Research on the Impact of Manufacturing Digital Innovation Resources on Knowledge Creation Based on SmartPlS: The Mediation Effect of Digital Innovation Ecosystem

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ABSTRACT

Executing digital innovation activities and creating a digital innovation ecosystem are critical engine for effectively promoting knowledge creation in the manufacturing industry, advocating deep integration of the digital economy and manufacturing industry, and achieving high-quality manufacturing industry development. Based on the panel data of 28 manufacturing industries in China from 2016 to 2020. This paper examines the relationships among digital innovation resource input, digital innovation ecosystem, and knowledge creation in the manufacturing industry. The results show that digital innovation resource input has a positive effect on digital innovation ecosystem and knowledge creation, and the digital innovation ecosystem acts as a partial intermediary between the two. Thus, this research is critical for accelerating the process of digital innovation in the manufacturing industry, establishing and playing a role in the digital innovation ecosystem, and realizing knowledge creation and knowledge appreciation in the manufacturing industry.

Keywords: *Digital innovation, Digital innovation ecosystem, Knowledge creation.*

1. INTRODUCTION

Along with the advancement of digital process, based on digital technology, such as 5G, AI, Industrial Internet, Internet of things, cloud computing, and many other digital innovations, have gradually penetrated and applied to the manufacturing industry. Digital technology breaks the space-time boundary barriers between the manufacturing industry and other innovation subjects, and effectively promotes collaborative communication between subjects. Innovation subjects, innovation resources and innovation processes in the innovation ecosystem have undergone fundamental changes such as digitalization, intelligence, platformization and ecologicalization [14]. Since knowledge is one of the competitiveness of the manufacturing industry, it can be highly shared in the digital innovation ecosystem due to these changes. The digital innovation ecosystem provides a good environment and support for knowledge creation to promote and guarantee the creation of better knowledge. The digital innovation ecosystem spawned by digital innovation is driving changes in manufacturing. It is meaningful to explore the relationships among digital innovation resource input, digital innovation ecosystem, and knowledge creation in the manufacturing industry.

2. THEORY AND HYPOTHESIS

2.1 Digital Innovation Resource Input and Knowledge Creation

The development of both enterprises and industries has gradually transformed into a process of acquiring knowledge and realizing the value-added of knowledge by using innovative resources [5]. Most scholars believe that innovation resources have a positive effect on knowledge creation, which is an essential part of scientific and technological innovation output. Under the impact of digital innovation, digital resources emerge as a brand-new production factor, profoundly affecting and participating in the process of innovation [8]. This phenomenon has gradually become an indispensable resource for the manufacturing industry. As digital innovation endorse digital resources with the ability to be

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liquefied, digital resources can quickly flow and be processed into knowledge, thus facilitating the creation of knowledge and creating value [7]. Fang found that under the influence of the Internet, knowledge creation, as a vital link of knowledge appreciation, is positively influenced by soft innovation resources such as soft technology-based capability resources and innovative cultural resources [6]. Sampson advocated that digital innovation resources are used as organizational resources, and the combination of capabilities brought by these resources can have an impact on the organization and jointly create value for the organization [10].

Digital innovation human resources are the primary resources to complete knowledge creation. Tacit knowledge exists in people's minds, and the conversion between tacit knowledge and explicit knowledge contributes to knowledge creation. Therefore, digital innovation human resources are both knowledge providers and knowledge creators. Digital innovation financial resources are a significant financial guarantee for digital innovation activities. Adequate and appropriate digital innovation financial resources are the solid foundation for knowledge creation and the prerequisite to ensure the smooth development of digital innovation activities. Digital innovation material resources are the material condition to realize the function and effectiveness of resources wherein the input has a certain promoting effect on the improvement of innovation ability. Digital innovation technology resources are a kind of utilization of early digital innovation output. New knowledge creation can be generated by purchasing technology, introducing, absorbing and improving technology. In this paper, the five resources above are collectively referred to as digital innovation resource input. Based on the above analysis, the following hypothesis is proposed:

H1: Digital innovation resource input has a positive effect on knowledge creation.

2.2 Digital Innovation Resource Input and Digital Innovation Ecosystem

Chae proved that due to the dynamic interaction of resources in the process of digital innovation, a digital innovation ecosystem is formed in constant variation and selective reservation [4]. It proposed to help form a digital innovation ecosystem by absorbing and gathering abundant digital industry innovation resources represented by digital technology. Digital innovation resource input provides energy for the digital innovation ecosystem and guarantee support for improving innovation efficiency of the system. The more available resources are invested, the more the competitiveness of the system will improve. Not only the support of innovation resources, their effective utilization is also crucial [13].

Through the optimal allocation of the digital innovation ecosystem, internal and external digital innovation resources can be effectively integrated and utilized. However, the lack of Multi-agent coordination will make the originally limited innovation resources become more dispersed and not give full play to the value of innovation resources. The manufacturing industry needs to cooperate with multiple innovation subjects in the digital innovation ecosystem, so that the acquisition of digital innovation resources can break through the spatial barrier, complete the effective allocation of resources, and create more and better values beyond their own role. Relying on the support of digital innovation resources, digital platforms came into being. This makes the collaborative mode of digital innovation subjects more flexible. The participants can connect by relying on the digital innovation platform, which provides a green channel for the resources sharing, information exchange, and complementary advantages of the subjects in the system, and hence enables the digital innovation ecosystem [11]. Based on the above analysis, the following hypotheses are proposed:

H2a: Digital innovation resource input has a positive effect on Digital innovation resource allocation.

H2b: Digital innovation resource input has a positive effect on Digital innovation Multi-agent collaboration.

H2c: Digital innovation resource input has a positive effect on Digital innovation platform empowerment.

2.3 Digital Innovation Ecosystem and Knowledge Creation

The original intention of the establishment of digital innovation ecosystem is to improve innovation performance and to achieve the goal of digital innovation of knowledge appreciation. Manufacturing companies have gradually shifted their focus from exclusively providing industrial products to providing comprehensive products and services [3]. So in addition to patents and projects, the provision of new products and services is a new manifestation of manufacturing knowledge creation. The research showed that the strategic choice of resource allocation will affect the sales revenue of new products, the quantity and quality of patents obtained. The effect of the combination of internal and external resources has a direct impact on the accumulation and appreciation of knowledge and the improvement of technological innovation capabilities. Meanwhile, industry-university-research collaborative innovation has a positive impact on innovation output. The barrier-free flow of various collaborative innovation resources between multiple innovation subjects promotes the flow and application of knowledge and achieves cyclic knowledge creation, which directly affects the capabilities and level of knowledge creation.

Some scholars have confirmed that digital empowerment plays a significant role in promoting technological innovation, especially for organizations that borrow digital platforms. Ardolino confirmed that the combination of the Internet of Things and cloud computing is critical for generating new knowledge and effectively facilitating the transformation of industrial enterprises into services [1]. Due to the modular characteristics of the digital innovation platform, it can realize the interconnection of everything and transfer key information, playing a key role in resources integration, improving the operation efficiency of customized services, and providing support for the manufacturing industry with diversified products and services [3], and thus improve the performance of knowledge creation. Based on the above analysis, the following hypotheses are proposed:

H3a: Digital innovation resource allocation has a positive effect on knowledge creation.

H3b: Digital innovation Multi-agent collaboration has a positive effect on knowledge creation.

H3c: Digital innovation platform empowerment has a positive effect on knowledge creation.

2.4 The Mediating Role of Digital Iinnovation Ecosystem

Compared with the ecosystem and innovation ecosystem, in the digital innovation ecosystem, the input of digital innovation resources is the material source of the system and provides a guarantee for the operation of the system. Due to the limited resources owned by the organization itself, in order to get rid of this dilemma, the organization needs to form a system of strategic cooperation with other organizations. Resources make the relationship between participants closer and reciprocal exchange more frequent, so as to creating new knowledge. The digital innovation ecosystem is the shared space of knowledge creation-- Ba. This frame composed of time and space gives vitality to knowledge resources and provides a platform for knowledge creation. In the system, the knowledge of one subject enters into the knowledge spiral of another subject as an input, and the knowledge output after processing evolution is injected into the innovation activities of other subjects in the form of input. In this way, continuous knowledge creation is promoted and the collaboration of digital innovation Multi-agent is also achieved. Nonaka stated that effectively facilitating and utilizing Ba and managing the knowledge spiral is the only way to promote the development of knowledge creation [9]. Empowered by the digital innovation platform, it accelerates the acquisition, flow, integration, transformation and collaboration of knowledge, thus encouraging the creation and rapid update of new knowledge. Based on the above analysis, the following hypothesis is proposed:

H4: Digital innovation ecosystem plays a mediating role between digital innovation resource input and knowledge creation.

3. RESEARCH DESIGN

3.1 Sample Selection and Data Sources

Based on the consideration of data integrity and the accuracy of data analysis, the statistical data of 28 manufacturing industries for five consecutive years from 2016 to 2020 are selected to form a panel data for empirical analysis. The data mainly come from various statistical yearbooks published by China, as well as official websites such as the National Bureau of Statistics and the State Intellectual Property Office.

3.2 Variables and Model

Combined with the emphasis of this study, research purpose, research methods and data availability of realistic problem, referring to several related researches at home and abroad such as Bi [2], the variables such as digital innovation resource input, digital innovation ecosystem and knowledge creation are measured and set. The concrete measure of each variable content as shown in table 1. Based on the existing research results and the hypotheses of the second part, this study constructs a model of the relationship between digital innovation resource input and knowledge creation, and discusses the mediating role of digital innovation ecosystem between the two (as shown in figure 1). Referring to the research of Viot [12], five resources such as digital innovation human resources are regarded as the first-order internal latent variables, and digital innovation resource input is taken as second-order external latent variables. The measurement variables of second-order latent variables are composed of first-order latent variables.

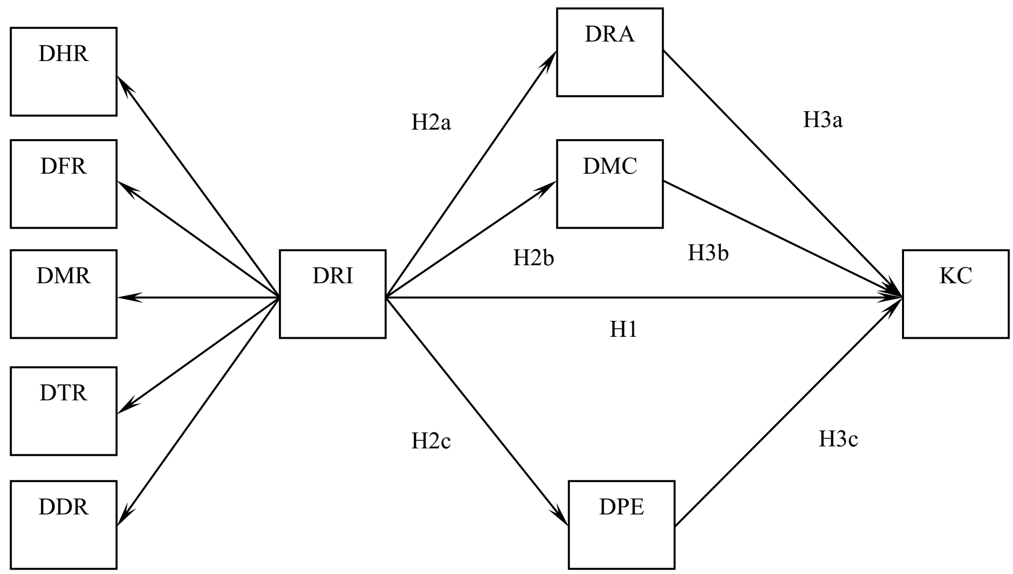

Figure 1 Conceptual Frame.

Table 1 Variables.

Variable Type	Variable Name	Measurement Iindex
Explanatory Variable- Digital innovation resource input (DRI)	Digital innovation human resources (DHR)	Full-time equivalent of R&D personnel in manufacturing digital innovation
		Number of manufacturing researchers
	Digital innovation financial resources (DFR)	Cost of software products purchased by manufacturing industry
		Cost of Manufacturing innovation
	Digital innovation material resources (DMR)	Number of research institutes with digital innovation activities in manufacturing industry
		Cost of Manufacturing digital innovation equipment and instrument
		Number of enterprises with R&D activities in manufacturing industry
	Digital innovation technology resources (DTR)	Cost of manufacturing industry purchases embedded software
		Total technology r&d expenditure in manufacturing industry
	Digital innovation digital resources (DDR)	Number of industrial robots installed in manufacturing industry per year
		Cost of Manufacturing Internet data center
Intermediary Variable- Digital	Digital innovation	The number of enterprises with digital innovation activities in manufacturing research institutions accounted for the number of enterprises with digital innovation in manufacturing

innovation ecosystem (DIE)	resource allocation (DRA)	The number of enterprises with digital innovation R&D activities in the manufacturing industry accounted for the number of digital innovation enterprises in the manufacturing industry
	Digital innovation Multi-agent collaboration (DMC)	Manufacturing industry investment in research institutions and universities
		Government investment in manufacturing R&D
		Other enterprises' R&D investment in manufacturing industry
	Digital innovation platform empowerment (DPE)	Number of FTTH in manufacturing
		Number of Manufacturing Websites
		Number of enterprises with e-commerce transactions
		Number of enterprises carrying out relevant production and operation activities through the Internet
		Number of enterprises that advertise and promote through the Internet
		The industrial Internet drives the added value of manufacturing industry
		Number of Internet broadband access ports in manufacturing industry
Explained variable-knowledge creation (KC)	patent	Number of manufacturing invention patents
	project	Number of manufacturing R&D projects
	service	Manufacturing service output value
	product	Manufacturing new product sales revenue

4. RESULTS

4.1 Reliability and Validity Test

In order to investigate the validity and reliability of the required data, a reliability test and validity test should be carried out on the data. This is a crucial step in ensuring the scientific integrity of empirical research. In academic research, Cronbach's α coefficient and combined reliability (CR) are employed to assess model reliability. In addition, factor loadings and average extracted variance (AVE) are used to judge the model's convergent validity. The results are shown in Table 2. Indicators of all variables meet the requirements, indicating that the variables selected by the model have decisive reliability and internal consistency. To evaluate the discriminant validity of a model, most scholars apply the criterion that the square root of AVE is greater than the correlation coefficient between variables. As shown in Table 3, all non-diagonal values are smaller than diagonal values, illustrating that each variable in this model has good discriminative validity.

Table 2 The reliability and validity test of the model.

Variable	Variable Name	Factor Loading	Cronbach's α	Composite Reliability	AVE
DHR	DHR1	0.930	0.879	0.942	0.891
	DHR2	0.958			
DFR	DFR1	0.929	0.869	0.938	0.883
	DFR2	0.950			
DMR	DMR1	0.969	0.893	0.935	0.828

	DMR2	0.811			
	DMR3	0.943			
DTR	DTR1	0.938	0.842	0.927	0.867
	DTR2	0.921			
DDR	DDR1	0.994	0.987	0.994	0.988
	DDR2	0.994			
DRA	DRA1	0.991	0.980	0.990	0.981
	DRA2	0.990			
DMC	DMC1	0.937	0.918	0.947	0.857
	DMC2	0.907			
	DMC3	0.933			
DPE	DPE1	0.994	0.997	0.998	0.984
	DPE2	0.991			
	DPE3	0.997			
	DPE4	0.995			
	DPE5	0.986			
	DPE6	0.984			
	DPE7	0.998			
KC	KC1	0.911	0.949	0.963	0.867
	KC2	0.932			
	KC3	0.947			
	KC4	0.935			

Table 3 Correlation coefficient and discriminant validity test.

	DHR	DFR	DMR	DTR	DDR	DRA	DMC	DPE	KC
DHR	0.944								
DFR	0.785	0.940							
DMR	0.906	0.730	0.910						
DTR	0.695	0.901	0.625	0.929					
DDR	0.678	0.905	0.682	0.904	0.994				
DRA	0.631	0.498	0.571	0.375	0.361	0.990			
DMC	0.908	0.861	0.758	0.779	0.731	0.616	0.926		
DPE	0.425	0.440	0.709	0.394	0.532	0.051	0.291	0.992	
KC	0.909	0.895	0.903	0.816	0.823	0.640	0.908	0.540	0.931

4.2 PLS-SEM Analysis

From the above reliability and validity analysis results, it is assured that the model can carry out the next path impact analysis. Using Smartpls software and Bootstrapping method (n=5000), the effect of each variable was estimated. All results were significant at the significance level of 0.1%, as shown in Table 4.

Digital innovation resource input has a positive impact on knowledge creation, and the path coefficient is 0.526. Digital innovation resource input has a positive effect on digital innovation resource allocation, digital innovation Multi-agent collaboration and digital innovation platform empowerment, and the path coefficients are 0.544, 0.886 and 0.570, respectively. Digital innovation resource allocation, digital innovation Multi-agent collaboration and digital innovation platform empowerment have positive impacts on knowledge creation, and the path coefficients are 0.162, 0.299 and 0.145, respectively.

Digital innovation resource input has a positive impact on knowledge creation through digital innovation resource allocation, digital innovation Multi-agent collaboration and digital innovation platform empowerment, and the indirect impact path coefficients are 0.088, 0.265 and 0.082, respectively. The total indirect effect path coefficient of digital innovation resource input on knowledge creation through digital innovation ecosystem is 0.436, and the intermediary effect reaches 45.32%. Therefore, digital innovation ecosystem plays a partial intermediary role between digital innovation resource input and knowledge creation. The path coefficients of the second-order variable digital innovation resource input to the first-order variable digital innovation human resources, digital innovation financial resources, digital innovation material resources, digital innovation technology resources and digital innovation digital resources are 0.903, 0.944, 0.887, 0.894 and 0.910 respectively, which were statistically significant. Based on this, all the hypotheses proposed in the second part of this study have been verified and their significance is confirmed, which is also consistent with the theoretical support mentioned above.

Table 4 Model path coefficient and test.

Relationship	path coefficient	T	P	inspection result
DRI→KC	0.526	8.823	***	Support H1
DRI→DRA	0.544	7.665	***	Support H2a
DRI→DMC	0.886	37.409	***	Support H2b
DRI→DPE	0.570	13.622	***	Support H2c
DRA→KC	0.162	5.749	***	Support H3a
DMC→KC	0.299	5.575	***	Support H3b
DPE→KC	0.145	5.266	***	Support H3c
DRI→DRA→KC	0.088	4.162	***	——
DRI→DMC→KC	0.265	5.609	***	——
DRI→DPE→KC	0.082	4.641	***	——
Total indirect effect	0.436	7.945	***	Support H4

Note: *P<0.05, **P<0.01, ***P<0.001.

5. CONCLUSION AND SUGGESTION

5.1 Conclusion

This study from the perspective of digital innovation to 28 manufacturing industries as the research object, digital innovation resource input as an explanatory variable, digital innovation ecosystem as an intermediary variable, and knowledge creation as an explained variable, and has achieved the following conclusions: Digital innovation resource input has a positive effect on knowledge creation. This indicates that increasing the quantity and enhancing the quality of digital innovation resource input will boost knowledge creation. Digital innovation resource input has a positive effect on digital innovation ecosystem. Thus, the digital innovation resource input accelerates the construction and development of digital innovation ecosystem. In addition, digital innovation ecosystem positively influences knowledge creation. It demonstrates that the construction of digital innovation ecosystem can effectively promote knowledge creation, improving the performance of digital innovation and obtaining a competitive advantage in manufacturing industry. Last but not least, digital innovation ecosystem plays an intermediary role between digital innovation resource input and knowledge creation. This view confirms that digital innovation resource input is put into the system as energy. After the configuration and processing of the system, it is fully utilized by the digital innovation subjects and participates in the empowerment of the platform, and finally realizes the creation of knowledge.

5.2 Suggestion

The manufacturing industry should give full play to the vitality of digital innovation resources, and accelerate the in-depth application of artificial intelligence, big data, cloud computing, 5G and other emerging technologies. Meanwhile, the policy makers should improve the construction of digital workshops, smart factories, and digital infrastructures. The policies to introduce digital innovation talents, industrial software, and industrial big data must be implemented. In order to lay the foundation for the construction of Industrial Internet and achieve intelligent manufacturing.

It is requisite to make full use of digital innovation and build digital innovation platform for the manufacturing industry. The manufacturing industry ought to give full play to the intelligent effects of digital platforms such as the IoT, Industrial Internet, and data centers. Through the above approaches, the purpose of empowering the manufacturing industry and reshaping manufacturing application scenarios is realized.

The construction of digital innovation ecosystem and digital integration of cross-border play significant roles in the manufacturing industry, which the policy makers should optimize resource allocation and maximize resource value. Because of multi-agent collaborative partnerships, the internal and external digital innovation resources in the manufacturing industry are merged. Hence, the manufacturing industry must apply the advantages of digital platforms to achieve collaborative innovation among various innovation subjects. In this way, it can make up for the shortcomings of research and development and resource constraints. Ultimately, knowledge creation and value co-creation are realize.

Knowledge creation is one of the influencing factors for the manufacturing industry to obtain industrial competitive advantage. Thus, the manufacturing industry need to pay full attention to the knowledge creation. Knowledge creation become an important engine for high-quality development of manufacturing industry in the era of digital innovation. As a result, the manufacturing managers are supposed to accelerate the speed and improve the quality of knowledge creation for realizing knowledge appreciation and industrial breakthrough.

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