborative fusion capabilities) between Industrial Internet utilization and intelligent transformation. It delves into the role of digital affordances and resource sharing (integrated interconnection capabilities, collaborative fusion capabilities) in the context of Industrial Internet use and intelligent transformation. This approach opens the "black box" of the Industrial Internet's effect on enterprise intelligent transformation, clarifies the distinct roles of various capabilities in intelligent transformation, and further enriches the research context of empowerment theory by integrating the theory of ecological psychology. Simultaneously, it broadens the avenues for small and medium-sized enterprises to undergo transformation through digitization, contributing to a deeper understanding within the context of intelligent manufacturing in Industry 4.0.

C. Managerial Contributions

1) Enterprises ought to expedite the development of pertinent supporting facilities. Simultaneously, the government should enhance its support for the industrial Internet within enterprises, facilitating a broader application of the industrial Internet. Enterprises need to not only monitor the impact of iterative updates of their resources and digital capabilities on the adoption of the industrial Internet but also assess the alignment between industrial Internet technology and their business. This involves a rigorous evaluation of business complexity to select appropriate industrial Internet services and applications. Additionally, the government should refine incentive policies for industrial Internet utilization and provide digital application scenarios tailored for small and medium-sized enterprises.
2) Enterprises should prioritize the cultivation of digital affordances and resource sharing capabilities to maximize the enabling impact of the industrial Internet on intelligent transformation. Enhancing the application of next-generation digital information technology is crucial to unlocking the value of industrial Internet data. Furthermore, strengthening integration capabilities with supply chain resource platforms is essential. This involves promoting technological integration innovation and commercial applications in information technology (IT), operational technology (OT), and other fields. By unleashing the value of the industrial Internet, enterprises can achieve intelligent transformation.

D. Limitations and Future Research Directions

Despite making every effort to ensure the scientific rigor and objectivity of the research during the investigation process, this study has some limitations. 1) While the sample of this study includes small and medium-sized manufacturing enterprises in Wuhu City, Anhui Province, it does not encompass data related to large enterprises and other provinces and cities. Consequently, the generalizability of the research results to large manufacturers is limited. Future research could broaden the sample to include manufacturing enterprises in different regions, diverse development stages, and varying technical levels. Additionally, comparisons can be made between the results of this study and those involving private enterprises versus state-owned enterprises. 2) Rooted in the perspective of technology affordance theory, this study explores the mechanism of industrial Internet usage in the intelligent transformation of small and medium-sized enterprises. In the future, the aforementioned mechanism can be explored from alternative angles to offer a fresh perspective on the research questions posed in this article. 3) The current investigation did not incorporate control variables. Future research endeavors may consider the inclusion of control variables for enhanced measurement and comprehensive analysis.

Acknowledgement

Funding support by Social Science Project of Wuhu City (WHSK202320): Research on Industrial Intelligent Path of Wuhu City in the Digital Age, Xiaoli Zhang.

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