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Original Paper

The Impact of Digital Transformation Strategy of Manufacturing Enterprises on Digital Innovation Performance

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Abstract

The digital transformation of manufacturing enterprises is in full swing. In practice, they often face the problems of resource constraints, lack of digital capability and changing environment, which leads to the dilemma of digital transformation. This paper uses the exploratory case study method to construct the strategic construct of digital transformation of manufacturing enterprises: The process of transforming enterprise strategy by applying digital technology under the leadership of senior management is an all-around transformation of enterprise organizational structure, operating process, business model and value creation mode. Case studies define the core concepts of this paper and discover the direct role of digital transformation strategy on digital innovation performance, the mediating role of resource patchwork and the mediating role of digital empowerment. Based on the results of case analysis and existing literature and theories, the research hypothesis is proposed and verified by empirical research. The results show that: (1) digital transformation strategy positively affects digital product and service innovation, performance and digital process innovation performance; (2) Environmental dynamics positively moderates the relationship between digital transformation strategy and digital process innovation performance, but has no significant positive moderating effect on the relationship between digital transformation strategy and digital product and service innovation performance. (3) Resource patchwork plays a partial mediating role between digital transformation strategy and innovation performance of digital products and services.

Keywords

digital transformation, manufacturing enterprises, digital empowerment, digital innovation performance

1. Introduction

The development of digital transformation practices in manufacturing enterprises has also prompted

scholars to begin to study the concept of digital transformation, driving antecedents and its impact on enterprises from various perspectives. In terms of the concept of digital transformation, the existing research mainly adopts theoretical research and case studies to clarify the concept of digital transformation. From a technology perspective, digital transformation is defined as the process of using digital technology to meet consumer needs to gain competitive advantage and revenue growth (Berman, 2012; Westerman, 2014). Based on an organizational perspective, digital transformation is defined as the process of transforming organizational structures and innovating business models (Hess, 2016; Vial, 2019). Due to differences in research perspectives, the academic community has not yet reached a clear consensus on the concept of digital transformation, and few studies have elevated digital transformation to the strategic level. However, the digital transformation of manufacturing enterprises has not only involved the transformation of organizational structure, business model and operation process, but also the transformation of enterprise strategy. Existing studies have found that internal factors such as organizational resources (Liu et al., 2011) and characteristics of senior management team (Matt et al., 2015) and external factors such as digital technology (Lv et al., 2019), market demand (Matt et al., 2015) and industry environment will promote the digital transformation of enterprises. In terms of the impact on enterprises, the existing researches mainly use case studies to explore the value creation path of digital transformation (Yang et al., 2022), and use empirical studies to verify its impact on enterprise performance. The research finds that although improving performance is one of the purposes of digital transformation, the dilemma of digital transformation will adversely affect organizational performance (Rolland et al., 2021).

The heterogeneity, programmability, self-reference and distribution ability of digital technologies have a profound impact on the innovation activities of organizations, resulting in digital innovations with characteristics of self-growth and integration (Yoo et al., 2010). Due to the emerging nature of digital innovation, existing research mainly uses exploratory case studies to explore its concepts and characteristics (Yoo et al., 2010; Nambisan et al., 2019). In terms of the concept of digital innovation, scholars based on innovation objects define digital innovation as a product, service, process, organization and business model innovation formed by the application of digital technology to change the existing business model or process (Nambisan et al., 2017). Scholars based on innovation approach define digital innovation as value creation mode innovation that reorganizes digital components to provide customers with new value (Fichman et al., 2014). Scholars based on innovation results define digital innovation as organizational innovation that applies digital tools to improve enterprise efficiency and innovation performance (Boland et al., 2007). In terms of the characteristics of digital innovation, different from traditional technological innovation, digital innovation has the characteristics of self-growth and integration, more diversified innovation subjects, and lower innovation threshold, which also poses a challenge to traditional innovation research. Digital innovation performance is derived from relevant research on digital innovation. By embedding digital technology into product and service innovation and process innovation, enterprises can obtain sustainable competitive advantages

and heterogeneous performance. The existing research mainly discusses how to effectively improve the digital innovation performance of enterprises from internal and external factors, including the digital platform and ecosystem of enterprises, digital infrastructure (Henfridsson, 2013) and organizational capacity (Patel, 1997). External factors include industry competitive pressures and technological development (Feng, 2021). In the process of applying digital technology to transform enterprise strategy, digital technology will be embedded in the enterprise's product and service innovation and process innovation, and improve the enterprise's digital product and service innovation, performance and digital process innovation performance. However, existing studies have been unable to answer the mechanism of the influence of digital transformation strategy on digital innovation performance of manufacturing enterprises, so this paper tries to answer this question.

2. Studies the Design

This paper focuses on describing the digital transformation of enterprises from the strategic level, that is, constructing the strategic construct of digital transformation and exploring its impact on digital innovation performance, which belongs to the category of answering the "How" and "Why" research questions. Due to the lack of existing literature on digital transformation strategy and digital innovation, the existing research cannot explain the impact of digital transformation strategy on digital innovation performance, and the existing literature alone cannot solve the research problem in this paper. Therefore, this chapter first selects Shenzhou Refrigeration, a typical enterprise of digital transformation, for a single case exploratory analysis, defines the connotation and correlation of the main constructs of this paper based on the three-level coding of grounded theory, and builds a theoretical model based on case discovery and communication with existing theories.

2.1 Case Selection

This paper takes Shandong Shenzhou Refrigeration Co., LTD. (Hereinafter referred to as "Shenzhou Refrigeration") as the research object. According to the statistics of China's cooling network, there are more than 600 refrigeration enterprises in Shandong Province, and the number is ranked first in the country. At the same time, as the only province in the country with all industry categories, Shandong Province was early to realize the demonstration role of specialization and innovation in the digital transformation practice of manufacturing enterprises. By 2022, Shandong Province have a total of 5,777 provincial and more than 756 national specialized new manufacturing enterprises, which undoubtedly makes Shandong Province, a fertile ground for cultivating specialized new manufacturing enterprises. Shenzhou Refrigeration began to implement the digital transformation strategy in 2017, and the carbon dioxide refrigeration technology of its intelligent cold chain equipment manufacturing project has reached the international level and the domestic leader and was successfully selected into the third batch of specialized and special new small giant enterprises and high-tech enterprises list in 2021.

To sum up, as a leading enterprise in China's refrigeration industry, Shenzhou Refrigeration takes into

account the principles of inspiration, data accessibility, typicality and represented in the selection of case study objects, which is consistent with the theoretical sampling principles of case studies. Especially in the period of regular epidemic prevention and control, the unit of the case enterprise and the researcher belong to the same city, which provides convenient conditions for field research in time and space. The research unit of the researcher is also one of Shenzhou refrigeration industry-university-research cooperative institutions, and the availability of research data is high, thus ensuring the feasibility of this case study.

2.2 Data Collection

After selecting the research object, this study conducted triangulation verification by obtaining data from multiple sources. It mainly includes: (1) To obtain first-hand data, the research team went to the production workshop of Shenzhou Refrigeration High-tech Industrial Park and the experience store of high-tech Zone respectively from September to November 2022, conducted 11 formal and informal interviews totaling 617 minutes, and collected more than 112,000 words of interview data. The information of the interviewees is shown in the table; (2) Participant observation: The research team followed the person in charge of the Shenzhou Refrigeration Sales Department to visit the exhibition hall, operation and maintenance service center, and production workshop of the company, and took photos after obtaining consent. Through in-depth field visits to the company, it is helpful to have an intuitive understanding of the digital transformation practice of Shenzhou Refrigeration. The logical relationship between theoretical basis, written data, and scene situation was established; (3) Obtain a variety of secondary materials such as the company's official website, social media publicity materials, and media reports. The details of the various data sources are shown in table 1~table 2.

Table 1. Interviewer Information

Interviewee	Number of people	Duration /min	Word count /thousand	Encoding
Technical Research and development manager	2	136	24	A_1
Production manager	1	45	9	A_2
Product Technology Manager	1	32	6	A_3
Purchasing manager	1	44	7	A_4
General management manager	1	31	8	A_5
Operation and maintenance manager	2	127	19	A_6
Manager of International Trade Department	1	46	7	A_7
Finance Department and Deputy General manager	1	41	8	A_8
Sales Department and Deputy General	1	115	22	A_9

manager				
General MANAGER	1	136	36	A_{10}

Table 2. Data Source Situation and Coding

Data source	Data content	Quantity	Encoding
Semi-structured Interview (A)	The company's departments of senior management and first-line grass-roots stuff	12	A_1-A_{12}
Participant observation (B_n)	Company digital exhibition hall, production workshop, physical stores, operation and maintenance service center	6	B_1-B_6
Internal Information (C_n)	Company internal meeting, sample instruction manual	9	C_1-C_9
External Information (de_n)	Government document	5	D_1-D_5
	Web data: enterprise official website, Baidu Encyclopedia	2	D_6-D_7
	Social media publicity materials: wechat public account, Douyin official account	2	D_8-D_9
	News reports: Sohu, Sina Finance, Jinan Daily, etc.	10	D_{10}-D_{19}
	Industry research report	1	D_{20}
	"Borderless Business School" interview video: Professor dialogue Shenzhou Refrigeration General manager talks about the understanding of digital transformation, the Chaoyang track of the Winter Olympics "little giant"	2	D_{21}-D_{22}

2.3 Reliability and Validity

In this paper, the reliability and validity of the research are guaranteed in all aspects of research design, data acquisition and data analysis. First of all, in the research design stage, this paper searches for literature related to the case phenomenon and theories conducive to explaining the case phenomenon to improve external validity. At the same time, secondary data is used to preliminarily understand the situation of the enterprise, and data is obtained through multiple channels such as official websites, media reports, industry websites, public annual reports of listed companies and academic journal resource libraries to improve construction validity. Secondly, in the data collection stage, this paper forms an evidence triangle mainly composed of field interviews and participant observation,

supplemented by relevant secondary data. Data from different sources complement and confirm each other. Before the field interview, I studied relevant books and literature on case study methodology, wrote the interview outline in advance, and revised it several times after communicating with the interviewees. The interview was led by a professor, including an associate professor who has long-term cooperation with the enterprise and three graduate students whose research direction is digital transformation. During the formal interview, two people were asked and the others assisted. A graduate student was responsible for taking shorthand on the spot and recording the whole process after explaining the purpose of the research to the interviewees. On the day after each interview, the recording was converted to text, and the doubtful vague recording was verified twice by comparing the sound and text, and the authenticity and accuracy of the content were repeatedly verified with the interviewees. Finally, in the data analysis stage, the kappa coefficient was more than 90% after the data was independently encoded by different coders and compared. To sum up, the evidence chain in this paper is clear and searchable, with good reliability and validity, and can be used for further case analysis.

3. Case Analysis

3.1 Background

Shenzhou Refrigeration was founded in 1989 and started a high-speed development mode after it was acquired by Yantai Ice Wheel Environment in 2014. Shenzhou Refrigeration is a company that focuses on providing customers with cold and thermal systems, environmental protection and energy-saving refrigeration system solutions, and its products are widely used in food, medical, chemical, logistics, freezing, and refrigeration industries. The development of Shenzhou refrigeration's digital transformation is mainly divided into four stages, and important events are sorted out as shown in the figure. The first stage (2014-2015): Sensing digital transformation opportunities, developing digital transformation strategies, and settling the digital foundation. Phase 2 (2016-2017): Integrate the resources at hand and apply digital technologies to empower the business. The third stage (2018-2019): to carry out digital innovation, transforming from a traditional equipment engineer to a digital and intelligent refrigeration service provider. The fourth stage (2020-present): product intelligence and digital services, taking an important stage of digital transformation results, after the outbreak of the epidemic, many pharmaceutical companies to provide -70℃ ultra-low temperature vaccine cold storage intelligent solutions, mass production of CO2 trans-critical refrigeration units successfully applied to the 2022 Beijing Winter Olympics speed skating hall and other projects, created four "world first".

3.2 Data Processing and Presentation

Based on the research method of grounded theory, this paper adopts the three-level coding method of selective coding to process the original data.

The case data show that Shenzhou Refrigeration developed a digital transformation strategy by perceiving digital opportunities in the initial stage of transformation, carried out process innovation by

embedding digital technology into the operation process and business process of the enterprise, and provided intelligent products and additional services by embedding digital technology into the products and services of the enterprise, which enhanced the competitiveness of the enterprise and improved the performance of the enterprise. According to the existing research on enterprise innovation and enterprise performance of digital transformation, digital transformation helps enterprises identify and utilize innovation opportunities in the environment, digitize enterprise elements through digital twins and digital simulation to achieve precision innovation, reduce innovation costs and improve innovation speed. Digital tools help enterprises provide a better customer experience and improve business competitiveness and business performance. As a result, digital transformation strategies improve digital innovation performance.

Case data show that in the digital era, Shenzhou Refrigeration industry technology is rapidly developing, competitors are fast moving, products and services are iterating fast, and consumer demand is changeable and unpredictable. In a highly dynamic digital environment, the case company Shenzhou Refrigeration in the application of digital technology in the process of transforming corporate strategy by embedding digital technology in the enterprise process innovation and product and service innovation, reshaping the enterprise's digital process to quickly respond to the environment, create intelligent products and provide digital services to meet the changing customer needs. This has greatly enhanced the competitive advantage of Shenzhou Refrigeration so that it has always been in the industry leading position. According to the research on the dynamic nature of the existing environment, the core competitiveness of enterprises can be improved only by constantly establishing, updating and reconfiguring their resources and capabilities to carry out innovative activities in a highly dynamic environment. Therefore, environmental dynamics will regulate the relationship between digital transformation strategy and digital innovation performance.

Case data show that Shenzhou Refrigeration has realized resource patchwork by implementing digital transformation strategy to identify and utilize digital opportunities, quickly respond to the market environment, establish a larger and more closely connected social network, and give existing resources digital attributes to innovate the use of resources. The research combined with existing resources shows that the digital transformation strategy expands the network scale of enterprises, helps enterprises to establish connections with more network members with various technology, capital and knowledge resources, and increases the probability of enterprises obtaining heterogeneous resources! 146) At the same time, it enhances the network strength of the social network, makes the relationship between the members of the network closet, brings social interaction and trust, and enhances the intention of resource exchange and sharing between the two sides, which stimulates the resource patchwork behavior of enterprises. As a result, digital transformation strategies promote resource pooling. Case data show that Shenzhou Refrigeration's innovative use of resources enables it to quickly respond to the environment, identify and take advantage of digital opportunities to carry out innovative activities, embed digital technology in the enterprise's process innovation and product and service innovation to

automate processes, intelligent products and provide digital services to help enterprises achieve sustainable competitive advantages and heterogeneous performance. Based on the research of existing resource patchwork to promote enterprise innovation and improve enterprise performance, this paper argues that resource patchwork can accelerate the speed of new product development, promote product innovation and process innovation, and the stronger the resource patchwork ability of enterprises, the more conducive to the transformation of innovation ability into innovation performance. Therefore, resource pooling improves digital innovation performance.

The case data show that the process of applying digital technology to transform enterprise strategy has enhanced the connectivity of enterprises, eliminated the structural barriers of enterprises to obtain information and resources, and embedded digital technology in the organizational structure of enterprises to improve the ability of enterprises to control and manage resources. Companies use big data analysis to identify new opportunities, digital technology connects human systems, companies, products and services, and data is applied to research and development, production, and manufacturing to form intelligent decisions based on data analysis. Research combining existing digital empowerment shows that both organizational strategy and the use of digital technologies promote digital empowerment. Therefore, digital transformation strategies promote digital empowerment.

The case data shows that Shenzhou Refrigeration has embedded digital technology into the operation process and business process of the enterprise, improved the enterprise's intelligent ability, connection ability and analysis ability, greatly improved the enterprise's innovation efficiency, and applied digital tools and platform infrastructure to support the enterprise's product and service innovation. This continuous innovation enables Shenzhou Refrigeration to have a sustainable competitive advantage in the industry competition and obtain excellent corporate performance. According to the existing research on enterprise performance based on digital empowerment, digital empowerment can improve supply chain agility and operational performance, form connectivity capabilities and improve process performance [and enhance digital management capabilities, digital innovation capabilities and big data analysis capabilities to improve enterprise innovation performance. Therefore, digital empowerment can improve digital innovation performance.

Table 3. The Logical Relation Structure between the Main Categories

The structure of the relationship between the main categories	Connotation of relationship structure
Digital Transformation Strategy → Digital Innovation Performance	Digital transformation strategies improve digital innovation performance
Digital Transformation Strategy→ Dynamic	Environmental dynamics moderates the relationship between digital transformation strategy and digital innovation performance

environment of digital innovation performance	
Digital transformation Strategy→ Resource patchwork	Digital transformation strategies promote resource pooling
Resource patchwork → Digital innovation performance	Resource pooling improves digital innovation performance
Digital Transformation Strategy→ Digital empowerment	Digital transformation strategies promote digital empowerment
Digital Empowerment → Digital Innovation, performance	Digital empowerment improves digital innovation performance

4. Case Discovery and Model Building

4.1 Case Discovery

According to the research theme of "The impact of digital transformation Strategy on digital innovation performance of Manufacturing enterprises", the independent variable of this study is digital transformation strategy, and the dependent variable is digital innovation performance. The direct impact of digital transformation strategy on digital innovation performance, the moderating effect of environmental dynamics, the mediating effect of resource patchwork and the mediating effect of digital empowerment are extracted by summarizing the relationship structure among the main categories. The logical relationship analysis in this paper shows a relatively clear story line: the digital transformation strategy of manufacturing enterprises can not only directly improve the digital innovation performance and be adjusted by the dynamic nature of the environment, but also improve the digital innovation performance by promoting resource patchwork and digital empowerment.

(1) Direct role

Digital transformation strategy is the process of transforming enterprise strategy by applying digital technology under the leadership of senior management, and it is the all-round transformation of enterprise organizational structure, operation process, business model and value creation mode. The digital transformation strategy encourages the case enterprise to embed digital technology into the innovation process of the enterprise, provide new attributes to the existing products and services, make the products more intelligent, meet the individual needs of consumers and provide additional service value, and bring beneficial results to the organizational performance and competitive advantage of the enterprise. For example, companies that incorporate it and sensors into their cooling products and provide digital operations services to customers have significantly improved the user experience and achieved heterogeneous performance beyond their peers. The digital transformation strategy also encourages the case enterprise to embed digital technology inside the enterprise to improve the innovation efficiency of the enterprise by changing the organizational structure and operation process

of the enterprise. For example, the case enterprise uses digital technology to reshape the production, transportation and other processes and thus improve the organizational performance.

(2) The regulatory role of environmental dynamics

The high-speed selection of digital technology makes the digital environment highly dynamic. It is difficult for enterprises to obtain sustainable competitive advantages by relying on specific resources, so they must constantly innovate their products and services by using digital technology. At the same time, digital technology makes it easier for consumers to understand product information and increase the personalized needs of products, which makes the digital environment of enterprises have a high degree of environmental dynamics. In this dynamic environment, the rapid technological innovation in the refrigeration industry, the rapid action of competitors, and the increasingly personalized needs of customers are bound to affect the digital innovation of manufacturing companies. In a highly dynamic environment, case companies must continue to innovate in the process of applying digital technology to transform corporate strategy to obtain sustainable competitive advantages and heterogeneous performance. The higher the degree of environmental dynamics, the more likely manufacturing enterprises will embed digital technology in their process innovation and product and service innovation to obtain sustainable competitive advantages and heterogeneous performance when applying digital technology to transform corporate strategy.

(3) The intermediary role of resource patchwork

In the digital context, the replicability, disseminability, searchability, editability, interactivity and reusability of digital resources make resource patchwork a widespread choice in the digital transformation process of case enterprises. Case companies make use of digital technology to make knowledge and the experience more easily disseminated, and form a network of stakeholders to trigger creativity among employees, customers, and suppliers to achieve smart allocation of resources. To cope with the new challenges brought by digital transformation, the enterprise reorganized digital resources according to the needs of customers, embedded digital technology into the products and services of the enterprise, and broke through resource constraints through small steps and fast iteration to achieve lean innovation with cost saving and rapid response. In the face of a changing and unpredictable digital environment, case companies focus on speed of market response and advocate immediate action without seeking optimal solutions to seize potential opportunities in the environment. The implementation of the digital transformation strategy encourages the case enterprises to quickly respond to market demand through resource patchwork, to achieve rapid update of products and services through continuous trial and error and iteration, and to improve the performance of digital innovation. Resource patchwork helps enterprises to realize rapid market response in the shortest time and at the lowest cost, thus promoting the digital innovation of enterprises.

(4) The mediating role of digital empowerment

Digital empowerment is "an empowering way to empower enterprises with digital capabilities through digital technology". Digital technology eliminates the structural obstacles for enterprises to obtain

information and resources, improves the ability of enterprises to control and manage resources, and gives enterprises important digital capabilities such as intelligence ability, connection ability and analysis ability. Enterprise digital transformation strategy connects innovation elements and innovation subjects, and removes structural barriers to enterprises' access to information and resources: Embedding digital technology in the organizational structure of enterprises improves enterprises' ability to control and manage resources, such as big data analysis, connectivity and intelligence. Digital technology connects people, systems, companies, products and services, and data is applied to research and development, production, and manufacturing to form intelligent decisions based on data analysis. On this basis, the product service innovation speed of the case enterprise is accelerated, the production cycle is reduced from the original average 7 days to the current 3 days, the refrigeration products are more intelligent, and the additional service value is provided according to the real-time analysis of front-end data, early warning and proactive service. The case enterprises also achieve platform empowerment and ecological empowerment by building digital platforms and digital ecological chains, which enhance the product competitiveness of the case enterprises, and create the competitive advantages of the case enterprises.

4.2 Theoretical Model Construction

In the early stage of transformation, Shenzhou Refrigeration faced with the rapid development of digital technology, in order to cope with the digital challenges, through the perception of transformation opportunities and identification of transformation needs to develop a digital transformation strategy, in this stage Shenzhou refrigeration clear the direction of digital transformation. In the middle period of transformation, faced with the dilemma of digital transformation due to resource constraints and insufficient digital capabilities, Shenzhou System broke through resource constraints through immediate actions, deconstruction of resources at hand, recombination of resources and other resource collection behaviors, and used digital technology to empower the enterprise with resources, structure, platform and ecological capabilities. At this stage, Shenzhou Refrigeration formed the resources and capabilities required for digital transformation. In the late period of transformation, Shenzhou Refrigeration has achieved sustainable competitive advantages and heterogeneous performance in the industry by embedding digital technologies into the company's product and service innovation and process innovation.

Through the exploratory study of the case enterprises, it can be found that the impact of digital transformation strategy on digital innovation performance is a complex process: First, in the process of applying digital technology to transform corporate strategy, manufacturing enterprises will embed digital technology into product and service innovation and process innovation to help enterprises obtain sustainable competitive advantages and heterogeneous performance. Secondly, in the digital environment with the rapid development of industry technology, the rapid action of competitors, the changeable and unpredictable demand, and the rapid iteration of enterprise products and services, enterprises are inevitably affected by environmental dynamics. Environmental dynamics positively

regulates the relationship between digital transformation strategy and digital innovation performance. Then, in the process of applying digital technology to transform corporate strategy, manufacturing enterprises will improve their digital innovation performance by promoting resource patchwork. In the process of applying digital technology to transform corporate strategy, manufacturing enterprises will break resource constraints by taking immediate actions, deconstructing resources at hand and recombining resources. Digital product and service innovation and digital process innovation help enterprises to obtain sustainable competitive advantages and heterogeneous performance; Finally, in the process of transforming enterprise strategy by applying digital technology, manufacturing enterprises will apply digital technology to empower enterprises. Through resource empowerment, structural empowerment, platform empowerment and ecological empowerment, digital product and service innovation and digital process innovation can help enterprises obtain sustainable competitive advantages and heterogeneous performance. Therefore, this paper builds a theoretical model based on the results of exploratory case studies and existing theories and literature.

5. Conclusion

This paper selects a typical enterprise, Shenzhou Refrigeration, to collect data by scientific methods to ensure the reliability and validity of the research, analyze the case and perform data processing, find out the hidden logical relationship based on the data processing results, and build the theoretical model of this paper.

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