Vilnius University Press

Content lists are available at VilniusUniversity Press

Transformations In Business & Economics
2025, Vol. 24 No 3 (66), pp.329-348.

ISSN 1648-4460 | E-ISSN 2538-872X
https://doi.org/10.15388/Tibe.2025.24.3.16

Chapter: Technological Transformation, Digitalization, and Innovation Dynamics as Drivers of Innovation, Organizational Change, and Process of Improvement

The impact of digital technology affordances on radical innovation: moderating effects of industry technological turbulence and regional innovation environment

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Annotation. To explore the mechanisms and conditions through which digital technology impacts radical innovation, this paper uses a sample of 409 firms to integrate digital technology affordances and radical innovation into the same research framework from the technology affordances' perspective while also assuming the effect of industry technological turbulence and regional innovation environments. The impact of digital technology accumulation affordance, variation affordance, and their comprehensive balance on radical innovation shows an "inverted U-shaped" relationship. Industry technological turbulence and regional innovation environment have a negative moderating impact on the above relationships. From the interaction viewpoint between internal technology and the external environment, this study explains the conditions under which digital technology affects radical innovation, harnessing digital technology for radical innovation.

Keywords: accumulation and variation affordances, radical innovation, technological turbulence.

JEL classification: O47, O31, O32, R58.

Introduction

Advancing breakthrough innovations have emerged as a novel driving force to escape the trap of low-end technology lock-in, address "bottleneck" challenges, and foster new quality productivity in China (Jingwei, 2023). The rapid technological advancements, such as AI, cloud computing, and blockchain, have enabled China to focus on innovation (Tian, Li, 2022). Fully leveraging digital technology is a key means to perform radical innovations (Liu *et al.*, 2023). However, the success rate of digital transformation among Chinese firms is only 20% (McKinsey survey report). Among firms, differences

Submitted on November 2024. Accepted on April 2025.

exist in the success rates of similar digital technology applications (Feng *et al*., 2022). Therefore, digital technology has affordances, and firms adopting diverse pathways yield different results in breakthrough innovations. Digital technology affordances refer to the corporate ability to leverage the same digital technologies to achieve differentiated objectives (Chatterjee *et al*., 2020). Based on the functional characteristics, digital technology affordances can be divided into accumulation and variation affordances (Feng *et al*., 2022; Autio *et al*., 2018). Accumulation affordance refers to firms leveraging digital technology to homogenise information related to production, manufacturing, sales, operations, and other aspects, enabling efficient storage, retrieval, sharing, and utilisation of information (Huang, 2024). This process establishes unified standards for interaction with other entities. Variation affordance refers to the firm's ability to support the integration and generation of digital technologies through the re-editing and implementation of digital technology (Verstegen *et al*., 2019). Unified standards offer resource and efficiency support for the integration and generation of diverse technologies, while the differentiated utilisation of digital technologies eventually expands the information scope. These two affordances are both independent and complementary, jointly exerting a notable impact on radical innovations. Accumulation affordance establishes a unified data port for firms through information homogenisation, which is conducive to improving the efficiency of resource storage, acquisition, and sharing. Excessive pursuit of accumulation may exacerbate resource dependence and path dependence, hindering disruptive innovation. Therefore, there exists an "optimal scale" for accumulation affordance. Similarly, variation affordance facilitates disruptive innovation through differentiated utilisation of digital technologies. However, excessively seeking variation affordance increases the cost of technology integration. Therefore, there is also an "optimal scale" for variation affordance. Exploring the optimal scale of accumulation and variation affordances represents a breakthrough for firms to overcome the disruptive innovation dilemma.

Existing research lacks the exploration of the optimal scale of digital technology affordances and has not studied the impact of the balance between different types of affordances on radical innovation (Haihua *et al*., 2023). Firstly, studies on the effects of digital technology affordances focus on its positive and negative impacts, including its impact on digital transformation, digital innovation, cross-border innovation, green innovation, business model innovation, and value chain upgrading (Wu *et al*., 2024; Feng *et al*., 2022). However, there is a lack of exploration into the optimal scale. Secondly, studies focus on the "net effect"[1] of accumulation affordance and variation affordance on firms (Sun, 2024). As carriers of digital technology combinations, firms must prioritise balancing different affordances (Wang, Zhou, 2022). Seeking a single affordance often leads to innovation failures. Therefore, studying the comprehensive balance between cumulative and variation affordances is crucial. Based on the affordance theory and the resource-based view, this paper adopts digital technology affordance and radical innovation into the same framework. Using 409 questionnaire data, it explores the effect of digital technology accumulation affordance and variation affordance on radical innovation and the internal mechanisms. The study also examines the moderating effects of industry technological turbulence and regional innovation environment on the above relationships, further opening up the mechanism black box and contingency conditions of digital technology affordance driving radical innovation.

[1] According to the research by Zhang Ming *et al*. (2023), the "net effect" refers to the independent influence of a single antecedent on enterprise innovation

1. Theoretical Analysis and Research Hypotheses

Affordance theory. The notion of "affordance" is used to describe the relationship between the environment and organisms. The ecologist James Gibon (1986) proposed that the environment provides organisms with action possibilities, and organisms can influence the environment, but they are still constrained by it. This phenomenon was defined as "affordance" (James, 1977). Later, this concept was extended to the IT field, forming the notion of "technical affordance". Technical affordance is defined as the potential for interaction in diverse contexts to interact continuously with technological subjects to produce various outcomes (Xie *et al.*, 2022). It focuses on the interactive relationship between the technological entity and its users, arguing that the technological effects depend on the technology and the actual situation of the users and their understanding and application of the technology (Li, Han, 2024; Krajčík *et al.*, 2023). Digital technology affordances refer to the possibilities that digital technology offers for firms (Wang *et al.*, 2023; Nambisan *et al.*, 2019; Bilan *et al.*, 2024), stressing that firms develop digital technology based on their business characteristics (Huang, 2024). Arguably, digital technology possesses affordances which are not only determined by the technology but also affected by the firm's differentiated cognition of digital technology. The digital technology affordances may be a significant factor leading to differentiated outcomes in radical innovation (Xianyun *et al.*, 2024). Diverse digital technology affordances have varying impacts on radical innovation, and the effect of digital technology affordances at different levels also differs.

Resource-based theory. This theory stresses the dependence of organisations on external resources since 1) organisations cannot be self-sufficient and must obtain development resources from the external environment; 2) power is related to resource dependence; an organisation's dependence on external resources determines the power of the external environment over the organisation; 3) the organisational resources come from the external environment where interdependent organisations are mutually independent (Lu *et al.*, 2024). Close relationship exists between a firm's acquisition, storage, utilisation, and sharing of resources and its innovative capability (Pfeffer, Salancik, 1978); diverse ways of utilising resources also have diverse impacts on product innovation (Dai *et al.*, 2022); firm resource contribution enhances innovation performance through different paths (Zhang *et al.*, 2024). The digital technology's affordances have altered the resource capabilities and firms' environment, impacting their radical innovations.

(1) The Impact of Digital Technology Accumulation Affordance on Radical Innovation

Radical innovation aims at disruptive changes, seeking more heterogeneous resources externally to drive innovation (Sun *et al.*, 2021). Accumulation affordance enables the homogenisation of internal and external information, establishes unified standards for data acquisition, storage, and sharing, and enhances resource utilisation efficiency (Yoo *et al.*, 2012), thereby facilitating disruptive innovation. As firms seek the accumulation affordance, the accumulation affordance exceeds a reasonable range, and the radical innovation declines since the excessive pursuit of homogenisation of resources increases the difficulty and cost of resource management. The dependence on unified standards makes it difficult for enterprises to break out of their original operational logic and pursue radical innovation (Velu, 2015).

H1: There is an inverted U-shaped relationship between the digital technology accumulation affordance and radical innovation. As the accumulation affordance increases, radical innovation first improves and then decreases.

(2) The Impact of Digital Technology Variation Affordance on Radical Innovation

The digital technology variation affordances stress the flexible application of digital technologies, enabling radical innovations (Autio *et al*., 2018). Reasonable variability affordances allow firms to reedit digital components for diverse needs, creating new products that disrupt existing rules and demands (Feng *et al*., 2022). Overseeking variation affordances leads to increased difficulty and costs in technology integration, reducing the success rate of disruptive innovations.

H2: There exists an inverted U-shaped relationship between the digital technology variation affordance and radical innovation, meaning that as the variation affordance increases, radical innovation first rises and then declines.

(3) The Impact of the Comprehensive Balance between the Digital Technology Accumulation Affordance and the Variation Affordance on Radical Innovation

The accumulation and variation affordances of digital technology complement each other. Former offers resource support for variation affordance by homogenising data, while the latter expands the information scope for accumulation affordance (Chatterjee *et al*., 2020). Realising a balance between the two is conducive to radical innovation (Markus, Silver, 2008). Though excessively seeking a comprehensive balance between the two consumes notable resources, it negatively affects radical innovation.

H3: There is an inverted U-shaped relationship between the comprehensive balance of accumulation affordance and variation affordance of digital technology and radical innovation. Specifically, as the degree of comprehensive balance between the two increases, radical innovation first rises and then declines.

(4) The Moderating Effect of Technological Turbulence

Previous studies show that technological turbulence has a notable effect on innovation. The rapidly changing technological environment increases the risk of firms losing their differentiated edges (Wang, Liu, 2020). It also forces firms to enhance their dynamic capabilities, which is conducive to breaking through technological barriers (Yin *et al*., 2014). These inferences are made on the effect of technological turbulence on the linkage between digital technology affordance and radical innovation.

Technological turbulence affects the linkage between the affordance of digital technology accumulation and radical innovation. A rapidly changing technological environment intensifies both the positive and negative effects of accumulation affordances on radical innovation. In highly volatile environments, firms must innovate to maintain their competitive edges. With stronger innovation demands, firms have stronger motives for innovation (Liu *et al*., 2024). Firms must unify data sharing standards, strengthening the positive role of accumulation. For firms that seek the accumulation of affordances, the external technological environment has become more difficult to predict (Jian *et al*., 2024).

H4a: Compared with enterprises in low-technology turbulence industries, the inverted U-shaped relationship between the digital technology accumulation affordance and radical innovation is steeper in high-technology turbulence industries, with a more significant positive effect of accumulation affordance on radical innovation and a higher inflection point.

In high technological turbulence, firms strive to enhance their resource bricolage capabilities and dynamic capabilities (Liu *et al*., 2024). By strengthening the application of digital technologies, these firms amplify the positive impact of variation affordance on radical innovation. Firms that excessively seek variation affordances may increase the risk of failure in radical innovation.

H4b: Compared with enterprises in low-technology turbulence industries, the inverted U-shaped relationship between digital technology variation affordance and radical innovation in high-technology turbulence industries is steeper, with a more significant positive effect of variation affordance on radical innovation and a higher inflection point.

Technological turbulence affects the linkage between the comprehensive balance between the accumulation affordance and variation affordance of digital technology and radical innovation. The highly turbulent technological environment offers firms abundant innovative resources, enhancing the positive impact of the comprehensive balance between accumulation and variation affordances on radical innovation. Excessively pursuing a thorough balance between the two leads to balancing resource acquisition (Liu *et al*., 2024), exacerbating the adverse effect of expanding the comprehensive balance between accumulation and variation affordances on radical innovation.

H4c: Compared with enterprises in low-technology turbulence industries, the inverted U-shaped relationship between the comprehensive balance of digital technology accumulation affordance and variability affordance and radical innovation is steeper in high-technology turbulence industries, with a more significant positive effect of this comprehensive balance on radical innovation and a higher inflection point.

(5) The Moderating Role of the Regional Innovation Environment

The regional innovation environment is an important factor influencing enterprise innovation (Liu *et al*., 2024; Luo *et al*., 2022; Zhou *et al*., 2024). A favourable environment in terms of key entities, culture, and policy serves as an important guarantee to cultivate their innovation capabilities (Luo *et al*., 2022). The differences in the innovation environment between regions affect the relationship between the digital technology accumulation affordance and radical innovation. In high-innovation regions, firms obtain more innovation resources (Zeng *et al*., 2022), enhancing the positive effects of accumulation affordance. However, firms that excessively seek the accumulation affordance may be more likely to fail in radical innovations (Liu *et al*., 2024).

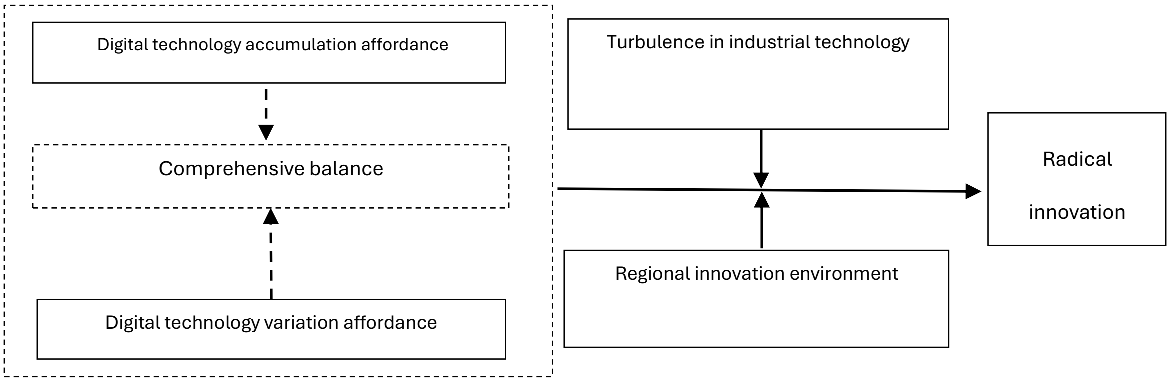
H5a: Compared to enterprises located in low-innovation regions, the inverted U-shaped relationship between the accumulation affordance of digital technology and radical innovation is steeper in high-innovation regions. The positive effect of accumulation affordance on radical innovation is greater, and the inflection point is higher.

Variances in the interregional innovation environment impact the linkage between digital technology variation affordance and radical innovation (Tsuja, Mariño, 2013). For firms with high variation affordance, the innovation enhances the path dependence, hinders technological change, and exacerbates the adverse impacts of an overemphasis on variation affordance.

H5b: Compared with enterprises located in low-innovation regions, the inverted U-shaped relationship between the variation affordance of digital technology and radical innovation is steeper in high-innovation regions. The positive effect of variation affordance on radical innovation is greater, and the inflection point is higher.

In high-innovation regions, abundant policy support and a well-established institutional environment are conducive to attracting digital technology talent (Zhang *et al*., 2020). These factors offer favourable conditions for firms to acquire resources and integrate technology, enhancing the positive effects of this comprehensive balance. However, abundant resources may increase the management costs of seeking such a balance (Nambisan *et al.*, 2019), further exacerbating the adverse impact on radical innovation.

H5c: Compared with enterprises in low-innovation regions, the inverted U-shaped relationship between the comprehensive balance of digital technology accumulation affordance and variation affordance and radical innovation is steeper in high-innovation regions. The positive effect of this comprehensive balance on radical innovation is greater, and the inflection point is higher.



Source: created by the authors.

Figure 1. **Theoretical Model**

Based on the above analysis, the following theoretical model diagram is obtained (see *Figure 1*).

2. Research Design

2.1 Sample Selection and Data Source

Both online and offline methods are used to distribute and collect questionnaires. Online surveys rely on governments, business relationships, and other means to contact survey respondents. Specifically, survey participants need to meet one of the following three criteria: 1) they shall be senior executives of enterprises; 2) they shall be middle-level managers in enterprises; 3) they shall be professional and technical personnel. Offline questionnaires were distributed and collected on-site through industry annual conferences, forums, and other channels. A total of 468 questionnaires were collected, with the following questionnaires deemed invalid: 1) The response time for the questionnaire is less than or equal to 60 seconds; 2) the options for the same type of items in the questionnaire lack logical consistency; 3) there are numerous consecutive identical options selected in the questionnaire. The final number of valid questionnaires was 409 (87.39% of recovery rate).

2.2 Variable Selection

A Likert 7-point scale (1 = Strongly Disagree; 7 = Strongly Agree) is adopted to gauge both the explanatory and explained variables, referring to Tian *et al.* (2018). The moderator variables are derived from national research reports. The selection of control variables refers to studies on innovation. *Table 1* shows the specific sources and measurement methods for all variables.

Table 1. Variable Definition

Variable type	Variable name	Variable symbol	Measurement	Reference
Dependent variable	Radical innovation	*RI*	Three issues, such as “Fundamental technological improvements have occurred?”	Haoet *et al.*（2020）
Independent variable	Digital technology accumulation affordance	*DTAA*	Four issues, such as “Enterprises are able to analyse various business data, including research and design, manufacturing, product services, and more”	Cheng *et al.*（2022)
	Digital technology variation affordance	*DTVA*	Three issues, such as “Enterprises are comprehensively promoting digital design, production, and management”	
	Balance	*BAL*	The product of the digital technology accumulation affordance and variation affordance	Yang *et al.*（2021)
Moderator variable	Industry technological Turbulence	*ITT*	Four issues, such as “The technology in this industry is rapidly changing”	Zhou and Wu（2010）
	Regional innovation environment	*RIE*	Using the comprehensive value of regional innovation capability from the “Evaluation Report on China’s Regional Innovation Capability 2023” compiled by the China Science and Technology Development Strategy Research Group as the evaluation criterion	Dang *et al.*（2008）
Control variable	Enterprise age	*Age*	The year this study was conducted (2024) minus the year the enterprise was established	Li *et al.*（2022）
	Enterprise scale	*Size*	Assign values from 1 to 7 according to the different total number of employees in a company (100 or fewer, 100-300, 301-500, 501-1000, 1001-2000, 2001-3000, and 3001 or more).	
	Nature of equity	*Owner*	Denote state-owned enterprises as 0 and other enterprises as 1	
	R&D investment	*R&D*	Based on a comparison with competitors in the same industry, score the level of own R&D investment, where “1 = higher than industry competitors” and “0 = lower than industry competitors”	
	Listed company	*GP*	Publicly listed companies are recorded as 1, and non-publicly listed companies are recorded as 0	
	Industry type	*Industry*	Virtual variable	
	Academic background	*AB*	Executives who have taught at universities or engaged in research work at research institutes or scientific associations are assigned a value of 1; otherwise, the value is 0	
	political background	*PT*	Executives who serve or have served as representatives of the people (party representatives), members of the CPPCC, or hold positions in the military or government are assigned a value of 1; otherwise, the value is 0	

Source: created by the authors.

A benchmark regression model is built with the breakthrough innovation as the dependent variable:

$$RI = \alpha_0 + \alpha_1 DTAA + \alpha_2 DTAA^2 + \sum \alpha_k Control + \varepsilon \qquad (1)$$

$$RI = \alpha_0 + \alpha_1 DTVA + \alpha_2 DTVA^2 + \sum \alpha_k Control + \varepsilon \qquad (2)$$

$$RI = \alpha_0 + \alpha_1 (DTAA \times DTVA) + \alpha_2 (DTAA \times DTVA)^2 + \sum \alpha_k Control + \varepsilon \qquad (3)$$

RI represents radical innovation. α_0 is the constant term. *DTAA* and $DTAA^2$ mean the linear and quadratic terms of digital technology accumulation affordance, respectively. *DTVA* and $DTVA^2$ connote the linear and quadratic terms of digital technology variation affordance, respectively. *(DTAA×DTVA)* and $(DTAA \times DTVA)^2$ indicate the linear and quadratic terms of the balance between the two. α_k denotes the coefficients of the control variables. ε shows the random error term.

2.3 Homologous Bias Analysis

The Harman method is used to test for common method biases (CMB). The variance explained by the first principal component after rotation was 23.345%, indicating that there is no issue with CMB.

2.4 Reliability and Validity Testing

This paper conducts EFA and CFA tests on the scale (*Table 2*).

Table 2. Results of Factor Analysis of Variables

Variables	Measurement items	Factor loading	Cronbach's Alpha	Cumulative explained variance	CR	AVE	KMO	Bartlett's Test of Sphericity	
								Approximate chi-square	Sig.
DTAA	$DTAA_1$	0.837	0.888	74.964%	0.923	0.756	0.835	909.420	0.000
	$DTAA_2$	0.893							
	$DTAA_3$	0.877							
	$DTAA_4$	0.855							
DTVA	$DTVA_1$	0.896	0.873	79.849%	0.923	0.799	0.742	617.292	0.000
	$DTVA_2$	0.894							
	$DTVA_3$	0.891							
ITT	ITT_1	0.822	0.860	70.576%	0.906	0.712	0.810	740.809	0.000
	ITT_2	0.836							
	ITT_3	0.872							
	ITT_4	0.829							
RI	RI_1	0.921	0.921	86.537%	0.951	0.865	0.865	919.519	0.000
	RI_2	0.939							
	RI_3	0.930							

Source: own calculations.

All factors' Cronbach's Alpha coefficients are above 0.8, and the CR coefficients are above 0.9; therefore, the scale has high reliability (Fornell & Larcker, 1981). All factor loading values of the scale items show that the scale has good convergent validity. The Bartlett's Test of Sphericity reached a significant level ($p<0.001$), with the cumulative explained variance of each variable exceeding 70%, which is much higher than the threshold of 40%. Further, the KMO values indicate that the items can explain a notable portion of the information related to the variables. In short, the adopted scale has high reliability and validity.

3. Empirical Analysis and Testing

3.1 Descriptive Statistical Analysis

Table 3. Descriptive Statistical Analysis (n=409)

Attribute	Classification	Number of samples	Percentage	Attribute	Classification	Number of samples	Percentage
Enterprise age	Within 10 years	174	42.543%	Industry	Service industry	227	55.502%
	10-20 years	171	41.809%		Manufacturing industry	117	28.606%
	Over 20 years	64	15.648%		Others	65	15.892%
Number of employees	0-500 people	181	44.254%	Listing situation	Be listed	230	56.235%
	501-1000 people	68	16.626%		Unlisted	179	43.765%
	Over 1000 people	160	39.120%	Source region	Eastern region	235	57.457%

Table 3 (*continuation*). Descriptive Statistical Analysis (n=409)

Nature of Business	State-owned enterprise	176	43.032%		Central region	57	13.936%
	Non-state-owned enterprises	233	56.968%		Western region	117	28.607%

Source: own calculations.

In this study, descriptive statistics of different attributes are reported including enterprise age, number of employees, and nature of business (*Table 3*).

3.2 Benchmark Regression Analysis

In *Table 4*, Model (1) includes all the control variables. Model (2) adopts the digital technology accumulation affordance and its squared term.

Table 4. Benchmark Regression Analysis Results (n=409)

Variables	*RI*			
	(1)	(2)	(3)	(4)
DTAA		1.238**(0.371)		
DTAA²		-0.128***(0.041)		
DTVA			0.709***(0.167)	
DTVA²			-0.069***(0.020)	
BAL				0.130***(0.023)
BAL²				-0.003***(0.001)
Age	-0.009(0.007)	-0.010(0.007)	-0.011(0.007)	-0.011*(0.007)
Scale	0.107***(0.032)	0.087***(0.032)	0.117***(0.031)	0.100***(0.013)
Nature of Business	1.170***(0.114)	1.122***(0.114)	1.060***(0.113)	1.051***(0.112)
Multinational company	0.013(0.374)	-0.117(0.371)	0.067(0.363)	-0.050(0.360)
Listed company	0.255**(0.117)	0.243**(0.116)	0.261**(0.113)	0.300***(0.112)
Variables	*RI*			
	(1)	(2)	(3)	(4)
Patent	0.397***(0.121)	0.355***(0.122)	0.308***(0.118)	0.344***(0.116)
Industry type	-0.024*(0.071)	-0.024(0.070)	-0.004(0.069)	-0.022(0.068)
Executive political background	0.728***(0.124)	0.678***(0.123)	0.586***(0.123)	0.619***(0.121)
Constant term	3.118***(0.199)	0.473(0.775)	1.706***(0.351)	2.061***(0.260)
R^2	0.466	0.484	0.503	0.510
F value	43.595***	37.342***	41.061***	41.444***

Notes: the values in parentheses show the standard error; *, **, and *** mean significance levels at 10-, 5-, and 1%, respectively.

Source: own calculations.

The coefficient of digital technology accumulation affordance is significant and positive (1.240). The coefficient of the squared term is significantly negative (-0.128). Thus, there is an inverted U-shaped relationship between digital technology accumulation affordance and radical innovation, therefore confirming H1. Model (3) includes the digital technology variation, the affordance, and its squared term. The coefficients for the digital technology variation affordance and the squared term are significantly positive (0.708) and negative, respectively (-0.069), indicating an inverted U-shaped relationship between the digital technology variation affordance and radical innovation, thereby validating H2. Model (4) employs the comprehensive balance between the accumulation affordance and the variation affordance of digital technology. The coefficient of the comprehensive balance between the two is positive and significant, while the coefficient of the squared term is negative and significant. This indicates an inverted U-shaped relationship between the comprehensive balance of digital technology accumulation affordance and variation affordance, and radical innovation. Hence, H3 is supported.

3.3 Testing for Moderating Effects

In *Table 5*, Model (1) shows that the interaction term coefficient between accumulation affordance squared and industry technological turbulence is negative and significant (-0.572).

Table 5. Benchmark Regression Analysis Results (n=409)

Variables	*RI*					
	(1)	(2)	(3)	(4)	(5)	(6)
DTAA	1.454*** (0.416)			1.559*** (0.412)		
DTAA²	-1.337*** (0.414)			-1.437*** (0.411)		
DTVA		1.043*** (0.246)			1.057*** (0.250)	
DTVA²		-0.791*** (0.243)			-0.810*** (0.252)	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
BAL			1.145*** (0.206)			1.213*** (0.209)
BAL²			-0.970*** (0.204)			-1.049*** (0.210)
ITT	0.268*** (0.055)	0.249*** (0.053)	0.236*** (0.053)			
RIE				0.184*** (0.054)	0.157*** (0.057)	0.142** (0.056)
DTAA×ITT	0.536* (0.284)					
DTAA²×ITT	-0.572** (0.290)					
DTVA ×ITT		0.615*** (0.222)				
DTVA²×ITT		-0.623*** (0.219)				
BAL ×ITT			0.268 (0.173)			
BAL²×ITT			-0.308* (0.172)			
DTAA×RIE				0.750** (0.354)		
DTAA²×RIE				-0.769** (0.355)		
DTVA×RIE					0.654*** (0.253)	
DTVA²×RIE					-0.658** (0.271)	
BAL×RIE						0.374* (0.208)
BAL²×RIE						-0.443* (0.231)
Age	-0.011* (0.007)	-0.010 (0.006)	-0.011* (0.006)	-0.009 (0.007)	-0.009 (0.006)	-0.011 (0.006)
Scale	0.097*** (0.032)	0.130*** (0.030)	0.112*** (0.030)	0.102*** (0.032)	0.134*** (0.031)	0.118*** (0.031)
Nature of enterprise	1.057*** (0.112)	1.001*** (0.109)	1.004*** (0.110)	1.034*** (0.115)	0.996*** (0.112)	0.987*** (0.112)
Multinational company	-0.021 (0.362)	0.104 (0.354)	0.053 (0.353)	-0.082 (0.365)	0.089 (0.358)	0.007 (0.357)
Listed company	0.185 (0.113)	0.169 (0.110)	0.218** (0.111)	0.176 (0.116)	0.165 (0.113)	0.212* (0.113)

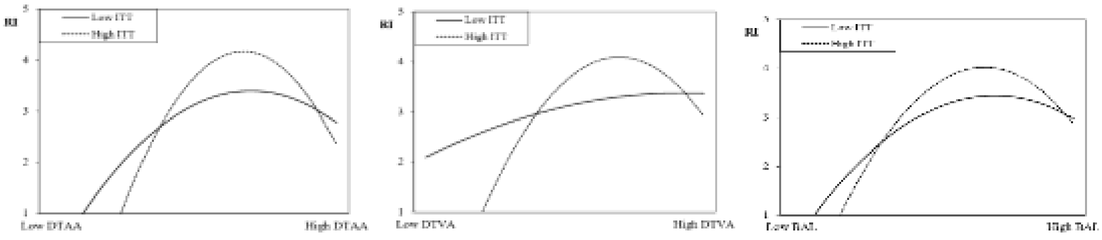
Table 5 (*continuation*). Benchmark Regression Analysis Results (n=409)

Variables	*RI*					
	(1)	(2)	(3)	(4)	(5)	(6)
Patent	0.337*** (0.118)	0.296*** (0.115)	0.340*** (0.114)	0.328*** (0.120)	0.280** (0.117)	0.332*** (0.115)
Industry type	-0.013 (0.069)	-0.002 (0.067)	-0.013 (0.067)	-0.007 (0.069)	0.013 (0.068)	-0.008 (0.067)
Executive political background	0.552*** (0.123)	0.444*** (0.122)	0.486*** (0.121)	-0.009*** (0.007)	-0.009*** (0.006)	0.557*** (0.121)
Constant term	3.393*** (0.198)	3.360*** (0.188)	3.392*** (0.190)	3.329*** (0.198)	3.270*** (0.191)	3.318*** (0.191)
R^2	0.515	0.539	0.538	0.053	0.508	0.526
F value	32.205***	35.461***	35.356***	30.808***	33.433***	33.743***

Source: own calculations.

Accordingly, industry technological turbulence has an adverse moderating effect on the impact of accumulation affordance on radical innovation, confirming H4a. Model (2) indicates that the interaction term coefficient between the square of variation affordance and industry technological turbulence is -0.623, with a 1% significance level. Hence, industry technological turbulence has an adverse moderating effect on the impact of variation affordance on radical innovation, thus validating H4b. Model (3) depicts that the coefficient of the interaction term between the squared term of the comprehensive balance of the two and the industry technological turbulence is -0.308, with a 10% significance level. Therefore, industry technological turbulence negatively moderates the linkage between the comprehensive balance of the two and radical innovation, supporting the H4c. Model (4) shows that the interaction term coefficient between accumulation affordance squared and regional innovation environment is -0.769, with a 5% significance level. Accordingly, the regional innovation environment negatively moderates the relationship between accumulation affordance and radical innovation, thus validating H5a. Model (5) shows that the coefficient of the interaction term between the square term of variation affordance and regional innovation environment is -0.658, with a 5% significance level, suggesting that the regional innovation environment negatively moderates the relationship between variation affordance and radical innovation, thereby validating hypothesis H5b. Model (6) indicates that the coefficient of the squared term of the comprehensive balance of the two and the interaction term with the regional innovation environment is negative and significant (-0.443). Thus, the regional innovation environment negatively moderates the relationship between the comprehensive balance of the two and radical innovation, supporting the H5c.

This study conducts a Simple Slope Analysis and plots the moderating effect diagrams (*Figure 2* and *Figure 3*). In industries with high technological turbulence, the inverted U-shaped curve is more compact and steep (*Figure 2*(a)-(c)). Hence, firms in industries with high technological turbulence experience a greater effect on radical innovation from the accumulation affordance, the variation affordance, and the balance of the two. The increase in technological turbulence within the industry reinforces an inverted U-shaped relationship between firms' accumulation affordance, variation affordance, the comprehensive balance between the two, and radical innovation, supporting H4a-4c.



(a) (b) (c)

Source: created by the authors.

Figure 2. **The Moderating Role of Industry Technological Turbulence in the Relationship Between the Digital Cumulative Affordance, Variant Affordance, and Radical Innovation**

In regions with a high-innovation environment, the inverted U-shaped curve pattern is more compact and steeper. Thus, the impact of digital technology accumulation affordance, variation affordance, and their comprehensive balance on radical innovation is greater for firms in a high-innovation environment (see *Figure 3(a)-(c)*). The inverted U-shaped relationship between the noticeable increase in the regional innovation environment, variation affordance, accumulation affordance, and the comprehensive balance of the two and radical innovation among them, is aligned with H5a-5c.

3.4 Robustness Check

1) Replace Variables. Drawing on Cao *et al*. and Wang and Wu, this study scales radical innovation (Cao *et al*., 2009) and then repeats the hypothesis testing steps (*Table* 6).

Table 6. Robustness Test Results After Replacing Variables (N=409)

Variables	RI									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DTAA		1.242*** (0.372)			1.467*** (0.416)			1.560*** (0.413)		
DTAA²		-0.128*** (0.042)			-1.344*** (0.415)			-1.434*** (0.412)		
DTVA			0.694*** (0.166)			1.009*** (0.245)			1.040*** (0.250)	
DTVA²			-0.065*** (0.020)			-0.734*** (0.242)			-0.777*** (0.252)	
BAL				0.127*** (0.023)			1.112*** (0.206)			1.186*** (0.209）
BAL²				-0.003*** (0.001)			-0.913*** (0.204)			-1.005*** (0.210）
ITT					0.273*** (0.055)	0.255*** (0.053)	0.243*** (0.053)			
RIE								0.181*** (0.054)	0.155*** (0.057)	0.139** (0.056）
DTAA×ITT					0.553* (0.284)					
DTAA²×ITT					-0.573** (0.290)					
DTVA ×ITT						0.571*** (0.222)				
DTVA²×ITT						-0.587*** (0.218)				
BAL ×ITT							0.269 (0.173)			
BAL²×ITT							-0.311* (0.172)			
DTAA×RIE								0.722** (0.354)		

Table 6 (*continuation*). Robustness Test Results After Replacing Variables (N=409)

Variables	RI									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DTAA²×RIE								-0.754** (0.355)		
DTVA×RIE									0.570** (0.253)	
DTVA²×RIE									-0.607** (0.271)	
BAL×RIE										0.304 (0.209）
BAL²×RIE										-0.404* (0.232）
Age	-0.012* (0.007)	-0.013** (0.007)	-0.014** (0.007)	-0.014** (0.007)	-0.014** (0.007)	-0.013** (0.006)	-0.014** (0.006)	-0.012* (0.007)	-0.012* (0.006)	-0.013** (0.006）
Scale	0.113*** (0.032)	0.093*** (0.032)	0.123*** (0.031)	0.106*** (0.031)	0.103*** (0.032)	0.136*** (0.030)	0.119*** (0.030)	0.108*** (0.032)	0.140*** (0.031)	0.124*** (0.031）
Nature of enterprise	1.150*** (0.115)	1.101*** (0.114)	1.033*** (0.112)	1.027*** (0.112)	1.039*** (0.113)	0.975*** (0.109)	0.978*** (0.110)	1.010*** (0.115)	0.968*** (0.112)	0.956*** (0.112）
Multinational company	0.037 (0.375)	-0.095 (0.371)	0.101 (0.362)	-0.016 (0.361)	0.007 (0.362)	0.151 (0.353)	0.091 (0.353)	-0.063 (0.366)	0.143 (0.358)	0.053 (0.357）
Listed company	0.231** (0.117)	0.220* (0.116)	0.236** (0.113)	0.276** (0.112)	0.160 (0.113)	0.143 (0.11)	0.192* (0.111)	0.155 (0.116)	0.144 (0.113)	0.191* (0.113）
Patent	0.390*** (0.121)	0.349*** (0.122)	0.295** (0.118)	0.336*** (0.117)	0.331*** (0.119)	0.284** (0.114)	0.332*** (0.114)	0.323*** (0.120)	0.274 (0.117)	0.327*** (0.115）
Industry type	-0.043 (0.071)	-0.044 (0.070)	-0.021 (0.069)	-0.040 (0.068)	-0.030 (0.069)	-0.018 (0.067)	-0.031 (0.067)	-0.028 (0.069)	-0.004 (0.068)	-0.026 (0.067）
Executive political background	0.707*** (0.125)	0.656*** (0.123)	0.558** *(0.123)	0.592*** (0.121)	0.528*** (0.123)	0.413*** (0.122)	-0.014*** (0.006)	0.602*** (0.123)	0.500*** (0.122)	0.530*** (0.121）
Constant term	3.193*** (0.198)	0.534 (0.776)	1.781*** (0.350)	2.145*** (0.260)	3.462*** (0.198)	3.445*** (0.188)	3.474*** (0.189)	3.407*** (0.199)	3.347*** (0.191)	3.397*** (0.191）
R^2	0.455	0.474	0.496	0.501	0.505	0.533	0.530	0.493	0.516	0.517
F value	41.714***	35.855***	39.144***	39.889***	31.028***	34.625***	34.272***	29.576***	32.347***	32.539***

Source: own calculations.

(2) Sample Modification. Given the relatively low innovation level among startups, this study excludes firms that have been established for less than 3 years, resulting in a new sample of 391 entries. The hypothesis testing steps were repeated (*Table 7*). All hypotheses were verified.

Table 7. The Robustness Test Results After Changing the Sample (N=391)

Variables	*RI*									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DTAA		1.271*** (0.379)			1.508*** (0.427)			1.603*** (0.424)		
DTAA²		-0.132*** (0.042)			-1.393*** (0.426)			-1.484*** (0.423)		
DTVA			0.698*** (0.170)			1.040*** (0.252)			1.060*** (0.257)	
DTVA²			-0.066*** (0.021)			-0.783*** (0.250)			-0.809*** (0.261)	
BAL				0.131*** (0.023)			1.169*** (0.212)			1.246*** (0.215)
BAL²				-0.003*** (0.001)			-0.992*** (0.209)			-1.085*** (0.217)
ITT					0.261*** (0.058)	0.242*** (0.055)	0.227*** (0.055)			
RIE								0.167*** (0.057)	0.141** (0.059)	0.120** (0.058)
DTAA×ITT					0.519* (0.293)					
DTAA²×ITT					-0.556* (0.300)					
DTVA ×ITT						0.589** (0.229)				

Table 7 (*continuation*). The Robustness Test Results After Changing the Sample (N=391)

Variables	RI									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DTVA²×ITT						-0.597*** (0.226)				
BAL ×ITT							0.256 (0.178)			
BAL²×ITT							-0.299* (0.177)			
DTAA×RIE								0.707* (0.366)		
DTAA²×RIE								-0.728** (0.367)		
DTVA×RIE									0.634** (0.262)	
DTVA²×RIE									-0.635** (0.283)	
BAL×RIE										0.382* (0.216)
BAL²×RIE										-0.459** (0.241)
Age	-0.006 (0.007)	-0.008 (0.007)	-0.007 (0.007)	-0.008 (0.007)	-0.010 (0.007)	-0.008 (0.007)	-0.009 (0.007)	-0.008 (0.007)	-0.007 (0.007)	-0.008 (0.007)
Scale	0.111*** (0.033)	0.091*** (0.033)	0.123*** (0.032)	0.105*** (0.032)	0.097*** (0.033)	0.132*** (0.031)	0.115*** (0.031)	0.102*** (0.033)	0.137*** (0.032)	0.121*** (0.032)
Nature of enterprise	1.161*** (0.118)	1.117*** (0.117)	1.055*** (0.116)	1.051*** (0.115)	1.060*** (0.116)	1.005*** (0.113)	1.010*** (0.113)	1.043*** (0.119)	1.005*** (0.115)	1.001*** (0.115)
Multinational company	0.090 (0.404)	-0.036 (0.400)	0.159 (0.391)	0.045 (0.388)	0.081 (0.392)	0.204 (0.385)	0.165 (0.382)	-0.013 (0.396)	0.155 (0.388)	0.085 (0.386)
Listed company	0.249* (0.122)	0.227* (0.120)	0.242* (0.118)	0.281** (0.117)	0.176 (0.118)	0.162 (0.115)	0.208* (0.115)	0.169 (0.121)	0.161 (0.118)	0.207* (0.118)
Patent	0.374*** (0.125)	0.331*** (0.126)	0.280** (0.122)	0.315*** (0.120)	0.324*** (0.123)	0.281** (0.119)	0.320*** (0.118)	0.315** (0.124)	0.263** (0.121)	0.309*** (0.119)
Industry type	-0.006 (0.073)	-0.003 (0.073)	0.018 (0.071)	0.000 (0.071)	0.005 (0.071)	0.013 (0.070)	0.003 (0.069)	0.009 (0.072)	0.028 (0.070)	0.008 (0.070)
Executive political background	0.700*** (0.128)	0.655*** (0.127)	0.566*** (0.126)	0.602*** (0.124)	0.545*** (0.126)	0.439*** (0.125)	0.485*** (0.125)	0.617*** (0.126)	0.518*** (0.125)	0.554*** (0.124)
Constant term	3.056*** (0.207)	0.347 (0.792)	1.633*** (0.361)	1.964*** (0.271)	3.358*** (0.207)	3.308*** (0.197)	3.335*** (0.198)	3.289*** (0.208)	3.212*** (0.200)	3.252*** (0.199)
R^2	0.449	0.468	0.488	0.496	0.497	0.521	0.521	0.484	0.506	0.509
F value	38.880***	33.481***	36.264***	37.393***	28.611***	31.571***	31.599***	27.204***	29.691***	30.095***

Source: own calculations.

Table 8. The Robustness Test Results After Changing the Regression Method

Variables	Equation	Model Summary			Parameter estimate		
		R^2	Adjusted R^2	F	Constant term	coefficient of the first-degree term (b1)	coefficient of the second-degree term (b2)
DTAA	Linear Estimation	0.023	0.020	9.384***	3.964*** (0.295)	0.190*** (0.062)	
	Curve Estimation	0.119	0.114	27.323***	-2.121** (0.957)	3.134*** (0.446)	-0.333*** (0.050)
DTVA	Linear Estimation	0.155	0.152	74.378***	3.405*** (0.179)	0.376*** (0.044)	
	Curve Estimation	0.192	0.188	48.318***	1.938*** (0.379)	1.241*** (0.203)	-0.109*** (0.025)
BAL	Linear Estimation	0.100	0.098	45.449***	3.940*** (0.150)	0.050*** (0.007)	
	Curve Estimation	0.173	0.169	42.530***	2.633*** (0.262)	0.214*** (0.028)	-0.004*** (0.001)

Source: own calculations.

(3) Change the regression method. Drawing on Aghion *et al*. (2005), the curve estimation method is used to establish relationship models between digital technology accumulation affordance, variation affordance, their comprehensive balance, and radical innovation, respectively. The fitting effect of the curved estimation is superior to that of the linear estimation (*Table 8*). The relationship between accumulation affordance and radical innovation fits an inverted U-shaped pattern more closely. The relationships between variation affordance, the integrated balance of both, and radical innovation also align closely with an inverted U-shaped pattern, confirming the results' robustness.

3.5 Further Analysis

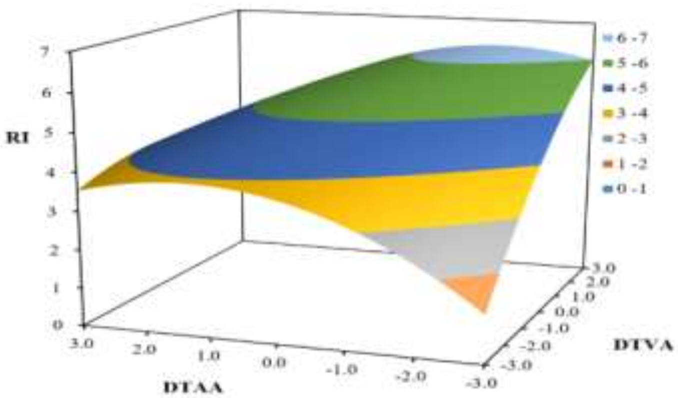
(1) The above section articulates the independent roles of the digital technology accumulation affordance and variation affordance in radical innovation, and initially explores the impact of their comprehensive balance on radical innovation. Though not all firms achieve a moderate balance between the two. Firms with a solid foundation in digital technology are more likely to achieve a balance among heterogeneous technologies. Hence, it is necessary to discuss the unbalanced effects of digital technology accumulation affordance and variation affordance on radical innovation (Verstegen et al., 2019). This paper employs response surface methodology to investigate how four combinations of balanced and unbalanced dual technology affordances affect radical innovation in enterprises. The 3-dimensional surface presented by response surface methodology depicts the effects of the "balanced relationship" and "unbalanced relationship" between the two on radical innovation.

Table 9. Response Surface Analysis Results

Variables	DI
DTAA	-0.025(0.056)
DTVA	0.386***(0.047)
$DTAA^2$	-0.140***(0.038)
DTAA × DTVA	-0.135***(0.036)
$DTVA^2$	-0.062**(0.025)
Slope of the concordance line（b1+b2）	0.361***
Uniform linear curvature（b3+b4+b5）	-0.337***
Slope of the inconsistent line（b1-b2）	-0.411***
Inconsistent line curvature（b3-b4+b5）	-0.068***
Control variable	Control
R^2	0.268
ΔR^2	0.260
F	29.567***

Source: own calculations.

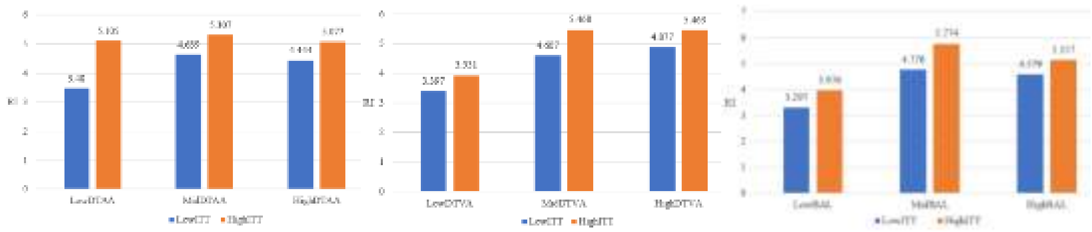
A response diagram was plotted (see *Table 9*), and the results are shown in *Figure 4*. The slope along the consistency line X=Y for radical innovation is significantly positive (slope = 0.361, $P < 0.01$), and the curvature is significantly negative (curvature = -0.337, $P < 0.01$), indicating an inverted U-shaped relationship. The level of radical innovation in firms increases as the consistency level of X and Y improves. The impact of "high accumulation affordance-high variation affordance" on radical innovation is superior to that of "low accumulation affordance-low variation affordance". However, there exists an inflection point. When the balance between accumulation affordance and variation affordance is excessively high, the effect of "beyond is as wrong as falling short" will emerge. The slope of radical innovation along the inconsistency line X = -Y is significantly negative, and the curvature is also significantly negative, which once again verifies that the higher the balance between accumulation affordance and variation affordance, the higher the level of radical innovation. Furthermore, when there is an imbalance between the two, the "low accumulation affordance-high variation affordance" effect prevails over the opposite effect.



Source: created by the authors.

Figure 4. **Multi-Layer Response Diagram**

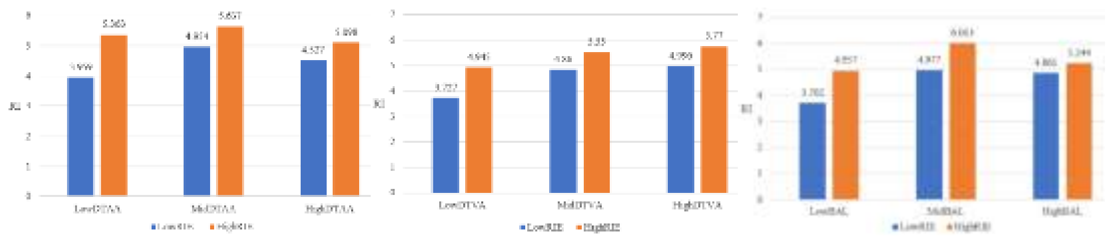
(2) There are noticeable interactive effects between accumulation affordance, variation affordance, and the external environment (industry technological turbulence, regional innovation environment). To explain the varied impacts of different matching patterns between firm digital technology characteristics and the external environment on radical innovation, digital technology accumulation affordances are classified into 3 tiers: low, medium, and high, using tertiles as the dividing criterion (similarly for variation affordances and their overall balance). Industry technological turbulence and regional innovation environments are stratified into high and low categories based on their respective mean values.



(a) (b) (c)

Source: created by the authors.

Figure 5. **The Impact of the Digital Cumulative Affordance, Variant Affordance, and Their Comprehensive Balance, and Industry Technological Turbulence on Radical Innovation**



(a) (b) (c)

Source: created by the authors.

Figure 6. **The Impact of the Digital Cumulative Affordance, Variant Affordance, and Their Comprehensive Balance, and Regional Innovation Environment on Radical Innovation**

Among the matching results of accumulation affordances and industry technological turbulence, the ranking is as follows (see *Figure 5*): medium DTAA-high ITT > low DTAA-high ITT > high DTAA-high ITT > medium DTAA-low ITT > high DTAA-low ITT > low DTAA-low ITT. Consequently, firms in industries with high technological turbulence, developing moderate accumulation affordances, are more conducive to promoting radical innovation. Similarly, medium DTVA with high ITT and medium BAL with high ITT are more conducive to fostering radical innovation. The matching results between digital technology accumulation affordance, variation affordance, their comprehensive balance, and regional innovation environment are shown in *Figure 6*. Among them, medium DTAA with high RIE, high DTVA with high RIE, and medium BAL with high RIE are more conducive to promoting radical innovation. Firms located in high-innovation regions have a larger range in which the positive impacts of variation affordance can be exerted, developing heterogeneous digital technologies.

Conclusions

The key findings of this study are as follows: firstly, the effect of digital technology accumulation affordance on radical innovation has an inverted U-shaped change, positive first and then negative. Only when the accumulation affordance falls within a reasonable range can it stimulate a positive effect. Excessively high levels of accumulation affordance increase the cost of resource management and the path dependence of resource utilisation, inhibiting radical innovation. Secondly, there is an inverted U-shaped relationship between the digital technology variation's affordance and radical innovation. Only by identifying the optimal scale of variation affordance can firms most effectively enhance their level of radical innovation. Excessive variation in affordance will increase the difficulty and cost of technology integration, thereby hindering radical innovation.

Thirdly, there is an inverted U-shaped relationship between the comprehensive balance of digital technology accumulation affordance and variation affordance, and radical innovation. Maintaining an appropriate balance between the two can stimulate the optimal effect on radical innovation. When balancing the two types of affordances, the impact of "high accumulation affordance-high variation affordance" on radical innovation is superior to that of "low accumulation affordance-low variation affordance". When there is an imbalance in the two types of affordances, "high variation affordance-low accumulation affordance" is more effective than "high accumulation affordance-low variation affordance".

Fourthly, the impact of digital technology accumulation affordance, variation affordance, and their comprehensive balance on radical innovation is affected by external environmental heterogeneity. Industry technological turbulence and regional innovation environment play a negative moderating role, i.e., for firms in industries with high technological turbulence and in regions with high innovation, the effects of digital technology accumulation affordance, variation affordance, and their comprehensive balance on radical innovation are more pronounced. Therefore, firms in high-technological-turbulence and high-innovation regions should be more cautious when leveraging digital technology for radical innovation. They should focus on industry technology, markets, and policies, and be vigilant against the adverse impacts of the external environment.

The conclusions offer managerial insights for firms. Firstly, firms should not blindly seek the continuous enhancement of digital technology affordances. To leverage the positive effects of digital technology affordances, firms should be maintained within a reasonable range. While leveraging digital technology to homogenise various resources, establish unified standards for resource sharing, and improve resource utilisation efficiency while seeking differentiated digital technology utilisation, the cost threshold of technology integration should be emphasised.

Secondly, enterprises can simultaneously seek both the accumulation affordance and variation affordance of digital technology. Maintaining a comprehensive balance between the two broadens resource access and technological generation for radical innovation. Still, it is crucial to allocate efforts reasonably to avoid the adverse impacts of over-investment. When firms can maintain this comprehensive balance, they can opt for a high-accumulation affordance and a high-variation affordance state. When firms are unable to maintain this balance, maintaining a high-variation affordance and low-accumulation affordance state is more conducive to radical innovation.

Lastly, firms located in regions with high technological turbulence and high innovation should increase their attention to industry technology, market trends, and policies. When digital technology exerts a positive effect, it should utilise the facilitating role of the external environment. In the contrary case, they should be vigilant against the adverse impacts of the external environment.

High technological turbulence in the industry and the regional innovation environment enhance the positive effect of digital technology affordances on radical innovation. Thus, governments can promote technological innovation by introducing supportive policies, such as providing financial subsidies to support digital infrastructure. However, due to the heterogeneous moderating effect of the external environment on the relationship between digital technology affordances and radical innovation, the state should also regulate firms to utilise external policies rationally.

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Acknowledgements

This study was supported by the Capital University of Economics and Business Postgraduate Science and Technology Innovation Project (No. 2023KJCX024).

SKAITMENINIŲ TECHNOLOGIJŲ GALIMYBIŲ POVEIKIS RADIKALIOMS INOVACIJOMS: MODERUOJANTIS PRAMONĖS TECHNOLOGINIO NESTABILUMO IR REGIONINĖS INOVACINĖS APLINKOS VAIDMUO

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Santrauka. Remiantis vidinių technologijų ir išorinės aplinkos sąveika, šiame tyrime nagrinėjamos sąlygos, kuriomis skaitmeninės technologijos lemia radikalių inovacijų atsiradimą, ir analizuojamas jų panaudojimas šių inovacijų skatinimui. Autoriai, pasitelkę technologinių galimybių (angl. *technology affordances*) perspektyvą ir remdamiesi 409 įmonių imtimi, skaitmeninių technologijų galimybes ir radikalias inovacijas integravo į bendrą tyrimo modelį. Tyrime įvertintas pramonės technologinio nestabilumo ir regioninės inovacinės aplinkos poveikis. Skaitmeninių technologijų kaupimo galimybių, variacijų galimybių ir jų visapusiško subalansavimo poveikis radikalioms inovacijoms rodo „apverstą U formos" santykį. Pramonės ir technologiniai pokyčiai bei regioninė inovacijų aplinka minėtus santykius veikia neigiamai švelninančiai.

Reikšminiai žodžiai: kaupimo ir įvairovės galimybės; radikali inovacija; technologinis nestabilumas.