

Research on the Impact of Enterprise Digitalization on the Governance of Multi-Partner R&D Alliances

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Abstract: Addressing the limitation of existing research that rarely focuses on the governance of digital transformation and R&D alliances, this study explores the impact of digital transformation on the number of new partners in R&D alliances. Based on an empirical analysis of 902 samples from 133 listed pharmaceutical manufacturing companies in Shanghai and Shenzhen A-share markets from 2011 to 2022, the results show that the degree of digital transformation promotes the number of new partners in R&D alliances, while the speed of digital transformation hinders it. These findings develop the theoretical framework for existing R&D alliance governance factors and deepen the academic understanding of the essence of digital transformation.

Keywords: Relationship Governance; Digital Transformation; Number of Relationships

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1. Introduction

The digital economy has become a core engine of global economic development and a key area and important engine for accelerating the development of new quality productivity. With the accelerated iteration and deep integration of digital technologies such as big data, artificial intelligence, and cloud computing, the business environment is undergoing profound changes characterized by digitalization. The comprehensive advancement of the Digital China strategy requires enterprises to widely apply new technologies such as informatization, digitalization, and artificial intelligence to accelerate their digital transformation. Against this macro-background, digitalization is no longer a strategic option for enterprises, but a crucial question concerning their survival and development.

Digitalization has not only reshaped internal production processes and management models within enterprises, but has also profoundly broken down traditional organizational boundaries, enabling companies to integrate resources and collaborate in a broader space. Theoretically, enhanced digital capabilities should help companies reduce collaboration search costs, improve information processing capabilities, and expand partner networks, thus providing strong support for the construction and expansion of R&D alliances. However, the reality presents a complex picture. In recent years, Chinese enterprises have frequently encountered governance challenges in collaborative innovation practices, such as inconsistent goals and difficulties in coordinating cooperative relationships, resulting in a persistently high failure rate for multi-partner R&D alliances. At the same time, enterprises still lack experience in operating R&D alliances; patents jointly applied for by multiple organizations account for only about 20%, reflecting that the penetration and maturity of multilateral collaborative innovation in Chinese

enterprise practices still need to be improved.

R&D alliances, as a crucial pathway for corporate innovation, are fundamentally about resource sharing, information exchange, and collaborative innovation among different companies based on shared technological goals. With the advancement of globalization, companies face increasing pressure to innovate, and the R&D capabilities of a single company are no longer sufficient to meet innovation demands. Therefore, more and more companies are choosing to form R&D alliances through collaboration with external companies, research institutions, and other stakeholders. The quality of relationships within an R&D alliance directly determines its innovative effectiveness. Research shows that good cooperative relationships effectively promote knowledge sharing, information flow, and technological innovation, while poor cooperative relationships can lead to resource waste, communication barriers, and even conflicts. Therefore, how to effectively manage and improve the quality of relationships within R&D alliances has become an important issue of concern for both academia and industry.

The theoretical contributions of this study include the following aspects. First, it deconstructs enterprise digitalization into two dimensions: the degree of digitalization and the speed of digitalization. This breaks through the limitations of previous studies that mostly focused on a single dimension, revealing the differentiated impact of different dimensions of digitalization on the expansion of R&D alliances and deepening the theoretical understanding of the connotation of digitalization. Second, it expands digitalization research from an internal enterprise perspective to an inter-organizational relationship perspective, exploring how digitalization affects the construction of external collaborative networks. Finally, it provides a new analytical framework for understanding the relationship between digitalization and innovation, revealing the “double-edged sword” effect of digitalization on the expansion of collaborative networks—the coexistence of the empowering effect of the degree of digitalization and the inhibitory effect of the speed of digitalization, which helps to reconcile the divergent conclusions in existing research on the effects of digitalization.

2. Literature Review

2.1 Digital Transformation

Existing research primarily discusses the connotation of digital transformation from two perspectives: enterprise technology and organizational change. From a technology perspective, scholars generally view digital transformation as a process of applying and integrating a series of advanced digital technologies, with technology as the core driving engine. Studies by Bharadwaj et al. argue that enterprises utilize digital technology resources such as big data, artificial intelligence, and cloud computing to build new digital capabilities and develop digital products and services. From an organizational change perspective, the focus shifts from the technological tools themselves to how technology triggers deep structural, process, and cultural changes within enterprises^[1]. Kane et al. pointed out that digital transformation is far from a simple technological upgrade, but rather a process in which enterprises carry out comprehensive innovation in organizational structure, business processes, talent skills and even organizational culture in order to cope with the disruptive changes in the digital environment^[2]. At the same time, some scholars tend to combine the perspectives of technology and organization to form a systematic understanding. Vial et al. believe that digital transformation is a process that triggers major changes through digital technology, aiming to cope with disruptive changes in the environment by improving existing or creating new value propositions, operating models, customer experiences and relationships^[3].

Digital transformation can be further divided into static digital transformation degree and dynamic digital transformation speed. Existing research on enterprise digital transformation largely focuses on the static digital transformation degree. These studies suggest that digital transformation can enhance an organization’s search and learning capabilities by expanding its search scope, increasing the amount of information and knowledge acquired, accelerating the processing speed of information and knowledge, and increasing the possible combinations of information and knowledge^[4]; Furthermore, digital transformation can also leverage digital technologies to integrate partners into digital platforms, reducing the costs and risks of inter-organizational collaboration and strengthening cooperation^[5].

Digital transformation is a dynamic and evolving process, and the speed of transformation is also a key characteristic. Enterprises need to find the optimal transformation speed based on their own resources and capabilities, balancing the

pressure of technological catch-up with the costs of organizational adaptation^[6]. Existing research indicates that while a faster pace of digital transformation accelerates a company's digital transformation process, the significant investment of capital, human resources, and effort can crowd out resources from other business operations^[7]. At the same time, rapid transformation in the short term poses significant challenges to the coordination between digital resources and capabilities and the organization's original resources and capabilities, as well as the coordination between new organizational rules under digitalization and existing organizational rules. This may lead to an imbalance in the dynamic capabilities of enterprise organizational management^[8].

Regarding the consequences of digital transformation, existing literature mainly studies its impact on corporate performance and innovation capabilities. Wang et al.'s research found that digital transformation improves corporate performance by reducing costs, increasing R&D intensity, and enhancing human resources, and has a significant positive impact on the overall manufacturing industry^[9]. Xu et al.'s research indicates that digital transformation significantly improves enterprises' innovation performance, and the dual mediating effect of big data capabilities and organizational agility is an important part of its influencing mechanism^[10].

2.2 Number of R&D Alliance Relationships

A research and development alliance (R&D alliance) refers to a formal, but not merged, cooperative organization formed by two or more enterprises and related institutions based on market opportunities and the need for independent innovation, with the aim of jointly developing new technologies and products. This alliance is characterized by complementary strengths, shared benefits, and shared risks. Depending on the name, R&D alliances include R&D alliances industry-academia-research alliances, technology alliances, knowledge alliances, patent alliances, technology standards alliances, joint R&D efforts, and virtual R&D alliances, etc.^[11]. Since the 1990s, some research has focused primarily on the issue of firms forming single R&D alliances from a bilateral perspective. During this phase, scholars mainly focused on the impact of individual partner characteristics on innovation performance, including the partner's type, resources, relationships, and geographical location^[12]. Since the 1990s, research on the governance effects of corporate innovation networks has attracted much attention from scholars. Among them, the theoretical perspective based on network relationships is an important entry point for the academic community to explain corporate innovation networks and outputs^[13]. This research approach often approaches innovation performance from the perspective of alliance governance, exploring the mechanisms by which relationships among participants influence innovation performance^[14]. These studies on network relationships primarily focus on the degree of development of cooperative relationships among partners, specifically including three dimensions: firstly, the number of cooperative relationships^[15]. Secondly, the strength of the relationship, including intimacy, familiarity, trust, relationship embedding, and frequency of interaction^[16]. The third is the fault of the relationship^[17]. Research on the relationship between network relationship governance and innovation performance has yielded inconsistent conclusions, suggesting that partnerships are a "double-edged sword," potentially promoting or hindering innovation under different conditions.

3. Theoretical Hypothesis

3.1 The Degree of Digital Transformation and the Number of New R&D Alliance Partners

This study elucidates the impact of digital transformation on the number of new partners in corporate R&D alliances from three aspects.

First, digitalization enhances a company's information processing capabilities, reducing partner search costs. Highly digitalized companies can leverage big data analytics, artificial intelligence algorithms, and other technological tools to identify potential partners in a broader context, assessing their technological capabilities, resource endowments, and reputation for cooperation, thereby significantly reducing information asymmetry and search costs. Second, digitalization strengthens a company's resource integration capabilities, increasing its attractiveness to new partners. Companies with higher levels of digitalization often possess stronger resource integration capabilities and technological compatibility, providing potential partners with more convenient interfaces and more efficient collaboration platforms. The construction of digital platforms allows companies to incorporate partners into a unified technological framework, reducing coordination costs and technological barriers in cross-organizational collaboration. This platform capability makes highly digitalized companies more attractive partners in R&D alliance networks,

attracting more partners to actively seek cooperation. Finally, digitalization promotes corporate knowledge transparency, strengthening the foundation of trust in cooperation. The application of digital technologies allows information such as a company's technological capabilities, R&D direction, and cooperation history to be presented more transparently, reducing the uncertainty of potential partners' perception of a company's capabilities. This transparency effect helps to quickly establish initial trust in the early stages of cooperation, laying the foundation for deeper collaboration later. Research on alliance and combination networks indicates that resource flow plays a positive mediating role between network connectivity and innovation capabilities, and the degree of digitalization is a key factor promoting resource flow. Based on the above analysis, this study proposes the following hypotheses.

H1: The degree of digital transformation contributes to the number of new partners in the R&D alliance.

3.2 Speed of Digital Transformation and Number of New Partners in R&D Alliances

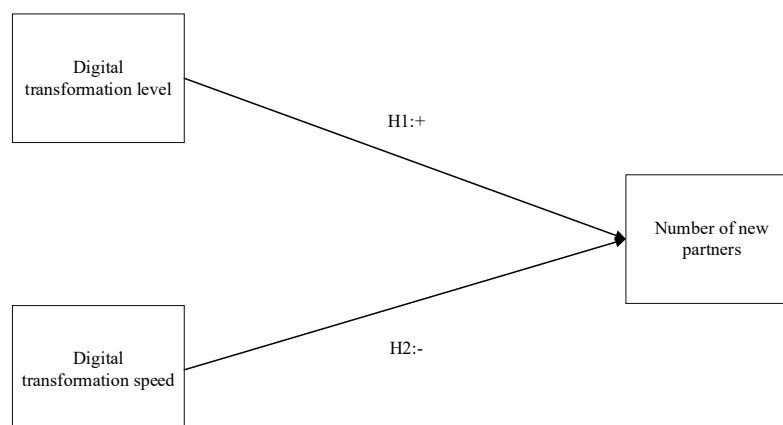
This study elucidates the impact of the speed of digital transformation on the number of new partners in corporate R&D alliances from three aspects.

First, rapid transformation leads to a resource crowding-out effect, dispersing resources needed for expanding cooperation. A faster pace of digital transformation means that companies need to invest significant funds, human resources, and management effort in technology upgrades, process reengineering, and talent development in the short term. These resource investments are highly exclusive, potentially crowding out resources that could be used to expand new partnerships and maintain existing ones. When companies focus primarily on internal digital transformation, their attention to and management of external cooperation networks inevitably decreases, thus inhibiting the establishment of new partnerships. Second, rapid transformation exacerbates internal organizational turmoil and reduces the stability of external cooperation. Excessive speed of digital transformation can lead to internal process turmoil, restructuring of authority and responsibility systems, and changes in personnel skills. These organizational-level instabilities will be transmitted to the external cooperation level. Potential partners may have doubts about the performance capabilities, technological compatibility, and sustainability of cooperation when establishing partnerships with companies undergoing rapid transformation, thus reducing their willingness to cooperate. Research on alliance management capabilities shows that effective alliance management requires a stable organizational foundation and continuous resource investment, which rapid transformation erodes. Finally, rapid transformation may lead to a lag in organizational learning capabilities, making it difficult to effectively absorb external knowledge. Dynamic capability theory suggests that the speed of organizational change should match its learning capacity. When the speed of digital transformation exceeds the organization's learning capacity, enterprises will fall into a "digestion" dilemma, struggling to effectively absorb and integrate external knowledge resources. In this situation, even if enterprises encounter new partners, they will find it difficult to obtain substantial innovative benefits from the collaboration, leading to superficial and short-term partnerships, which is detrimental to establishing sustainable and stable R&D alliances. Based on the above analysis, this study proposes the following hypothesis:

H2: The speed of digital transformation hinders the number of new partners in R&D alliances.

Figure 1 is the research model diagram of this paper.

Figure 1 Research model



4. Research Design

4.1 Samples and Data Sources

This study selected listed companies in China's pharmaceutical manufacturing industry from 2011 to 2022 as research subjects. The pharmaceutical manufacturing industry is characterized by its technology innovation orientation and R&D alliance orientation. This research is suitable for studying issues related to R&D alliances, and many existing studies on corporate R&D alliances are based on the pharmaceutical manufacturing industry^[19]. This study determines the formation of R&D alliances and the selection of partners based on enterprise patent data^[20]. The required patent data was obtained from the China National Intellectual Property Administration. The study also retrieved historical financial information and corporate governance data from company websites and the Guotai An database. Regarding data processing, this study first eliminated ST/PT companies and samples with excessive missing data based on the list of listed pharmaceutical manufacturing companies published by the China Securities Regulatory Commission to ensure data completeness and reliability. Secondly, it identified other organizations that had jointly applied for patents with the aforementioned companies within a certain period, using patent data disclosed by the China National Intellectual Property Administration, to establish R&D alliances^[21]. The required patent data was obtained from the China National Intellectual Property Administration. The study also retrieved historical financial information and corporate governance data from company websites and the Guotai An database. Regarding data processing, this study first eliminated ST/PT companies and samples with excessive missing data based on the list of listed pharmaceutical manufacturing companies published by the China Securities Regulatory Commission to ensure data completeness and reliability. Secondly, it identified other organizations that had jointly applied for patents with the aforementioned companies within a certain period, using patent data disclosed by the China National Intellectual Property Administration, to establish R&D alliances.^[18] Then, all continuous variables were shortened at the 1st and 99th percentiles to address outlier issues. Finally, considering the causal relationship between the independent and dependent variables, the variables were lagged by one period to address reverse causality. After these processing steps, this study obtained a sample of 902 R&D alliances from 133 listed companies in China's pharmaceutical manufacturing industry from 2011 to 2022.

4.2 Variable measurement

4.2.1 Explained Variable

Number of new R&D alliance partners (NEW). The selection of new R&D alliance partners refers to a company's choice of partners who possess heterogeneous knowledge resources, cutting-edge technological capabilities, and a high willingness to take risks^[22]. Existing research typically uses new partners with whom one has never collaborated before as a proxy for new partner selection^[23]. Therefore, this study also adopts this approach, using the number of other organizations with which firms have no prior patent collaborations as a measure of the degree of exploratory partner selection. Specifically, this study counts the number of new partners with which firms engage in patent collaboration for the first time within a five-year window of a specific year. Considering the potential for significant bias in the final data, to ensure the robustness of the results, this study adds 1 to the number of new partners and then takes the logarithm^[24].

4.2.2 Explanatory Variables

Digital Transformation Degree (DT): Referring to the research of Li Yingmei et al^[25], this paper uses the logarithm of the enterprise's digital intangible assets to measure the degree of enterprise digital transformation. Specifically, the first step is to refer to existing research to determine the keyword "digitalization" and identify the digital part of the enterprise's intangible assets through this digital keyword. That is, according to the name of the detailed account of "intangible assets" in the financial statements of listed companies, the digital keyword is screened, and the investment is the investment related to digitalization. Digital Transformation Speed (DTV): Based on the approach of Du Shanzhong and Ma Lianfu^[26], this paper also uses the above-mentioned degree of enterprise digital transformation as the basis and adopts relative speed to measure the speed of enterprise digital transformation, so as to more directly reflect its changing trend.

4.2.3 Control Variables

Referring to the existing research, this study selects enterprise age, enterprise size, R&D expenses, partner type, equity

concentration, market-oriented index, operating income growth rate, and debt ratio as control variables.

4.3 Model Building

To investigate the impact of digital transformation on the number of new partners in R&D alliances, this study focuses on listed pharmaceutical manufacturing companies in Shanghai and Shenzhen, China, and employs a multidimensional fixed effects model for estimation, specifically a dual fixed effects model that controls for time trends and individual factors, for data analysis. Robust standard errors were assumed in the regression tests.

5. Results

5.1 Descriptive Statistics

Table 1 shows the mean, standard deviation, and correlation coefficient analysis results of the variables in this study. The absolute values of the correlation coefficients among all variables are less than 0.5, indicating that high correlation between variables will not lead to estimation bias. Furthermore, the VIF (Variance Inflation Factor) values for all variables are less than 10, indicating that there is no serious multicollinearity problem among the variables.

5.2 Benchmark Regression

Table 2 presents the regression results of the degree and speed of digital transformation on the number of new partners in the R&D alliance.

Hypothesis 1 proposes that the degree of digital transformation promotes the number of new partners in the R&D alliance. The first column of Table 2 shows that the degree of digital transformation has a significant positive effect on the number of new partners in the R&D alliance; that is, as the degree of digital transformation of an enterprise increase, it can attract more new partners to join the R&D alliance. Thus, Hypothesis 1 is true.

Hypothesis 2 proposes that the speed of digital transformation hinders the number of new partners in the R&D alliance. The second column of Table 2 shows that the speed of digital transformation has a significant negative effect on the number of new partners in the R&D alliance, meaning that excessively rapid digital transformation may have a limiting effect on attracting new partners. Thus, Hypothesis 2 is true.

Table 1 Descriptive statistics and correlation coefficient analysis

	NEW	DT	DTV	Fage	Size	Rd	Partner type	Market	Growth	Lev	Top10
NEW	1.000										
DT	0.209***	1.000									
DTV	-0.038	0.128***	1.000								
Fage	0.041	0.243***	-0.024	1.000							
Size	0.207***	0.554***	0.057*	0.226***	1.000						
Rd	0.141***	0.068**	0.063*	0.167***	0.215***	1.000					
Partner type	0.658***	0.122***	-0.002	0.110***	0.212***	0.028	1.000				
Market	0.140***	0.198***	0.041	0.215***	0.210***	0.155***	0.179***	1.000			
Growth	-0.010	-0.029	0.063*	-0.095***	-0.036	-0.026	0.001	0.005	1.000		
Lev	-0.028	0.270***	0.022	0.124***	0.319***	-0.044	0.018	0.037	-0.006	1.000	
Top10	0.015	0.016	0.077**	-0.150***	0.108***	0.059*	-0.094***	-0.130***	0.109***	-0.172***	1.000
Mean	1.971	14.606	0.016	2.917	7.880	17.306	1.261	9.112	0.164	0.322	57.688
SD	1.863	1.504	0.526	0.304	0.963	18.891	0.848	1.971	0.278	0.164	13.359

Note: Correlation coefficients with absolute values higher than 0.057 are significant at a two-tailed test of 0.1, and correlation coefficients with absolute values higher than 0.094 are significant at a two-tailed test of 0.01. N=902.

Table 2 Benchmark effects

	(1)	(2)
	NEW	NEW
DT	0.078(0.045)**	
DTV		-1.740(0.857)**
Control variables	Include	Include
Year mute variable	Include	Include
cons	7.617(3.861)**	8.096(3.817)**
F	33.956	34.181
adj. R ²	0.623	0.624

Note: Standard errors in parentheses. Hypothesis test coefficients are one-tailed, control variable coefficients are two-tailed; * p<0.1, ** p<0.05, *** p<0.01. N=902.

6. Conclusion and Discussion

Given the limited scope of existing research on digital transformation and the governance of R&D alliance relationships, this study analyzes the impact of digital transformation on the number of new partners in R&D alliances. The results show that (1) as the degree of digital transformation increases, more new partners can be attracted to join the R&D alliance. (2) Overly rapid digital transformation may have a limiting effect on attracting new partners.

The main contributions of this paper are as follows: First, it expands the research perspective on digital transformation, extending it from the internal performance level of enterprises to the external cooperation network level, revealing the promoting effect of the degree of digital transformation on the number of new partners in R&D alliances. Second, it distinguishes between the two dimensions of transformation degree and transformation speed, finding that they have opposite effects, enriching the theoretical connotation of the dynamic process of digital transformation. Finally, this study provides a reference for enterprises to formulate the pace and path of digital transformation, emphasizing that while increasing the depth of transformation, the speed of advancement should be reasonably controlled to achieve a steady expansion of the cooperation network.

This study also has certain limitations. First, the sample data mainly comes from certain specific industries and regions and may not fully represent the situation of enterprises in all industries and regions. Secondly, the study only focused on the single dimension of the degree and speed of digital transformation, without exploring other factors that may influence the number of new partners in R&D alliances, such as corporate culture and management models. Future research could consider collecting data from a broader scope to further enrich the theoretical model and explore the impact of other variables on partner selection.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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