R&D Management

R&D MANAGEMENT

RESEARCH ARTICLE OPEN ACCESS

Digital Technologies and Innovation Ecosystems in the Post-Pandemic Era

Empowering Radical Innovation: How Digital Technologies Drive Knowledge Transfer and Co-Creation in Innovation Ecosystems

Jianwen Zheng[1] | Justin Zuopeng Zhang[2] | Muhammad Mustafa Kamal[3] | Huan Wang[1] | Yifan Yang[1] | Bidit Dey[4] | Chrysostomos Apostolidis[5]

[1]Department of Strategic Management and Organization, International Business School Suzhou, Xi'an Jiaotong-Liverpool University, China | [2]Department of Management, Coggin College of Business, University of North Florida, USA | [3]Operations and Analytics, Management Department, University of Exeter Business School, University of Exeter, Exeter, UK | [4]Sheffield University Management School, University of Sheffield, UK | [5]Durham University Business School, Durham University, UK

Correspondence: Muhammad Mustafa Kamal (m.m.kamal@exeter.ac.uk)

Received: 3 March 2023 | **Revised:** 12 November 2024 | **Accepted:** 26 February 2025

Funding: The authors received no specific funding for this work.

Keywords: digital technologies | innovation ecosystem | knowledge co-creation | knowledge transfer | radical innovation

ABSTRACT

This study investigates the impact of digital technologies on firm radical innovation and explores the mediating mechanisms of knowledge transfer and knowledge co-creation. Utilizing a sample of 152 high-technology entrepreneurial firms, we present compelling evidence that digital technologies positively influence the radical innovation of these firms. Furthermore, our analysis reveals that knowledge transfer and knowledge co-creation serve as critical mediating mechanisms, elucidating how digital technologies affect firm radical innovation. These findings significantly contribute to the existing literature by bridging the gap between research on technology adoption, knowledge management, and firm radical innovation. By highlighting the role of digital technologies and the underlying knowledge processes in firm radical innovation, this study enhances the understanding of the dynamics involved in fostering innovation within entrepreneurial contexts.

1 | Introduction

The adoption of digital technologies by businesses has initiated a transformative shift that has dramatically reshaped how companies operate and compete (Ardolino et al. 2018). Digital technologies denote a constellation of intelligent and innovative technologies central to the Industry 4.0 revolution, such as big data analytics, the Internet of Things, and cloud computing. These technologies facilitate unprecedented connectivity, seamless communication, and extensive automation across multiple sectors (Ivanov et al. 2019; Li et al. 2020). Academics have emphasized the necessity to expand analyses on the adoption and application of digital technologies to enhance firms' innovation activities (Boeker et al. 2021; Holmström 2018; Urbinati et al. 2020; Usai et al. 2021; Yoo et al. 2012). While some researchers have theorized that digital technologies facilitate the innovation process (Urbinati et al. 2020), others have empirically demonstrated their vital contribution to product and process innovation (Ardito et al. 2021; Blichfeldt and Faullant 2021; Hanelt et al. 2021; Usai et al. 2021). However, there has been less focus on the impact of digital technologies on the novelty of innovations, and the current literature has not adequately explored the mechanisms through which digital technologies foster radical innovations.

Recent scholarship and industry practices have shown an increasing concern about integrating the value of digital technologies into firms' radical innovation efforts. This integration has

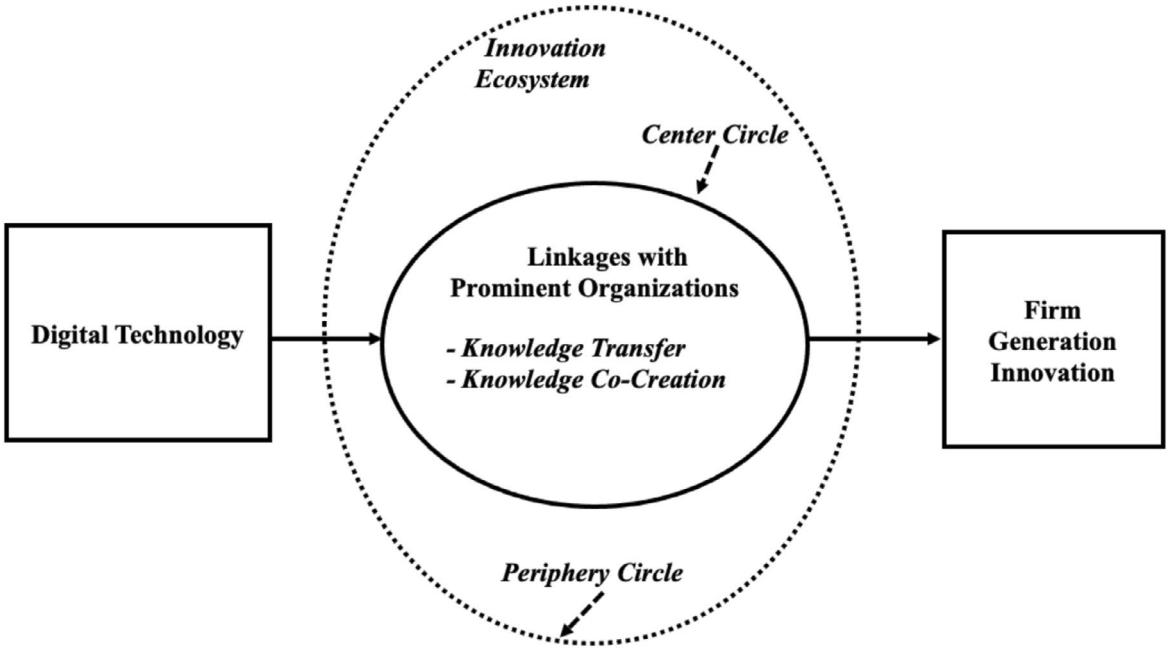

FIGURE 1 | Conceptual framework.

highlighted the need to develop robust knowledge collaboration strategies (Jiang 2022; Urbinati et al. 2020). Participating in radical innovation is crucial for entrepreneurial firms in an era of continual digital technological evolution, as it enables broader value creation through reshaping competitive advantages and establishing capabilities for creative disruptions (Christensen et al. 2018). The more flexible and less bureaucratic organizational structures of entrepreneurial firms facilitate their engagement in radical innovation activities (Zheng et al. 2021). Radical innovation is rooted in transformative shifts in the meanings of internal services and products, requiring extensive interaction with external resources beyond the support of internal knowledge (Story et al. 2011). Due to the discontinuity and complexity of radical innovation, the knowledge interactions and flows between firms and external knowledge networks become more complex (Subramanian et al. 2018). Recent research has thus pointed to the relevance of studying the innovation ecosystem (IE) as a context for external knowledge collaboration (Mei et al. 2019). An IE is defined as "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" (Adner 2006: 2). According to resource dependency theory, the acquisition of external knowledge spillovers from prominent actors in the IE (e.g., customers, suppliers, competitors, and complementors) is beneficial for the radical innovation activities of an entrepreneurial firm (see Figure 1). This is because the acquired external expertise and information can promote the emergence of new ideas that contribute to substantial changes in the traditional technological paradigms and integrate with internal resources (Roper et al. 2017; van Beers and Zand 2014).

Existing literature has begun to explore knowledge management through the lens of the IE (Bacon et al. 2019; Wang et al. 2024). Knowledge management, an essential facet of innovation, involves a systematic approach to knowledge creation, dissemination, and application (Di Vaio et al. 2021). The integration of digital technologies in these processes can radically transform how knowledge is curated and applied, thus influencing radical innovation (Zia 2020). Studies focusing on knowledge management within the IE context have primarily examined different types of knowledge collaborators, such as core and peripheral participants (Mei et al. 2019) and complementors with varying degrees of complementarity (Wang et al. 2024). They have also explored different kinds of knowledge, such as explicit or tacit knowledge (Bacon et al. 2019). Although these studies are insightful, they overlook the varied types of knowledge collaboration activities in which firms engage within the IE. To address this gap, this study draws on the framework proposed by De Silva et al. (2023) for knowledge transfer and co-creation to further explore knowledge management empowered by digital technology adoptions in entrepreneurial firms within the IE context. Specifically, knowledge transfer refers to the exchange and transmission of existing knowledge among different IE actors (Bacon et al. 2019; Teece 1977). Knowledge co-creation refers to the collaborative generation of new knowledge, ideas, and practices through partnering interactions in the IE (Chang et al. 2020). We suggest that digital technologies serve as accelerators for knowledge transfer and co-creation by enabling real-time collaboration, optimizing knowledge workflows, and allowing the amalgamation of diverse knowledge strands—all of which are critical for driving radical innovation within ecosystems. Therefore, this study proposes the following research question: How does the adoption of digital technology by entrepreneurial firms impact their radical innovation in the IE, and how is this relationship affected by their engagement in knowledge transfer and co-creation with prominent IE actors?

This study advances the literature by presenting three pivotal contributions. First, it probes the role of digital technologies in the nuanced setting of IE within the purview of entrepreneurial firms. This study complements the existing investigation of resource dependence theory from the emerging perspective of the ecosystem. By underpinning the adoption of digital technology by entrepreneurial firms, this study highlights the

mechanisms necessary to achieve radical innovation, emphasizing the crucial resources provided by prominent collaborators in IE. This study heeds the call of entrepreneurship scholars for more granular investigations into the ramifications of digital technology for innovation processes and its influence mechanisms. Second, this study delineates the mediating role of knowledge transfer and knowledge co-creation in the nexus between the adoption of digital technology and radical innovation. This conceptual bridge synthesizes strands of literature that have examined the impact of digital technologies on knowledge management engagements and their subsequent influence on innovation outcomes. Third, it enhances the discourse on digital technology adoption and radical innovation by rigorously examining boundary conditions. By scrutinizing the interplay between entrepreneurial entities and their strategic partners, the study clarifies the mediating effects of knowledge dynamics and thus offers a more intricate understanding of the mechanisms through which digital technologies can catalyze radical innovation.

The remainder of the paper is structured as follows. In the next section, we delve into the theoretical background and provide a comprehensive understanding of the topic under study. In Section 3, we develop our hypotheses, formulating clear and testable statements. In Section 4, we outline the research method we employed to gather and analyze data. In Section 5, we present the results and findings derived from the analysis. Last, in Section 6, we discuss in detail the theoretical and practical implications of this study and suggest future research directions.

2 | Theoretical Background

2.1 | An Emerging Innovation Ecosystem Perspective

The concept of the ecosystem originally emerged from the recognition of the interdependencies between firms and their activities (Adner 2006). Building upon this perspective of multilateral interdependence, Adner (2006) introduces the concept of an innovation ecosystem (IE), which emphasizes focal innovations and advocates for a complementarity approach that involves engaging with a diverse set of complementors and components through collaborative partnerships. Participation in knowledge collaboration within IEs is crucial for entrepreneurial firms, as these enterprises often face the liabilities of smallness, which limit their knowledge to develop innovation activities independently (Zheng et al. 2021). Entrepreneurial firms can benefit from reduced bureaucracy, enhanced flexibility, and rapid responsiveness—key attributes that would facilitate their effective engagement in knowledge collaboration within IEs (Wang et al. 2024).

Existing research on resource dependence theory proposes that entrepreneurial firms rely on various types of resources to carry out innovation, which come from related heterogeneous stakeholders (Boyd 1990). The stakeholders in an IE include suppliers, customers, research institutions, and government agencies. The existing research on the heterogeneity of IE participants proposes a bipartite structure of the ecosystem, which separates the stakeholders of the core enterprise into the center and the periphery (Moore 1993). According to this structural logic, Mei et al. (2019) take a focal firm as the center and divide the heterogeneous collaborators into prominent organizations and service intermediaries. This research primarily explores entrepreneurial firms' knowledge collaboration with prominent organizations. The connection between entrepreneurial firms and prominent organizations occupies the central circle of the IE and plays a leading role in its evolution (Mei et al. 2019; Moore 1993). These organizations include downstream and upstream suppliers, competitors, and customers related to the industry. The collaboration between entrepreneurial firms and prominent organizations facilitates their access to industry-related resources such as nonpublic information and tacit knowledge (Xie and Wang 2021). Entrepreneurial firms' knowledge collaboration with prominent organizations can capture inaccessible or nonpublic knowledge about the industry (Geletkanycz and Hambrick 1997). In this case, entrepreneurial firms can deepen their understanding of customers, suppliers, and competitors, keep abreast of market changes, and discover new value propositions.

2.2 | Adoption of Digital Technology and Knowledge Management

Existing research highlights the crucial role of digitalization's development in driving the ecosystem phenomenon (Thomas and Autio 2020). Digital technology promotes the integration of organizational and environmental dimensions (El Sawy et al. 2010). In recent decades, many organizations have moved from hierarchically integrated supply chains to more decentralized networks collaborating with external stakeholders (Rahmati et al. 2021). The application of different digital technologies (e.g., artificial intelligence, blockchain technology, and the Internet of things) has enabled IE actors to participate in exchange networks that are easy to form, grow, and dissolve again, which has facilitated the convergence of the industry (Yoo et al. 2012). Firms can collaborate with various heterogeneous IE actors beyond traditional suppliers and customers (El Sawy and Pereira 2013). Recent studies show that the knowledge collaborative network among IE participants relies heavily on these digital technologies, which allow the degree of interconnectedness and dependency among partners to emerge and steadily increase (Audretsch et al. 2023; Liang and Li 2023). Thus, the adoption of digital technologies in existing entrepreneurial firms necessitates a shift in research focus toward collaboration among a broad range of actors within the context of IE (Wang et al. 2024).

Previous literature has widely recognized the role of digital technology adoptions in the knowledge management of entrepreneurial firms, yet there is a lack of research in the context of IE. Existing studies have attempted to explore this from a resource-based perspective, discussing the need for entrepreneurial firms to collaborate with various types of IE participants due to their own lack of knowledge capabilities, involving core and peripheral participants (Mei et al. 2019), upstream suppliers, and downstream complementors (Adner and Kapoor 2010), as well as complementors with varying degrees of complementarity (Wang et al. 2024). Although insightful, they overlook the different forms that firm engagement in knowledge collaboration

in IE can take. Therefore, building on the gaps identified in the literature, this study draws on De Silva et al. (2023) propositions of knowledge transfer and co-creation to explore more comprehensively the knowledge management empowered by digital technology applications in entrepreneurial firms within the IE context.

Knowledge transfer, as originally proposed by Teece (1977), refers to the exchange and transmission of existing knowledge among different actors. The literature has explored knowledge sharing across multiple dimensions, focusing on the participants in the process (e.g., inter-organizational collaborations, explicit and tacit knowledge) and the nature of the content shared, such as the quality and specialization of knowledge (Cummings and Teng 2003). Knowledge co-creation refers to the collaborative generation of new knowledge, ideas, and practices through partnering interactions (Chang et al. 2020; Choo et al. 2007; Linderman et al. 2004). In the context of IEs, knowledge co-creation enables partners to complement each other by leveraging their respective resources. In the process of knowledge co-creation, firms and their partner organizations pool their expertise and create new knowledge by combining and interacting with their resources (Das and Teng 2000).

2.3 | Engagement in Knowledge Transfer and Knowledge Co-Creation

The innovation literature suggests that firms operating in IEs can enhance their organizational resources through collaborations with other ecosystem participants (e.g., Adner 2006). However, the empirical findings in this regard have been inconsistent. Some studies have found a negative effect, indicating that firms may rely more on cooperative and opportunistic behavior rather than on seeking direct solutions (e.g., Adner and Kapoor 2010). Conversely, other studies have reported a positive effect, highlighting that firms can leverage shared knowledge and resources to achieve product innovation and technological advancement (e.g., Reynolds and Uygun 2018; Xie and Wang 2021). However, these studies have generally defined product innovation as the utilization and development of new ideas manifested through new products or services (Pérez-Luño et al. 2011). In contrast, this study aims to capture the essence of product innovation by specifically focusing on its scope of newness, categorized as radical innovation (Pérez-Luño et al. 2011; Zheng et al. 2021). Radical innovation refers to the entrepreneurial firms' creation of entirely new products that are novel to the world (Zheng et al. 2022). By adopting this approach, we seek to provide a more nuanced understanding of the impact of IEs on radical innovation.

Radical innovation activities are characterized by their complexity and novelty of knowledge (Pérez-Luño et al. 2011). Entrepreneurial firms rely on multiple resources and interfaces outside and inside the organization to acquire, adapt, and commercialize knowledge (Acs et al. 2009; Audretsch and Keilbach 2007) and progressively engage in knowledge collaboration activities (e.g., Knowledge transfer and knowledge co-creation). In terms of knowledge transfer, the adoption of digital technologies aids entrepreneurial firms in IE by capturing user-transmitted consumer behavior data and corresponding demands, thereby stimulating activities related to radical innovation (Boeker et al. 2021). Secondly, digital technologies enhance firms' ability to absorb knowledge, promoting radical innovation through more efficient internal knowledge dissemination and incorporating a broader range of external knowledge sources (Jandhyala and Phene 2015). Furthermore, the adoption of digital technologies aids knowledge co-creation by enhancing interactions and the integration of resources and expertise between focal firms and collaborators, leading to faster innovation cycles. These technologies enable real-time collaboration and efficient communication, which are crucial for generating new, specialized knowledge (Arias-Pérez et al. 2021; Chang et al. 2020). This co-creation process disrupts existing innovation trajectories and stimulates fresh ideas conducive to radical innovation (Malhotra 2005; Smith and Smith 2021).

3 | Hypothesis Development

3.1 | Adoption of Digital Technology and Radical Innovation

Acquiring fresh external knowledge is crucial for firm product innovation (Audretsch and Belitski 2023; Subramaniam and Venkatraman 2001). Digital technologies serve as disruptive tools, enabling firms to effectively access and integrate both external and internal information (Mondal et al. 2023). These technologies facilitate radical innovation in several ways.

First, digital technologies provide firms with channels to access a broader knowledge base from prominent organizations, enhancing the efficiency of radical innovations (Martínez-Caro et al. 2020). Digital collaboration communities allow firms to collect and analyze vast amounts of data from suppliers, lead users, customers, complementors, and competitors, unrestricted by time and space (Han and Trimi 2022). This process generates valuable insights for further innovation by leveraging capabilities in big data analysis (Urbinati et al. 2020). By using digital technologies, firms continuously extract information patterns from their collaborative networks and the broader environment, identifying future innovation directions (Katsikeas et al. 2020).

Second, developing innovative products requires effectively integrating externally acquired knowledge with internal resources (Marsh and Stock 2003). Digital technologies provide infrastructures such as cloud computing, storage systems, and network connectivity, enhancing integration processes in radical innovation (Urbinati et al. 2020). Studies indicate that digital technologies facilitate idea generation, product development, and commercialization (Bstieler et al. 2018; Durmuşoğlu and Barczak 2011; Kawakami et al. 2015). For instance, cloud computing enables data storage and access, promoting collaboration across departments and with external partners. Network connectivity and application systems enable seamless communication, integrating diverse knowledge inputs (Di Vaio et al. 2021). By leveraging these infrastructures, firms achieve higher levels of integration, leading to more substantial innovation outcomes.

In line with this discussion, we hypothesize that digital technologies have a significant positive impact on innovation processes. Therefore, we propose the following hypothesis:

H1. *Digital technology is positively associated with firm radical innovation.*

3.2 | The Mediating Role of Knowledge Transfer

The evolution of digital technologies has revolutionized knowledge transfer, exerting a significant influence on radical innovation. These technologies enhance the accessibility, velocity, and efficiency of knowledge dissemination (Deng et al. 2023; Hossain and Lassen 2017). In contrast to traditional methods, digital tools facilitate streamlined access to information through connections with prominent organizations, thereby accelerating and enhancing the efficiency of knowledge sharing (Hossain and Lassen 2017). For instance, firms can collaborate digitally with suppliers to access advanced manufacturing techniques, which can be integrated into product innovation, enhancing efficiency and quality.

Furthermore, digital technologies optimize the management and application of knowledge (Zhao and Canales 2021). Firms utilizing these tools can effectively organize and retrieve extensive data. Shared platforms allow partners to provide insights into customer behavior and preferences, enabling firms to innovate products that better meet market demands. Digital technologies also enhance collaboration between firms and key partners within the core ecosystem (Boeker et al. 2021; Patrucco et al. 2021). Real-time data exchange allows rapid implementation of feedback from customers, leading to more agile and responsive innovation processes.

The knowledge transferred through these linkages plays a pivotal role in the generation and dissemination of innovative ideas, thereby facilitating radical innovation. High levels of knowledge transfer foster continuous learning, skill development, and the exploration of novel initiatives (Jandhyala and Phene 2015). This accelerated transfer allows partners to acquire experiences and develop novel solutions (Gilbert and Cordey-Hayes 1996). Collaborations that enhance knowledge transfer contribute to the development of robust networks between firms and their partners, further supporting radical innovation (Boeker et al. 2021).

Taken together, digital technologies facilitate knowledge transfer through connections with key collaborators, thereby enabling radical innovation. Therefore, we propose the following hypothesis:

H2. *Knowledge transfer through linkages with prominent organizations mediates the relationship between digital technologies and firm radical innovation.*

3.3 | The Mediating Role of Knowledge Co-Creation

Digital technologies facilitate not only knowledge transfer but also knowledge co-creation between focal firms and prominent collaborators (Arias-Pérez et al. 2021). These technologies expedite the integration of collaborators' competencies with the firm's resources, enhancing the efficiency of generating new knowledge (Chang et al. 2020). For instance, companies can use digital platforms like shared R&D software to collaborate with suppliers, co-developing new manufacturing techniques that improve efficiency and reduce costs.

Moreover, digital technologies enable frequent, efficient interactions and real-time collaboration, which are critical for co-creation (Malhotra 2005; Chang et al. 2020). Firms that leverage these technologies are better equipped to acquire and create unique, specialized knowledge with their collaborators (Smith and Smith 2021). For example, using customer feedback tools, firms can gather insights and work directly with users to co-design product features that meet specific needs.

Knowledge co-creation through digital platforms encourages the generation of creative ideas (Bouncken et al. 2021; Hardy et al. 2003; Parmentier and Mangematin 2014). Collaboratively created knowledge motivates firms to explore unconventional approaches to problem-solving (Bouncken et al. 2021). For instance, online innovation hubs allow firms to partner with tech startups, integrating novel technologies into their product lines. Additionally, co-created knowledge supports the development of new technologies by combining resources and expertise to drive innovation (Tootell et al. 2021). A firm might use digital ecosystems to collaborate with research institutions, applying academic insights to commercial applications, thus accelerating innovation. This collaborative process fosters innovation by integrating diverse perspectives and skills, generating fresh insights (Kazadi et al. 2016; Malhotra 2005; Samaddar and Kadiyala 2006). Firms with high levels of co-created knowledge can better understand stakeholder needs, leading to higher-quality innovations (Bouncken et al. 2021). For instance, digital collaboration with stakeholders helps refine and enhance product offerings to cater to diverse market segments.

Taken together, we propose the following hypothesis:

H3. *Knowledge co-creation through linkages with prominent organizations mediates the relationship between digital technology and firm radical innovation.*

4 | Research Method

4.1 | Sample and Data

A survey was conducted in Zhongguancun National Innovation Demonstration Zone, Beijing, to collect data from small and medium enterprises (SMEs) and test the proposed hypotheses. This Zone is widely recognized as the most innovative park in China, and Beijing has a prominent global startup ecosystem. The government is actively promoting the evolution of SMEs to enable China to transition from being a manufacturing giant to becoming a world manufacturing power, in alignment with the objectives of the "Made in China 2025" initiative. The research team and assistants collected data from identified SMEs and various innovation and industrial parks in the greater area of Zhongguancun National Innovation Demonstration Zone from July to August 2021. The survey targeted the chief executive officers (CEOs)

of the identified SMEs. Questionnaires were distributed to these individuals. The Ministry of Science and Technology provided a list of 8124 SMEs, and the research team identified 4346 SMEs in the greater area of Zhongguancun National Innovation Demonstration Zone. Out of these, 3672 SMEs had been established for five or more years and were contacted to determine their willingness to participate in the survey. A total of 593 firms confirmed their intention to participate, and the questionnaires were sent to them. In August 2021, the research team received completed questionnaires from 247 firms. After excluding 22 firms that were less than 5 years old and 13 firms that were not involved in innovation activities, a final sample of 212 responses matched the sample selection criteria. Among these, 152 responses were considered valid and formed the dataset for testing the proposed hypotheses.

4.2 | Measurements

4.2.1 | Dependent Variables

Firm radical innovation. We adopted two multi-item scales to measure firm radical innovation in the main and robustness tests correspondingly. First, in the main test, radical innovation was captured on a scale adapted from Pérez-Luño et al.'s (2011) study. Responders were asked to indicate the proportion of the introduced products that were "new to the company," "new to the market," and "new to the world" in the previous 3 years. Then, to measure radical innovation, we multiplied the number of "new to the world" products launched by the total number of new products launched. Second, to conduct robustness tests, we used Govindarajan et al.'s (2011) scale with slight modifications. Respondents were asked to answer questions regarding the products provided in the previous 3 years by using a three-item, 7-point scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). The scale contains three items to assess the new product's degree of radical innovativeness, the firm's frequency in introducing products radically different from existing products, and the firm's primacy in introducing radical innovations.

4.2.2 | Independent Variable

Digital technologies' value development (Comprehensive reliability = 0.811; Cronbach's $\alpha = 0.660$; average variance extracted = 0.590). To capture the value generated by digital technologies, we adopted Martínez-Caro et al.'s (2020) three-item, 7-point scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). The scale contains three items to assess the value developed in business operations due to digital technological improvements for stakeholders (e.g., employees, customers, and suppliers) and business management since improvements in data collection and analysis can be used to scale business operations quickly. In particular, the construct of digital technologies' value development encompasses three key elements, namely, that the firm "Has technological solutions that digitally connect essential business activities with customers, suppliers, employees, and assets"; "Has defined how to assign data a central role in decision-making and business management"; and "Uses an open digital platform to implement innovative new ideas rapidly in support of business activities.".

4.2.3 | Moderating Variables

Knowledge transfer (Comprehensive reliability = 0.884; Cronbach's $\alpha = 0.843$; average variance extracted = 0.562). We adopted Ko et al.'s (2005) scale and conducted slight modifications to assess focal firms' acquisition of knowledge transfer. The six-item, 7-point scale ranges from "strongly disagree" to "strongly agree." Knowledge transfer acquisition is considered the focal firm's learning and application by acquiring the knowledge communicated by ecosystem partners (Ko et al. 2005). Thus, we developed the measurement of knowledge transfer by focusing on ecosystem partners' knowledge communication outcomes. Specifically, the six items were designed to assess how the focal firms' interactions with ecosystem partners enhanced their learning and application of digital technologies, focusing on technology integration modes, framing techniques, knowledge of the technology, training materials, supporting business processes, and their capacity to develop new technologies.

Knowledge co-creation (Comprehensive reliability = 0.864; Cronbach's $\alpha = 0.768$; average variance extracted = 0.679). We adapted Chang et al.'s (2020) scale to measure the focal firms' involvement with their ecosystem partners for knowledge co-creation. The four-item, 7-point scale ranges from "strongly disagree" to "strongly agree." Specifically, the four items are designed to measure the degree to which the focal firm and its ecosystem partners engage in the codification of best collaboration practices, the formalization of management practices and industry trade, the generation of the best production protocol, the formation of best practices, and the development of guidance.

4.2.4 | Control Variables

We controlled for several types of variables. For the individual and team-level factors, following Karaevli and Zajac (2013), we controlled for *the educational background* of the CEO on a 5-point scale, in which high school was coded as "1," college as "2," undergraduate degree as "3," graduate degree as "4," and doctoral degree as "5." *Founding team size* was captured by the number of founders and cofounders of the focal firms. For the firm-level factors, we controlled for *firm size* as the log-transformed value of the total number of employees. *Firm age* was captured as the number of years since the focal firm's establishment. We controlled for *sales growth* as the focal firm's average sales growth rate over the past 3 years. We adopted a 6-point scale, ranging from 1 for focal firms without sales growth to 6 for those with more than 100% growth (Zheng et al. 2021). *R&D expenditure* was computed as the average proportion of sales revenues for the past 3 years of the focal firm. We adopted a 7-point scale, ranging from 1 to 7 for R&D investment of less than 1% and more than 25%, respectively (Cui and Wu 2017). Further, we controlled for *patents* by using the total number of patents acquired by the focal firm for its inventions in the previous 3 years.

4.3 | Reliability and Validity

To test the adequacy of the measures, this study employed SPSS software to conduct reliability and validity analyses. Referencing Samagaio et al. (2018), a cut-off level of 0.6 was

used to assess project loading; we found that all project loadings exceeded this threshold. For reliability testing, the commonly accepted standard is that Cronbach's alpha should be greater than 0.7, with values closer to 1 indicating higher reliability. The analysis results revealed that Cronbach's α values for all variables were above 0.7, except for digital technologies' value development, which was 0.66 but still close to 0.7. Further comprehensive reliability analysis showed that all item results surpassed the recommended threshold of 0.7, indicating the questionnaire possesses reasonable reliability. Concerning validity, the average variance extracted (AVE) for each construct exceeded the recommended threshold of 0.5, and the square roots of the AVEs were greater than the estimated correlations among the constructs, demonstrating that the scale is valid and possesses strong validity. Therefore, the reliability and validity tests confirm that the scales used in this study are reliable for further analysis.

5 | Results

5.1 | Descriptive Statistics

The overview of the descriptive statistics and correlations for the relevant variables is presented in Table 1. The radical innovation that firms conducted was slightly more than one, on average. Concerning correlations, we noted that radical innovation positively correlates with digital technologies' value development. We conducted a variance inflation factor (VIF) analysis to test for multicollinearity. The mean VIF value was 1.47, which indicated that multicollinearity was not an issue in our analysis.

5.2 | Main Hypotheses Test

We selected the ordinary least squares regression model for our data analysis. The results of statistics on firms' radical innovation are depicted in Table 2. The results show that digital technologies' value development positively influences firms' radical innovation ($\beta = 0.2721$; $p < 0.01$); therefore, Hypothesis 1 is supported. This finding indicates that firms that capture the higher value generated by digital technologies pursue more radical innovation than those that conduct lower-value development in digital technologies. The analysis results in Table 3 and Table 4 also support this finding about the positive relationship consistently.

5.3 | Mediating Hypotheses Test

Next, we tested the mediating effects of knowledge transfer and knowledge co-creation. To test these hypotheses, we referred to the method proposed by Baron and Kenny (1986) and took knowledge transfer and knowledge co-creation as intermediary variables to construct the mediating effect model. Specifically, Table 3 presents the mediating effect of knowledge transfer. First, to test the direct effect, radical innovation was applied as the explained variable, and the digital technologies' value development was applied as the explanatory variable to conduct the regression analysis (Model 1). Second,

TABLE 1 | Descriptive statistics and correlations.

	Mean	SD	1	2	3	4	5	6	7	8	9	10
1. Radical innovation	1.257	1.379	1									
2. Digital technologies' value development	4.428	1.17	0.292***	1								
3. Knowledge transfer	4.565	1.08	0.306***	0.371***	1							
4. Knowledge co-creation	4.072	1.206	0.270***	0.230***	0.420***	1						
5. Firm age	4.539	0.736	−0.092	−0.08	−0.125	−0.017	1					
6. Firm size	3.902	0.503	−0.043	−0.116	−0.014	−0.054	−0.169**	1				
7. CEO education	3.862	0.899	0.146*	0.172**	0.018	0.091	−0.087	0.025	1			
8. Founding team size	3.138	0.846	0.021	−0.1	−0.03	−0.016	0.124	0.09	0.008	1		
9. R&D intensity	3.191	1.206	0.381***	0.139*	0.193**	0.182**	−0.132	−0.135*	−0.073	−0.045	1	
10. Patent	2.184	1.665	0.305***	0.016	−0.027	−0.017	0.01	0.014	0.159*	0.254***	0.217***	1
11. Sales growth	0.178	0.354	0.035	−0.042	−0.138*	0.039	0.151*	0.034	0.072	0.028	−0.01	0.079

Note: $n = 152$; ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

TABLE 2 | Regression results for radical innovation.

	Radical innovation	
	Model 1	**Model 2**
Digital technologies' value development		0.2721**
		(0.0878)
Firm age	−0.0762	−0.0553
	(0.1460)	(0.1420)
Firm size	−0.0268	0.0379
	(0.2094)	(0.2045)
CEO education	0.2032+	0.1372
	(0.1163)	(0.1149)
Founding team size	−0.0232	0.0049
	(0.1264)	(0.1231)
R&D intensity	0.3854***	0.3504***
	(0.0894)	(0.0876)
Patent	0.1771**	0.1805**
	(0.0662)	(0.0644)
Sales growth	0.0727	0.1085
	(0.2925)	(0.2843)
Constant	−0.6347	−1.9221
	(1.3595)	(1.3844)
Prob > F	0.0000	0.0000
F/Likelihood	5.72	6.5
R-squared	0.1795	0.2668

Note: Standard errors in parentheses; ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, + $p < 0.1$.

knowledge transfer was applied as the explained variable, and the digital technologies' value development was used as the explanatory variable to conduct the regression analysis (Model 2). Third, to test the indirect effect, radical innovation, digital technologies' value development, and knowledge transfer were included in the regression analysis to observe the change in the main effect (Model 3). Suppose the coefficients of explained variables in the previous three regression analyses (Models 1–3) are significant, and the coefficients of the explanatory variable in Model 3 become either smaller or less significant than the coefficients of the explanatory variable in the regression analysis of Hypothesis 1, for which knowledge transfer was not included in the regression analysis. In that case, there is a mediating effect.

In Table 3, the regression coefficient of digital technologies' value development in Model 1 is significantly positive ($\beta = 0.2721$; $p < 0.01$), which indicates that the firm captures the value generated through the improved knowledge transfer made possible by using digital technologies. The regression coefficient of knowledge transfer in Model 2 is 0.3254 and is statistically significant ($p < 0.001$), showing that digital technologies' value significantly improved firms' acquisition of knowledge transfer. In Model 3, the digital technologies' value development ($\beta = 0.1878$; $p < 0.05$) and knowledge transfer ($\beta = 0.2591$; $p < 0.01$) were both included in the regression analysis. The regression coefficient of such value development is significantly positive, and the coefficient is smaller and less significant than that found in the Hypothesis 1 test, in which the intermediate variable was not included in the regression analysis, indicating that knowledge transfer has a mediating effect. Therefore, Hypothesis 2 is supported. This finding indicates that the value development due to the firm's digital technologies increased radical innovation by promoting knowledge transfer.

Similarly, in Table 4, the regression coefficient of digital technologies' value development in Model 1 is significantly positive ($\beta = 0.2721$; $p < 0.01$). The regression coefficient of digital technologies' value development in Model 2 is significantly positive ($\beta = 0.2042$; $p < 0.05$), which indicates that the firm captured the value generated through the improved knowledge co-creation made possible by using digital technologies. In Model 3, digital technologies' value development and knowledge co-creation were both included in the regression analysis. The regression coefficient of such value development is significantly positive ($\beta = 0.2321$; $p < 0.01$), and the coefficient is smaller than that found in the Hypothesis 1 test ($\beta = 0.2721$; $p < 0.01$), in which the intermediate variable was not included in the regression analysis, indicating that knowledge co-creation has a mediating effect. Therefore, Hypothesis 3 is supported. This finding indicates that the value development due to the firm's digital technologies increased radical innovation by promoting knowledge co-creation.

5.4 | Robustness Check

To confirm the reliability of the results obtained through the regression analysis, we conducted robustness tests. We used an alternative variable to measure radical innovation. We also applied an ordinary least squares regression model in our data analysis. The results of statistics on firms' radical innovation are depicted in Table 5. The results show that digital technologies' value development positively influences firms' radical innovation ($\beta = 0.3372$; $p < 0.001$). This finding supports Hypothesis 1 consistently. In Table 6, the coefficient of digital technologies' value development in Model 1 is significantly positive ($\beta = 0.3372$; $p < 0.001$). The coefficient of knowledge transfer in Model 2 is 0.3254 and statistically significant ($p < 0.001$). In Model 3, the regression coefficient of digital technologies' value development is significantly positive ($\beta = 0.2506$; $p < 0.05$), and the coefficient is smaller and less significant than that in Model 1, for which the intermediate variable was not included in the regression analysis. This result indicates that knowledge transfer has a mediating effect and supports Hypothesis 2 consistently. Similarly, in Table 7, the regression coefficient of digital technologies' value development in Model 1 is significantly positive ($\beta = 0.3372$; $p < 0.001$). The regression coefficient of knowledge co-creation in Model 2 is significantly positive ($\beta = 0.2042$; $p < 0.05$). In Model 3, the regression coefficient of digital technologies' value development is significantly positive ($\beta = 0.2888$; $p < 0.01$), and the coefficient is also smaller and less significant than that in Model

TABLE 3 | Mediating effect of knowledge transfer.

	Radical innovation	Knowledge transfer	Radical innovation
	Model 1	Model 2	Model 3
Digital technologies' value development	0.2721**	0.3254***	0.1878*
	(0.0878)	(0.0726)	(0.0919)
Knowledge transfer			0.2591**
			(0.0991)
Firm age	−0.0553	−0.0858	−0.0331
	(0.1420)	(0.1175)	(0.1395)
Firm size	0.0379	0.0859	0.0157
	(0.2045)	(0.1692)	(0.2006)
CEO education	0.1372	−0.0233	0.1433
	(0.1149)	(0.0951)	(0.1127)
Founding team size	0.0049	0.0445	−0.0066
	(0.1231)	(0.1019)	(0.1208)
R&D intensity	0.3504***	0.1384+	0.3145***
	(0.0876)	(0.0725)	(0.0869)
Patent	0.1805**	−0.0410	0.1912**
	(0.0644)	(0.0532)	(0.0632)
Sales growth	0.1085	−0.3306	0.1942
	(0.2843)	(0.2352)	(0.2806)
Constant	−1.9221	2.8351*	−2.6568+
	(1.3844)	(1.1454)	(1.3857)
Prob > F	0.0000	0.0003	0.0000
F/Likelihood	6.50	3.99	6.78
R-squared	0.2668	0.1823	0.3005

Note: Standard errors in parentheses; ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, +$p < 0.1$.

1, indicating that knowledge co-creation has a mediating effect. Therefore, Hypothesis 3 is supported consistently.

6 | Discussion

Our findings provide strong evidence that digital technologies have a significant positive impact on radical innovation in the firms included in this study. Furthermore, our analysis demonstrates that knowledge transfer and knowledge co-creation play vital roles as mediating mechanisms, and it thus elucidates how digital technologies influence radical innovation within firms.

6.1 | Theoretical Implications

Our study contributes to the field in three key ways and accordingly advances the understanding of the effects of digital technologies on firm radical innovation within IEs.

First, we make a significant contribution by empirically examining the role of digital technologies in the context of IEs and the collaborations between entrepreneurial firms and their prominent collaborators. While prior studies have acknowledged the importance of digital technologies for overall firm performance (Urbinati et al. 2020; Usai et al. 2021), our study ventures beyond and specifically investigates their impact on radical innovation in entrepreneurial firms. This focused investigation fills a critical gap in the existing literature, which has primarily focused on the broader implications of digital technologies rather than their specific influence on radical innovation. By addressing this unique aspect, we provide a more nuanced understanding of the relationship between digital technologies and firm radical innovation, contributing to a deeper comprehension of the role of technology adoption in driving innovation outcomes in IEs. By examining the impact of digital technologies on radical innovation, we shed light on how these technologies enable entrepreneurial firms to create and introduce novel ideas, products, or services into the market. This empirical investigation helps unravel the intricate

TABLE 4 | Mediating effect of knowledge co-creation.

	Radical innovation	Knowledge co-creation	Radical innovation
	Model 1	Model 2	Model 3
Digital technologies' value development	0.2721**	0.2042*	0.2321**
	(0.0878)	(0.0856)	(0.0882)
Knowledge co-creation			0.1959*
			(0.0845)
Firm age	−0.0553	0.0304	−0.0613
	(0.1420)	(0.1385)	(0.1399)
Firm size	0.0379	−0.0200	0.0419
	(0.2045)	(0.1993)	(0.2014)
CEO education	0.1372	0.1091	0.1159
	(0.1149)	(0.1120)	(0.1136)
Founding team size	0.0049	0.0419	−0.0033
	(0.1231)	(0.1201)	(0.1214)
R&D intensity	0.3504***	0.1814*	0.3149***
	(0.0876)	(0.0854)	(0.0876)
Patent	0.1805**	−0.0602	0.1923**
	(0.0644)	(0.0627)	(0.0636)
Sales growth	0.1085	0.1598	0.0772
	(0.2843)	(0.2772)	(0.2804)
Constant	−1.9221	2.0802	−2.3295+
	(1.3844)	(1.3497)	(1.3749)
Prob > F	0.0000	0.0000	0.0000
F/Likelihood	6.50	1.74	6.56
R-squared	0.2668	0.0889	0.2935

Note: Standard errors in parentheses; ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, + $p < 0.1$.

TABLE 5 | Robustness test results for radical innovation.

	Radical innovation	
	Model 1	Model 2
Digital technologies' value development		0.3372***
		(0.0923)
Firm age	−0.0136	0.0122
	(0.1555)	(0.1494)
Firm size	−0.1044	−0.0242
	(0.2230)	(0.2151)
CEO education	0.1801	0.0983
	(0.1238)	(0.1209)
Founding team size	0.2021	0.2369+
	(0.1346)	(0.1296)
R&D intensity	0.4707***	0.4273***
	(0.0952)	(0.0922)
Patent	0.1666*	0.1709*
	(0.0705)	(0.0677)
Sales growth	0.0555	0.0999
	(0.3114)	(0.2991)
Constant	1.0406	−0.5550
	(1.4477)	(1.4565)
Prob > F	0.0000	0.0000
F/Likelihood	6.71	8.04
R-squared	0.2460	0.3104

Note: Standard errors in parentheses; ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, + $p < 0.1$.

dynamics between digital technologies and the innovation process, offering insights into how firms leverage digital tools, platforms, and capabilities to foster radical innovation within the collaborative context of IEs.

Second, our study makes a significant contribution to the understanding of the relationship between digital technology adoption and firm innovation performance by identifying and examining two crucial mediating mechanisms: knowledge transfer and knowledge co-creation. Therefore, this study complements the existing investigation of resource dependence theory in the context of IE. While prior studies have proposed the crucial role of IE collaborators in providing resources to support firms' innovation, they separately explored the effects of digital technologies on a firm's knowledge management (Deng et al. 2023; Di Vaio et al. 2021; Sambamurthy and Subramani 2005) and of knowledge management on innovation performance (Donate and Guadamillas 2011; Jin and Shao 2022; Montani and Staglianò 2022). Although insightful, they overlook the different forms that firm engagement in knowledge collaboration in IE can take. This study integrates perspectives of IE collaboration and knowledge management by investigating the mediating effects of knowledge transfer and knowledge co-creation. This integration allows us to provide a more comprehensive understanding of how digital technologies facilitate firm radical innovation through knowledge-related processes and thus contributes to theory by revealing the underlying mechanisms through which digital technology adoption influences innovation performance.

By examining these mediating effects, we uncover the intricate pathways through which digital technologies enable firms to leverage and enhance their existing knowledge base while also fostering the creation of new knowledge. Our study's focus on the mediating mechanisms of knowledge transfer and knowledge co-creation enhances the theoretical understanding of how digital technology adoption influences firm innovation performance. By illuminating these underlying mechanisms, we contribute to the literature by providing a more comprehensive and nuanced explanation of how digital technologies facilitate radical innovation. This knowledge-driven perspective offers

TABLE 6 | Robustness test results for the mediating effect of knowledge transfer.

	Radical innovation	Knowledge transfer	Radical innovation
	Model 1	Model 2	Model 3
Digital technologies' value development	0.3372***	0.3254***	0.2506*
	(0.0923)	(0.0726)	(0.0968)
Knowledge transfer			0.2662*
			(0.1043)
Firm age	0.0122	−0.0858	0.0350
	(0.1494)	(0.1175)	(0.1469)
Firm size	−0.0242	0.0859	−0.0471
	(0.2151)	(0.1692)	(0.2113)
CEO education	0.0983	−0.0233	0.1045
	(0.1209)	(0.0951)	(0.1187)
Founding team size	0.2369+	0.0445	0.2250+
	(0.1296)	(0.1019)	(0.1272)
R&D intensity	0.4273***	0.1384	0.3904***
	(0.0922)	(0.0725)	(0.0916)
Patent	0.1709*	−0.0410	0.1819**
	(0.0677)	(0.0532)	(0.0666)
Sales growth	0.0999	−0.3306	0.1879
	(0.2991)	(0.2352)	(0.2955)
Constant	−0.5550	2.8351*	−1.3098
	(1.4565)	(1.1454)	(1.4595)
Prob > F	0.0000	0.0000	0.0000
F/Likelihood	8.04	3.99	8.15
R-squared	0.3104	0.1823	0.3406

Note: Standard errors in parentheses; ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, + $p < 0.1$.

valuable insights into the specific processes through which firms harness digital technologies to drive innovation outcomes within IEs.

Third, our study makes a significant contribution to the literature on digital technology adoption, knowledge management, and innovation by emphasizing the importance of boundary conditions. We recognize the critique that some management studies often overlook boundary issues (Foss and Saebi 2017), and therefore, we explicitly consider knowledge transfer and knowledge co-creation as crucial linkages between entrepreneurial firms and their prominent collaborators in IEs. By doing so, we shed light on the boundary conditions that influence the relationship between digital technologies and radical innovation. This contribution enhances the theoretical understanding of how collaboration and the exchange of knowledge within IEs shape the effects of digital technologies on firm innovation.

Through this study, we uncover the ways in which digital technologies act as enablers of knowledge transfer and knowledge co-creation across these boundaries. Digital tools and platforms facilitate the exchange of knowledge between different actors by helping to overcome geographical and organizational barriers. They enhance access to external knowledge sources and enable firms to tap into diverse expertise and perspectives, which foster collaboration and innovation. By examining the boundary conditions that influence the relationship between digital technologies and radical innovation, we provide valuable insights into the contextual factors that shape the effectiveness of technology adoption efforts within IEs. By emphasizing the importance of boundary conditions, our study contributes to the theoretical understanding of how the collaboration and exchange of knowledge within IEs shape the effects of digital technologies on firm innovation. This emphasis addresses a gap in the literature, which has often focused on the internal aspects of technology adoption and innovation and has neglected the contextual dynamics that influence these processes. Our study offers a more holistic, nuanced perspective by highlighting the significance of boundary conditions and their role in shaping the outcomes of technology adoption efforts.

TABLE 7 | Robustness test results for the mediating effect of knowledge co-creation.

	Radical innovation	Knowledge co-creation	Radical innovation
	Model 1	Model 2	Model 3
Digital technologies' value development	0.3372***	0.2042*	0.2888**
	(0.0923)	(0.0856)	(0.0922)
Knowledge co-creation			0.1959*
			(0.0845)
Firm age	0.0122	0.0304	0.0050
	(0.1494)	(0.1385)	(0.1463)
Firm size	−0.0242	−0.0200	−0.0195
	(0.2151)	(0.1993)	(0.2106)
CEO education	0.0983	0.1091	0.0725
	(0.1209)	(0.1120)	(0.1188)
Founding team size	0.2369+	0.0419	0.2269
	(0.1296)	(0.1201)	(0.1269)
R&D intensity	0.4273***	0.1814*	0.3843***
	(0.0922)	(0.0854)	(0.0916)
Patent	0.1709*	−0.0602	0.1852**
	(0.0677)	(0.0627)	(0.0665)
Sales growth	0.0999	0.1598	0.0620
	(0.2991)	(0.2772)	(0.2932)
Constant	−0.5550	2.0802	−1.0479
	(1.4565)	(1.3497)	(1.4377)
Prob > F	0.0000	0.0000	0.0000
F/Likelihood	8.04	1.74	8.26
R-squared	0.3104	0.0889	0.3436

Note: Standard errors in parentheses; ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, + $p < 0.1$.

6.2 | Practical Implications

The findings of our study provide compelling evidence that digital technologies have a significant positive impact on radical innovation within firms. These insights have important practical implications for firm managers and would serve to guide them in adopting effective strategies to leverage digital technologies and foster innovation within their organizations.

First and foremost, firm managers should prioritize the strategic integration of digital technologies into their innovation processes and practices. This process involves identifying and implementing the appropriate digital tools and platforms that align with the firm's specific needs and goals. By investing in advanced technologies, such as artificial intelligence, data analytics, and cloud computing, managers can unlock new possibilities for knowledge acquisition, analysis, and utilization. Embracing these technologies enables firms to tap into vast amounts of data, extract valuable insights, and generate innovative ideas that can drive competitive advantage.

Furthermore, our findings highlight the importance of forging collaborative partnerships and networks with external stakeholders. Firm managers should actively seek out opportunities to collaborate with customers, complementors, and other innovative firms. Digital technologies can play a crucial role in enabling and facilitating such collaborations, for they provide platforms for virtual meetings, shared workspaces, and real-time interactions. Through these partnerships, managers can access diverse knowledge pools, leverage external expertise, and co-create innovative solutions that may not be possible within the confines of their organization alone.

To fully leverage the potential of digital technologies in driving innovation, firm managers should also invest in developing the digital skills and capabilities of their workforce. This process involves identifying skill gaps, providing training programs, and fostering a culture of continuous learning and adaptation. By enhancing employees' digital literacy and proficiency, managers can empower their teams to effectively utilize digital tools and technologies for knowledge transfer, co-creation, and innovation. In addition, managers should encourage employees to experiment and take risks, and allow them the freedom to explore new ideas, which would create an organizational climate that nurtures creativity and innovation.

6.3 | Limitations and Future Research Directions

Although this study contributes meaningfully to the existing body of knowledge, it is not without limitations that open avenues for future research. First, the generalizability of our findings needs further validation. Although we have investigated the effects of digital technologies on radical innovation within the entrepreneurial context, the applicability of these results to other sectors and organizational types remains to be examined. Future research could extend this inquiry to different contexts, such as established corporations, nonprofits, or public sector organizations, to assess the universality of our findings. Second, alternative mechanisms through which digital technologies influence innovation need to be explored. Although this study has shed light on the role of knowledge management as a mediating factor, other potential mechanisms remain unexplored. For instance, studies could investigate how factors such as organizational culture, structure, or leadership may interact with digital technology to affect innovation processes.

Third, conditional factors present another fertile ground for examination, and accordingly, studies could focus on identifying and understanding the specific conditions under which digital technologies are most effective in enhancing radical innovation. These conditions could include industry-specific conditions, the technological readiness of the firm, or the digital literacy of the workforce, among others. Fourth, longitudinal studies would be instrumental in capturing the evolution of the impact of digital technologies on innovation

over time. As the digital landscape continues to evolve rapidly, understanding the dynamic relationship between technology adoption and innovation performance could yield valuable insights.

Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

Acs, Z. J., P. Braunerhjelm, D. B. Audretsch, and B. Carlsson. 2009. "The Knowledge Spillover Theory of Entrepreneurship." *Small Business Economics* 32: 15–30.

Adner, R. 2006. "Match Your Innovation Strategy to Your Innovation Ecosystem." *Harvard Business Review* 84, no. 4: 98.

Adner, R., and R. Kapoor. 2010. "Value Creation in Innovation Ecosystems: How the Structure of Technological Interdependence Affects Firm Performance in New Technology Generations." *Strategic Management Journal* 31, no. 3: 306–333.

Ardito, L., S. Raby, V. Albino, and B. Bertoldi. 2021. "The Duality of Digital and Environmental Orientations in the Context of SMEs: Implications for Innovation Performance." *Journal of Business Research* 123: 44–56.

Ardolino, M., M. Rapaccini, N. Saccani, P. Gaiardelli, G. Crespi, and C. Ruggeri. 2018. "The Role of Digital Technologies for the Service Transformation of Industrial Companies." *International Journal of Production Research* 56, no. 6: 2116–2132.

Arias-Pérez, J., J. Velez-Ocampo, and J. Cepeda-Cardona. 2021. "Strategic Orientation Toward Digitalization to Improve Innovation Capability: Why Knowledge Acquisition and Exploitation Through External Embeddedness Matter." *Journal of Knowledge Management* 25, no. 5: 1319–1335.

Audretsch, D. B., and M. Belitski. 2023. "Evaluating Internal and External Knowledge Sources in Firm Innovation and Productivity: An Industry Perspective." *R&D Management* 53, no. 1: 168–192.

Audretsch, D. B., M. Belitski, R. Caiazza, F. Chowdhury, and M. Menter. 2023. "Entrepreneurial Growth, Value Creation and New Technologies." *Journal of Technology Transfer* 48, no. 5: 1535–1551.

Audretsch, D. B., and M. Keilbach. 2007. "The Theory of Knowledge Spillover Entrepreneurship." *Journal of Management Studies* 44, no. 7: 1242–1254.

Bacon, E., M. D. Williams, and G. H. Davies. 2019. "Recipes for Success: Conditions for Knowledge Transfer Across Open Innovation Ecosystems." *International Journal of Information Management* 49: 377–387.

Baron, R. M., and D. A. Kenny. 1986. "The Moderator–Mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations." *Journal of Personality and Social Psychology* 51, no. 6: 1173.

van Beers, C., and F. Zand. 2014. "R&D Cooperation, Partner Diversity, and Innovation Performance: An Empirical Analysis." *Journal of Product Innovation Management* 31, no. 2: 292–312.

Blichfeldt, H., and R. Faullant. 2021. "Performance Effects of Digital Technology Adoption and Product & Service Innovation–A Process-Industry Perspective." *Technovation* 105: 102275.

Boeker, W., M. D. Howard, S. Basu, and A. Sahaym. 2021. "Interpersonal Relationships, Digital Technologies, and Innovation in Entrepreneurial Ventures." *Journal of Business Research* 125: 495–507.

Bouncken, R. B., M. Ratzmann, and S. Kraus. 2021. "Anti-Aging: How Innovation Is Shaped by Firm Age and Mutual Knowledge Creation in an Alliance." *Journal of Business Research* 137: 422–429.

Boyd, B. 1990. "Corporate Linkages and Organizational Environment: A Test of the Resource Dependence Model." *Strategic Management Journal* 11, no. 6: 419–430.

Bstieler, L., T. Gruen, B. Akdeniz, et al. 2018. "Emerging Research Themes in Innovation and New Product Development. Insights From the 2017 PDMA-UNH Doctoral Consortium." *Journal of Product Innovation Management* 35, no. 3: 300–307.

Chang, J., J. J. Wang, and X. Bai. 2020. "Good Match Matters: Knowledge Co-Creation in International Joint Ventures." *Industrial Marketing Management* 84: 138–150.

Choo, A. S., K. W. Linderman, and R. G. Schroeder. 2007. "Method and Context Perspectives on Learning and Knowledge Creation in Quality Management." *Journal of Operations Management* 25, no. 4: 918–931.

Christensen, C. M., R. McDonald, E. J. Altman, and J. E. Palmer. 2018. "Disruptive Innovation: An Intellectual History and Directions for Future Research." *Journal of Management Studies* 55, no. 7: 1043–1078.

Cui, A. S., and F. Wu. 2017. "The Impact of Customer Involvement on New Product Development: Contingent and Substitutive Effects." *Journal of Product Innovation Management* 34, no. 1: 60–80.

Cummings, J. L., and B. S. Teng. 2003. "Transferring R&D Knowledge: The Key Factors Affecting Knowledge Transfer Success." *Journal of Engineering and Technology Management* 20, no. 1–2: 39–68.

Das, T. K., and B. S. Teng. 2000. "A Resource-Based Theory of Strategic Alliances." *Journal of Management* 26, no. 1: 31–61.

de Silva, M., O. Al-Tabbaa, and J. Pinto. 2023. "Academics Engaging in Knowledge Transfer and Co-Creation: Push Causation and Pull Effectuation?" *Research Policy* 52, no. 2: 104668.

Deng, H., S. X. Duan, and S. Wibowo. 2023. "Digital Technology Driven Knowledge Sharing for Job Performance." *Journal of Knowledge Management* 27, no. 2: 404–425.

Donate, M. J., and F. Guadamillas. 2011. "Organizational Factors to Support Knowledge Management and Innovation." *Journal of Knowledge Management* 15, no. 6: 890–914.

Durmuşoğlu, S. S., and G. Barczak. 2011. "The Use of Information Technology Tools in New Product Development Phases: Analysis of Effects on New Product Innovativeness, Quality, and Market Performance." *Industrial Marketing Management* 40, no. 2: 321–330.

Foss, N. J., and T. Saebi. 2017. "Fifteen Years of Research on Business Model Innovation: How Far Have We Come, and Where Should We Go?" *Journal of Management* 43, no. 1: 200–227.

Geletkanycz, M. A., and D. C. Hambrick. 1997. "The External Ties of Top Executives: Implications for Strategic Choice and Performance." *Administrative Science Quarterly* 42, no. 4: 654–681. https://doi.org/10.2307/2393653.

Gilbert, M., and M. Cordey-Hayes. 1996. "Understanding the Process of Knowledge Transfer to Achieve Successful Technological Innovation." *Technovation* 16, no. 6: 301–312.

Govindarajan, V., P. K. Kopalle, and E. Danneels. 2011. "The Effects of Mainstream and Emerging Customer Orientations on Radical and Disruptive Innovations." *Journal of Product Innovation Management* 28, no. s1: 121–132.

Han, H., and S. Trimi. 2022. "Towards a Data Science Platform for Improving SME Collaboration Through Industry 4.0 Technologies." *Technological Forecasting and Social Change* 174: 121242.

Hanelt, A., S. Firk, B. Hildebrandt, and L. M. Kolbe. 2021. "Digital M&A, Digital Innovation, and Firm Performance: An Empirical Investigation." *European Journal of Information Systems* 30, no. 1: 3–26.

Hardy, C., N. Phillips, and T. B. Lawrence. 2003. "Resources, Knowledge and Influence: The Organizational Effects of Interorganizational Collaboration." *Journal of Management Studies* 40, no. 2: 321–347.

Holmström, J. 2018. "Recombination in Digital Innovation: Challenges, Opportunities, and the Importance of a Theoretical Framework." *Information and Organization* 28, no. 2: 107–110.

Hossain, M., and A. H. Lassen. 2017. "How Do Digital Platforms for Ideas, Technologies, and Knowledge Transfer Act as Enablers for Digital Transformation?" *Technology Innovation Management Review* 7, no. 9: 55–60.

Ivanov, D., A. Dolgui, and B. Sokolov. 2019. "The Impact of Digital Technology and Industry 4.0 on the Ripple Effect and Supply Chain Risk Analytics." *International Journal of Production Research* 57, no. 3: 829–846.

Jandhyala, S., and A. Phene. 2015. "The Role of Intergovernmental Organizations in Cross-Border Knowledge Transfer and Innovation." *Administrative Science Quarterly* 60, no. 4: 712–743.

Jiang, S. Y. 2022. "Transition and Innovation Ecosystem–Investigating Technologies, Focal Actors, and Institution in eHealth Innovations." *Technological Forecasting and Social Change* 175: 121369.

Jin, Y., and Y. F. Shao. 2022. "Power-Leveraging Paradox and Firm Innovation: The Influence of Network Power, Knowledge Integration and Breakthrough Innovation." *Industrial Marketing Management* 102: 205–215.

Karaevli, A., and E. J. Zajac. 2013. "When Do Outsider CEOs Generate Strategic Change? The Enabling Role of Corporate Stability." *Journal of Management Studies* 50, no. 7: 1267–1294.

Katsikeas, C., L. Leonidou, and A. Zeriti. 2020. "Revisiting International Marketing Strategy in a Digital Era: Opportunities, Challenges, and Research Directions." *International Marketing Review* 37, no. 3: 405–424.

Kawakami, T., G. Barczak, and S. S. Durmuşoğlu. 2015. "Information Technology Tools in New Product Development: The Impact of Complementary Resources." *Journal of Product Innovation Management* 32, no. 4: 622–635.

Kazadi, K., A. Lievens, and D. Mahr. 2016. "Stakeholder Co-Creation During the Innovation Process: Identifying Capabilities for Knowledge Creation Among Multiple Stakeholders." *Journal of Business Research* 69, no. 2: 525–540.

Ko, D. G., L. J. Kirsch, and W. R. King. 2005. "Antecedents of Knowledge Transfer From Consultants to Clients in Enterprise System Implementations." *MIS Quarterly* 29, no. 1: 59–85.

Li, Y., J. Dai, and L. Cui. 2020. "The Impact of Digital Technologies on Economic and Environmental Performance in the Context of Industry 4.0: A Moderated Mediation Model." *International Journal of Production Economics* 229: 107777.

Liang, L., and Y. Li. 2023. "How Does Government Support Promote Digital Economy Development in China? The Mediating Role of Regional Innovation Ecosystem Resilience." *Technological Forecasting and Social Change* 188: 122328.

Linderman, K., R. G. Schroeder, S. Zaheer, C. Liedtke, and A. S. Choo. 2004. "Integrating Quality Management Practices With Knowledge Creation Processes." *Journal of Operations Management* 22, no. 6: 589–607.

Malhotra, Y. 2005. "Integrating Knowledge Management Technologies in Organizational Business Processes: Getting Real Time Enterprises to Deliver Real Business Performance." *Journal of Knowledge Management* 9, no. 1: 7–28.

Marsh, S. J., and G. N. Stock. 2003. "Building Dynamic Capabilities in New Product Development Through Intertemporal Integration." *Journal of Product Innovation Management* 20, no. 2: 136–148.

Martínez-Caro, E., J. G. Cegarra-Navarro, and F. J. Alfonso-Ruiz. 2020. "Digital Technologies and Firm Performance: The Role of Digital Organisational Culture." *Technological Forecasting and Social Change* 154: 119962.

Mei, L., T. Zhang, and J. Chen. 2019. "Exploring the Effects of Inter-Firm Linkages on SMEs' Open Innovation From an Ecosystem Perspective: An Empirical Study of Chinese Manufacturing SMEs." *Technological Forecasting and Social Change* 144: 118–128.

Mondal, S., S. Das, and V. G. Vrana. 2023. "How to Bell the Cat? A Theoretical Review of Generative Artificial Intelligence Towards Digital Disruption in all Walks of Life." *Technologies* 11, no. 2: 44.

Montani, F., and R. Staglianò. 2022. "Innovation in Times of Pandemic: The Moderating Effect of Knowledge Sharing on the Relationship Between COVID-19-Induced Job Stress and Employee Innovation." *R&D Management* 52, no. 2: 193–205.

Moore, J. F. 1993. "Predators and Prey: A New Ecology of Competition." *Harvard Business Review* 71, no. 3: 75–86.

Parmentier, G., and V. Mangematin. 2014. "Orchestrating Innovation With User Communities in the Creative Industries." *Technological Forecasting and Social Change* 83: 40–53.

Patrucco, A., A. Moretto, D. Trabucchi, and R. Golini. 2021. "How Do Industry 4.0 Technologies Boost Collaborations in Buyer-Supplier Relationships?" *Research-Technology Management* 65, no. 1: 48–58.

Pérez-Luño, A., J. Wiklund, and R. V. Cabrera. 2011. "The Dual Nature of Innovative Activity: How Entrepreneurial Orientation Influences Innovation Generation and Adoption." *Journal of Business Venturing* 26, no. 5: 555–571.

Rahmati, P., A. Tafti, J. C. Westland, and C. Hidalgo. 2021. "When all Products Are Digital: Complexity and Intangible Value in the Ecosystem of Digitizing Firms." *MIS Quarterly* 45, no. 3: 1025–1058.

Reynolds, E. B., and Y. Uygun. 2018. "Strengthening Advanced Manufacturing Innovation Ecosystems: The Case of Massachusetts." *Technological Forecasting and Social Change* 136: 178–191.

Roper, S., J. H. Love, and K. Bonner. 2017. "Firms' Knowledge Search and Local Knowledge Externalities in Innovation Performance." *Research Policy* 46, no. 1: 43–56.

Samaddar, S., and S. S. Kadiyala. 2006. "An Analysis of Interorganizational Resource Sharing Decisions in Collaborative Knowledge Creation." *European Journal of Operational Research* 170, no. 1: 192–210.

Samagaio, A., N. F. Crespo, and R. Rodrigues. 2018. "Management Control Systems in High-Tech Startups: An Empirical Investigation." *Journal of Business Research* 89: 351–360.

Sambamurthy, V., and M. Subramani. 2005. "Special Issue on Information Technologies and Knowledge Management." *MIS Quarterly* 29, no. 1: 1–7.

El Sawy, O. A., A. Malhotra, Y. Park, and P. A. Pavlou. 2010. "Research Commentary—Seeking the Configurations of Digital Ecodynamics: It Takes Three to Tango." *Information Systems Research* 21, no. 4: 835–848.

El Sawy, O. A., and F. Pereira. 2013. *Business Modelling in the Dynamic Digital Space: An Ecosystem Approach*. Springer. https://doi.org/10.1007/978-3-642-31765-1.

Smith, C. G., and J. B. Smith. 2021. "Founders' Uses of Digital Networks for Resource Acquisition: Extending Network Theory Online." *Journal of Business Research* 125: 466–482.

Story, V., L. O'Malley, and S. Hart. 2011. "Roles, Role Performance, and Radical Innovation Competences." *Industrial Marketing Management* 40, no. 6: 952–966.

Subramaniam, M., and N. Venkatraman. 2001. "Determinants of Transnational New Product Development Capability: Testing the Influence of Transferring and Deploying Tacit Overseas Knowledge." *Strategic Management Journal* 22, no. 4: 359–378.

Subramanian, A. M., W. Bo, and C. Kah-Hin. 2018. "The Role of Knowledge Base Homogeneity in Learning From Strategic Alliances." *Research Policy* 47, no. 1: 158–168.

Teece, D. J. 1977. "Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-How." *Economic Journal* 87, no. 346: 242–261.

Thomas, L. D. W., and E. Autio. 2020. "Innovation Ecosystems in Management: An Organizing Typology." In *Oxford Research Encyclopedia of Business and Management*, 1–38. Oxford University Press. https://doi.org/10.1093/acrefore/9780190224851.013.203.

Tootell, A., E. Kyriazis, J. Billsberry, V. Ambrosini, S. Garrett-Jones, and G. Wallace. 2021. "Knowledge Creation in Complex Inter-Organizational Arrangements: Understanding the Barriers and Enablers of University-Industry Knowledge Creation in Science-Based Cooperation." *Journal of Knowledge Management* 25, no. 4: 743–769.

Urbinati, A., D. Chiaroni, V. Chiesa, and F. Frattini. 2020. "The Role of Digital Technologies in Open Innovation Processes: An Exploratory Multiple Case Study Analysis." *R&D Management* 50, no. 1: 136–160.

Usai, A., F. Fiano, A. M. Petruzzelli, P. Paoloni, M. F. Briamonte, and B. Orlando. 2021. "Unveiling the Impact of the Adoption of Digital Technologies on firms' Innovation Performance." *Journal of Business Research* 133: 327–336.

Di Vaio, A., R. Palladino, A. Pezzi, and D. E. Kalisz. 2021. "The Role of Digital Innovation in Knowledge Management Systems: A Systematic Literature Review." *Journal of Business Research* 123: 220–231.

Wang, H., L. J. Zheng, J. Z. Zhang, A. Kumar, and P. R. Srivastava. 2024. "Unpacking Complementarity in Innovation Ecosystems: A Configurational Analysis of Knowledge Transfer for Achieving Breakthrough Innovation." *Technological Forecasting and Social Change* 198: 122974.

Xie, X., and H. Wang. 2021. "How to Bridge the Gap Between Innovation Niches and Exploratory and Exploitative Innovations in Open Innovation Ecosystems." *Journal of Business Research* 124: 299–311.

Yoo, Y., R. J. Boland Jr., K. Lyytinen, and A. Majchrzak. 2012. "Organizing for Innovation in the Digitized World." *Organization Science* 23: 1398–1408.

Zhao, Y., and J. I. Canales. 2021. "Never the Twain Shall Meet? Knowledge Strategies for Digitalization in Healthcare." *Technological Forecasting and Social Change* 170: 120923.

Zheng, L. J., Y. Fan, H. Wang, and W. Liu. 2021. "Born Innovator? How Founder Birth Order Influences Product Innovation Generation and Adoption in Entrepreneurial Firms." *Journal of Business Research* 136: 414–430.

Zheng, L. J., Y. Zhang, W. Zhan, and P. Sharma. 2022. "How B2B Relationships Influence New Product Development in Entrepreneurial Firms? The Role of Psychological Tension." *Journal of Business Research* 139: 1451–1462.

Zia, N. U. 2020. "Knowledge-Oriented Leadership, Knowledge Management Behaviour and Innovation Performance in Project-Based SMEs: The Moderating Role of Goal Orientations." *Journal of Knowledge Management* 24, no. 8: 1819–1839.