Journal of the Knowledge Economy
https://doi.org/10.1007/s13132-024-02058-w

Innovation Performance in the Digital Divide Context: Nexus of Digital Infrastructure, Digital Innovation, and E-knowledge

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Received: 27 August 2023 / Accepted: 3 May 2024

Abstract
Due to speedily changing surroundings and market opportunities, a firm's digital infrastructure is becoming increasingly significant as it performs a vital role in enhancing its innovation performance and equals viable benefits to the digital divide. The firm's success is mainly dependent on its novelty and ability to innovate. The pivotal role of the digital infrastructure in increasing innovation performance has been explored in studies relating to innovation. The current research explores how digital infrastructure enhances innovation performance by examining the interplay between digital innovation and the moderating role of e-knowledge. Utilizing quantitative methods, this study gathered data through questionnaires from 383 respondents across various SMEs in China. The results highlight the significant impact of digital infrastructure on improving innovation performance. Additionally, the findings emphasize that digital innovation plays a crucial role in influencing the relationship between digital infrastructure and innovation performance. Furthermore, the study reveals that e-knowledge intervenes in this relationship, acting as a critical moderator. These insights underscore the complex dynamics of digital infrastructure's role in fostering innovation within SMEs. The study extends an existing pool of knowledge regarding the large-scale influence of digital infrastructure on innovation performance. This shows that digital innovations and e-knowledge deliver through the mechanism of digital infrastructure linkage and contribute to improved innovation performance.

Keywords Digital infrastructure · Digital innovation · E-knowledge · Innovation performance

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Published online: 13 June 2024

Introduction

In the last decade, the world has witnessed a significant shift toward integrating digital technology in workplaces, a movement led by small and medium enterprises (SMEs) who hope to improve their products and services to gain a competitive edge through innovativeness (Jabbouri et al., 2016). The SMEs of China have been through an impacting change after the 1980s, which is also reflected in the country's economic development (Cunningham, 2011). Constituting 99% of all businesses, they wield substantial influence, contributing more than 59% of the GDP, 50% of tax revenue, 68% of international trade, and 75% of urban employment annually (Zhang, 2005). Remarkably, they account for 80% of novel products and 65% of innovative patents, optimizing resource allocation (Cunningham, 2011). Entities like Zhong-guancun Science and Technology Park showcase their role by hosting 10,000 businesses and attracting 1000 newcomers annually, thus catalyzing industry diversification and resource efficiency within China's economy (ILO report, 2003). This growing trend is underscored by the increasing desire of firms to invest in robust internal automation competencies and internet-based computerization infrastructure (Shenglin et al., 2017).

Digital infrastructure, with the internet at its core, is progressively narrowing the digital divide, which has long stood as a barrier to equitable access to digital resources (Wen et al., 2023). This infrastructure is not limited to the web; it encompasses a network of cellular and satellite systems, yet the internet, complemented by essential devices like PCs and smartphones, is critical in revolutionizing how we access information and services, as well as how we interact and transact globally (Shenglin et al., 2017). Technological advancements make business communication easier and faster on an international level. The digital divide can be classified as the gaps in digital access and usage between the different groups in society and regions, highlighting urgent issues, especially in emerging economies and marginalized groups (Shenglin et al., 2017). These practices narrow the gap that is getting wider every day, which may be the stepping stone for increasing economic development and decreasing inequality so that growth will be sustainable. Events that disrupt the transmission infrastructures of the digital world are among those that can redefine the concept of a digital divide (Zhang et al., 2022). The main difficulty of inclusive availability in the information society is the improvement of physical infrastructure and developing digital literacy according to competency. Digital innovations would also need to be embraced alongside making comprehensive inclusion possible for everyone (Shenglin et al., 2017).

Also, recognizing the strategic role of digital innovation could be the keystone that leads to increased productivity levels and triggers innovation in SMEs. Digital infrastructure, being the backbone of such a system, will play a critical role in strengthening human resources' capabilities for innovation (Fichman et al., 2014). Moreover, including e-knowledge is a vital attribute that sustains and interlinks technology development among different fields (Kostadinova, 2019; Norris et al., 2003). The earlier study demonstrated how information technology boosts performance and efficiency (Scuotto et al., 2017). Digital innovation

portrays technological resourcefulness in an organization (Nambisan et al., 2017). It is reflected in various business dimensions, including team communication, corporate culture, workflows, creativity, and the broader economic and innovation climate (Sofka and Grimpe, 2010). Therefore, the expansion and optimization of digital infrastructure bridge the digital divide and propel digital innovation, fostering an environment where socio-economic integration is achievable, and the innovation performance of SMEs and regions is enhanced.

While China demonstrates significant efforts to overcome geographical, social, and economic disparities by providing more citizens with IT network access, it is critical to recognize that investing in specific physical infrastructure is insufficient to augment inclusion in the information society. Therefore, promoting digital infrastructure in most disadvantaged areas is vital in supporting inclusiveness, although public establishments should also implement corollary guidelines to encourage social and economic consistency (Bygstad and Øvrelid, 2020). Digital infrastructure comprises a network of remotely hosted servers on the internet, responsible for processing, managing, and storing data before it reaches a personal computer or local server (Weber et al., 2018). Therefore, many SMEs have significantly adopted private servers in their workplaces (Wang et al., 2021).

Therefore, this study explores the intricate interplay between digital infrastructure, digital innovation, e-knowledge, and innovation performance in China's SMEs, aiming to bridge the existing knowledge gap. Previous research has pointed out the determinants of innovation performance in developing societies, like the influence of informational networks and internationalization strategies (Zeng et al., 2010; Kafouros et al., 2008), as well as the function of social network structures (Muller & Peres, 2019). Fully grasping these processes is necessary to build those policy frameworks for engineering such sustainable ways of production in SMEs. The government must design policy frameworks and digital strategies to meet the developmental needs of the SME industry. This will produce effective digital transformation policies for the regions in China that are region-sensitive. This research sheds light on a new area of knowledge: whether digital infrastructure influences innovation results. Through regression analysis and surveys conducted on SMEs, the outcome of the digital infrastructures provides a digital innovation, plus it has the most substantial influence, mainly with e-knowledge that emerged as the moderator. This complies with the previous research (Bhatti et al.,2022a, b; Träskman & Skoog, 2022) confirming that a well-developed digital infrastructure arrangement enables the design of new products and services among the SMEs, which further makes the business trend develop maturely. These insights are not the only inputs needed for making tactical choices through which developmental progress is created for the economy and society, and the SME's development is secured.

Further, this study addresses a critical gap in the IT literature on digital innovation. While prior research has examined individual elements of digital innovation, this study takes a more holistic approach, investigating how these elements interact to drive successful IT innovation. In contrast, present work integrates e-knowledge, digital innovation, and digital infrastructure into a unified framework, pioneering a comprehensive approach to understanding their collective impact. Additionally, this research delves into the intricacies of digital infrastructure's influence on innovation

within SMEs in China, assessing how e-knowledge and digital innovation interplay with this relationship. We illuminate an underexplored area by conducting an in-depth analysis of the combined effects of digital infrastructure, digital innovation, and e-knowledge on innovation performance. The study systematically investigates these components' individual and collective contributions to SME performance and ideation, focusing mainly on China's SME sector. By coalescing various factors into a holistic model, our approach fills contemporary knowledge gaps and reframes the discourse on the complex interdependencies among digital infrastructure, innovation, and knowledge management in fostering innovation performance.

The subsequent sections of this paper are structured as follows: The "Literature Review" section reviews the relevant literature and examines the background of digital infrastructure, digital divide, and digital innovation, including the development of hypotheses. The "Mediating Role of Digital Innovation" section delineates the research data and the measurement of variables. The "Methodology" section outlines the research methodology. Results and discussions are presented in the "Discussion and conclusions" section. The paper concludes with implications in the "Limitations and Prospects" section.

Literature Review

The Role of Digital Infrastructure in Enhancing Innovation Performance and Reducing the Digital Divide

Digital infrastructure forms the cornerstone of modern businesses, facilitating the provision of state-of-the-art services and fostering high levels of efficiency and competence crucial for boosting innovation performance (Träskman & Skoog, 2022). A robust digital infrastructure is the core characteristic of a successful SME. It comprises office automation, internet connectivity, and all types of information networks. Consequently, in combination, these aspects will propel business development. They can also help SMEs produce the next generation of products and services, take the lead from newer production methods, and run successful innovation programs (Bhatti et al., 2022a, b; Krenz et al., n.d). The robust base also ensures that the accumulation of intellectual capital adds another impetus to the innovation fully linked to long-term aspirations and competitive advantage (Tilson et al., 2010).

Digital infrastructure is central to maintaining viable innovation within the digital ecosystem. Through information exchange, knowledge sharing, and problem-solving, it becomes a center that teaches, provides (the know-how), and compels creative solutions, as well as the core competencies needed for continuous innovation (Allwein & Venters, 2017; Cheng et al., 2014). This pragmatic collection of resources, covering software, personnel, hardware, networks, and databases, supports scientists and engineers in conducting relentless research and making progressive innovations. Consequently, digital infrastructure closes the digital divide gap by exposing the masses to resources such as computers and the internet (Øvrelid & Kempton, 2020). The result of such a mechanism is integration among different groups into the digital economy that strengthens

their contribution to furthering overall innovation in all sectors. This opening up allows for better production, fast and efficient information systems, and the creation of groundbreaking products and services resulting from innovative technologies (Queiroz et al., 2020). Given these insights, the following hypothesis is proposed:

H1: Strong digital infrastructure positively influences a firm's innovative performance.

Mediating Role of Digital Innovation

Digital innovation, in general, is regarded as the transformation of the business process, product line, and business model that is driven by digital technology (Svahn et al., 2017). Such a comprehensive perspective comprehends several relevant innovation outcomes, including new platforms, services, and products and enhanced customer experiences (Zorina and Dutton, 2021). These ends are attained through the deployment of digital infrastructures, which are pivotal for their actualization. Digital infrastructure is implicitly connected to the methods and procedures these components entail, such as computer software and instructions specific to this software. The above-listed components help make digital tools that ensure that the likes of business operations are managed, coordinated, and transformed across industries, thereby offering innovation that leads to improved innovation performance (Hings et al., 2018). This relationship, a vital source of digital foundation that drives digital innovation, underscores that standing on a more robust digital infrastructure is the nonnegotiable element of business strategy in the digital age. Digital innovation will enable the company to exceed its success in innovation performance and competitiveness (Khin & Ho, 2018). It is a factor in accelerating changes and reforming how digital infrastructure can be innovative (Nambisan et al., 2019). This includes the information and communication infrastructure of applications such as computing and internetworking. They were creating a climate where centers of strength become allies for each other to build innovative solutions in the field of customers, competitors, employees, and organizational growth (Nambisan et al., 2019). Technology tools such as IoT, VR, AI, and physical systems are the components of this infrastructure. These make the development of such infrastructure possible (Papadonikolaki & Morgan, 2020). This allows brands to build a strong reputation, massively improving their innovativeness, and hence, they start churning out more cutting-edge ideas. Thus, as posited above, the mediation of digital innovation in the relationship between digital infrastructure and innovation performance emerges as a fundamental proposition.

H2: The connection between digital infrastructure and innovation performance is mediated by digital innovation.

E-knowledge Helps to Moderate

Digital infrastructure is the organic fusion of IT and physical components such as software, hardware, and databases, which promote employees' creative and technical abilities (Dwivedi & Joshi, 2019). Many businesses train their employees on how to use the latest technologies and inventions, as well as improve their e-knowledge competencies, enabling businesses to promote inventive items and enhance their innovation performance(Tian & Hong, 2022). For example, e-knowledge is a better understanding of technologies like intelligent agents, data warehouse technologies, decision support systems, and so on, which helps design better digital infrastructures that lead to high innovation performance in firms (Haghighi et al., 2015). Digital infrastructure is the set of digital servers, software, and physical networks that assist in organizing and delivering knowledge and information (Melville & Kohli, 2021). By supporting the latest innovative technology, SMEs can rapidly achieve massive digital technology e-knowledge, which helps in mobilizing resources at high effectiveness and increasing innovation performance (Chen & Xu, 2022). In this research, we evaluate the moderating effect of e-knowledge on the association between digital infrastructure and innovation performance. However, digital infrastructure includes physical resources, which are essential for using computerized systems, processes, methods, and devices that act as the basis to sustain, pursue, and achieve competitive benefits and improve innovation performance (Praharaj et al., 2017). E-knowledge is made possible by combining knowledge and information management, inter-organizational structures, and web-based platforms, allowing customers, suppliers, competitors, markets, and others to share knowledge continuously. This helps design valuable techniques to improve innovation performance (Alotaibi, 2017). The theoritical framework of this study is shown in Fig. 1.

H3: E-knowledge moderates the connection between digital infrastructure and innovation performance.

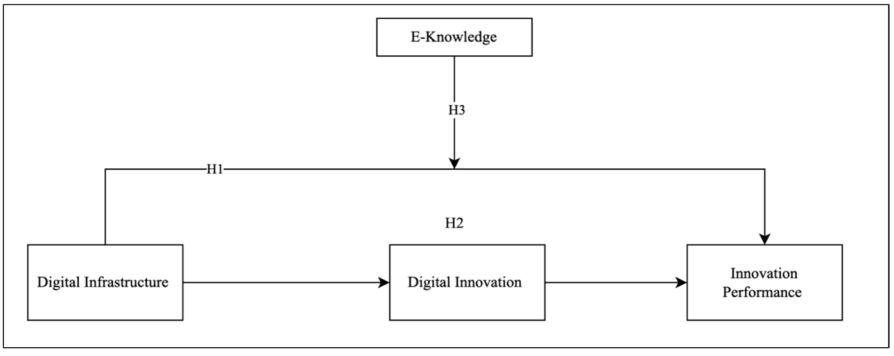

Fig. 1 Theoretical framework of the study

Methodology

We employed quantitative techniques and questionnaires to amass data for the current investigation. The distribution of these questionnaires was orchestrated with the assistance of the HR department. A randomized sampling approach was adopted to select owners, managers, executive officers, and operational managers of SMEs in China. The surveys were disseminated through email addresses sourced from pertinent SME management and conventional postal mail delivery methods. A corresponding translation method was employed in which adapted items were first translated from English to Chinese and subsequently translated back by other experts into English. Then, all the variations were reconciled between these experts. Six workers enlisted in an executive development plan functioning in the same industry pre-tested the aptness of the Chinese version of the questionnaire. The questionnaire is organized into three major sections. Section A consists two questions related to business age with the first question asking details such as what is the age of business and how many years have passed successfully since business is operationalized. The second question in the section captures the size of business, i.e., number of total employees working in that business. Section B shifts the focus to the employees, asking first about their educational backgrounds and second about their work experience, specifically the years they have spent within the industry. Section C explores the study variables along with items details, which are elaborated on in the Appendix.

We disseminated 440 questionnaires online and in various SMEs across China, specifically targeting those prioritizing digital infrastructure. We got 383 questionnaires out of 440 questionnaires from SMEs, which makes a return rate of 87.04%. We requested the owners and management of the concerned SMEs to support us in filling out the questionnaire from participants. Meanwhile, we described the study's objectives and ensured anonymity. This study questionnaire is divided into two sections. In Section 1, each participant was requested to provide their demographic details like age, gender, tenure, and education. However, the next section will detail every component of the study's variables. In the total sample size, 43.25% of respondents were female, and the other 56.75% of participants were male. Nevertheless, 49% of employees got bachelor's degrees, 32.51% of employees obtained master's degrees, and the remaining 18.48% of employees did Matric. Meanwhile, the average participant's tenure ranged from 4 to 8 years. Furthermore, we informed participants about the research objectives and ensured their discretion and secrecy.

Measurement

To test this study hypothesis, multi-item scales were adapted from prior literature to measure the variables. Initially, the original items were written in English. To test English into Chinese translations, we pre-tested this with academic experts and eradicated discrepancies in the translation. The details of each item for scales

used in this study are shown in the Appendix. However, 5-point scales were used for this study construct, ranging from 1 = strongly agree to 5 = strongly disagree.

Digital Infrastructure

In this study, we employed a 7-point measurement scale to determine the level of digital infrastructure. Inspired by Ghosh's (2009) and Greenstein's (2019) work, this scale represents the key features of digital infrastructure that have been carefully tailored to encapsulate the diverse facets relevant to this research. It allows us to evaluate various dimensions and provide a comprehensive picture of the impact of infrastructure.

Digital Innovation

In this study, we employed a tailored 5-point scale to measure digital innovation, adapting it to precisely capture its unique aspects as outlined by Hildebrandt et al. (2022) and Khin and Ho (2018). This approach enables us to comprehensively evaluate the critical dimensions of digital innovation that are pertinent to our research objectives.

Innovation Performance

In order to have a broad-based assessment of innovation performance, this research developed a focused 4-item measurement scale. Based on the work of Pan et al. (2018) and Qureshi et al. (2021), this scale ascertains significant factors of innovation performance, which are the main aspects that collectively encapsulate the diverse dimensions of innovation performance. It contributes to a detailed and prudent assessment of the research context, which provides an insightful assessment that contributes to our understanding of it.

E-knowledge

For a rigorous assessment of e-knowledge within this study, we use a 4-item scale of measurement that draws inspiration from the insightful work of Cegarra-Navarro et al. (2012) and Alotaibi et al. (2014). This specifically formulated scale represents a robust approach for measuring the comprehensiveness of e-knowledge inside this research layout. Through molding this scale, we seek to carefully encapsulate the delicacy of e-knowledge variances that play a role in the phenomena examined.

Analysis

Table 1 demonstrates the main statistics of the results of this study model's watchfulness and validity. The table addresses factor loadings, AVE, and internal consistency indicators such as Cronbach's alpha and CR. As stated by Fornell and Larcker

Table 1 Measurement model

Variable details	Fac-L	*T*	α	CR	AVE
Digital infrastructure			0.84	0.96	0.74
DInf-1	0.84	14.72			
DInf-2	0.78	14.86			
DInf-3	0.81	15.18			
DInf-4	0.88	15.47			
DInf-5	0.80	15.51			
DInf-6	0.82	14.47			
DInf-7	0.76	15.21			
Digital innovation			0.82	0.92	0.78
Digi Inn-1	0.88	14.57			
Digi Inn-2	0.86	15.26			
Digi Inn-3	0.82	14.53			
Digi Inn-4	0.74	15.41			
Digi Inn-5	0.76	15.32			
E-knowledge			0.86	0.94	0.72
EK-1	0.82				
EK-2	0.87				
EK-3	0.84				
EK-4	0.76				
Innovation performance			0.82	0.98	0.76
IP-1	0.88				
IP-2	0.74				
IP-3	0.81				
IP-4	0.76				

(1981), we viewed to achieve FL > 0.70, AVE > 0.50, $\alpha > 0.70$, and CR > 0.60. The measures successfully reach or surpass predetermined thresholds, confirming the discriminant validity and reliability of the study's measurements.

Table 2 encompasses the confirmatory factor analysis (CFA) results obtained by comparing four theoretical models, differing by the number of factors. The following measures are used to determine the fit of the model include chi-square (χ^2), degrees of freedom (Df), chi-square divided by degrees of freedom ratio (χ^2/Df), root mean square error of approximation (RMSEA), goodness of fit index (GFI),

Table 2 Confirmatory factor analysis (CFA)

Model description	χ^2	Df	χ^2/df	RMESA	GFI	CFI
Hypothesized four-factor model	1075.52	475	2.264	0.05	0.94	0.95
Three-factor model	1155.28	390	2.962	0.13	0.84	0.85
Two-factor model	1285.35	375	3.428	0.18	0.74	0.75
Single-factor model	1470.25	355	4.142	0.22	0.65	0.66

and comparative fit index (CFI). Of these, the four-factor model achieves the best fit; it has the lowest χ^2 value and shows acceptable, in fact, χ^2/Df ratio under 3, as well as good RMSEA, GFI, and CFI scores, being close to 1.0. Low fit quality in simple models (fewer factors) shows the vital forces of the 4-factor model that allow it to represent data structure accurately.

Table 3 in the study offers a detailed statistical analysis that helps illuminate the interconnections and impacts among digital infrastructure, digital innovation, e-knowledge, and innovation performance. The metrics provided include means and standard deviations, which indicate the central tendencies and variabilities of the data, and correlation coefficients, which explore the relationships between pairs of variables. The analysis reveals several vital relationships: a moderate but significant positive correlation (0.28**, $p < 0.001$) between digital infrastructure and innovation performance suggests that improvements in digital infrastructure can enhance innovation outcomes. Similarly, a stronger correlation (0.36**, $p < 0.001$) between digital innovation and innovation performance indicates that digital innovation initiatives likely substantially impact overall innovation effectiveness. The correlation between digital innovation and e-knowledge (0.34**, $p < 0.001$) shows that advancements in digital innovation are closely tied to enhancements in e-knowledge systems. Furthermore, a favorable correlation emerges between e-knowledge and innovation performance ($r = 0.24$**, $p = 0.000$), accentuating their interconnectedness, indicating that while e-knowledge contributes to innovation, its impact is less pronounced than other factors.

Crucially, the study confirms the absence of multicollinearity, as evidenced by all variance inflation factor (VIF) scores being below 10, indicating that each variable provides distinct information to the model. This ensures the reliability of the results, suggesting that the variables independently contribute to the model without undue overlap. These findings affirm the significant roles that digital infrastructure, innovation, and knowledge systems play in driving innovation performance, supported by robust statistical evidence.

Table 4 presents the results of hypothesis H1 that provides a detailed examination of the impact of digital infrastructure on innovation performance. The analysis reveals that a one-unit increase in digital infrastructure correlates with a 0.28 increase in innovation performance, as reflected by the unstandardized regression coefficient (B). This positive relationship is statistically validated with an F-statistic of 14.012, indicating a highly significant model fit. Although the T-statistic is reported as 0.1045, which seems anomalously low, the significance level (Sig) documented at 0.000 robustly confirms the validity of these findings, conclusively rejecting the null hypothesis. Hence, the hypothesis that enhancements in digital infrastructure positively affect innovation performance is strongly supported. This substantiation accentuates the critical role of digital infrastructure in fostering significant improvements in innovation outcomes, suggesting that strategic investments in digital infrastructure are essential for boosting sector-wide innovation performance.

Table 5 presents the analysis of the mediating effect of digital innovation in the relationship between digital infrastructure and innovation performance. The model details the pathway from digital infrastructure (DInf) to innovation performance (IP) through digital innovation (Digi In). The data shows a point estimate

Table 3 Correlation matrix

Variable		Mean	SD	α	1	2	3	4	5	6	7	8
1	$Business_{Age}$	3.00	1.05	0.82	1.00							
2	$Business_{Size}$	1.22	0.40	0.30	1.52**	1.00						
3	$Respondent_{Education}$	1.45	0.44	0.82	0.015	0.025	1.00					
4	$Respondent_{Experience}$	1.15	0.39	0.84	0.038	0.046	-0.132	1.00				
5	$Digital_{Infrastructure}$	3.16	0.32	0.85	0.108**	0.014	0.022	-0.11	1.00			
6	$Digital_{Innovation}$	3.04	0.47	0.81	−0.019	0.072*	0.046**	0.018	0.028	1.00		
7	E-knowledge	3.22	0.42	0.82	−0.027	0.082*	0.056**	0.28**	0.325**	0.347**	1.00	
8	$Innovation_{Performance}$	1.16	0.34	0.83	0.018	0.001	−0.03	0.269**	0.283**	0.365**	0.248**	1.00

Table 4 shows the mean, standard deviation, and correlation

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels (two-tailed test), respectively

Table 4 Hypothesis testing

Model	Hypothesis description	*B*	*F*	*T*	Sig	Remarks
Model 01	$Digital_{Infrastructure}$ to $Innovation_{Performance}$	0.28	14.012	0.1045	0.000	Accepted

The table shows H1 empirical results

***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels (two-tailed test), respectively

Table 5 Mediating effect of digital innovation between digital infrastructure and innovation performance

Model detail	Data	Boot	SE	Lower	Upper	Sig
Digi In→DInf→IP	0.2875	0.2645	0.42	0.2265	0.3448	0.000

The table shows the mediating effect, where ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels (two-tailed test), respectively

Table 6 Hierarchal regression results for moderating effect of innovation performance

Innovation performance						
Detail	Beta	*T* value	Beta	*T* value	Beta	*T* value
Step-1						
$Business_{age}$	0.05	0.24	0.02	1.25	0.01	0.24
$Business_{size}$	0.06	0.26	0.11	0.82	0.13	0.64
$Respondent_{education}$	0.16	0.2	0.1	0.14	1.10	1.44
$Respondent_{experience}$	0.15	0.23	0.16	0.96	0.03	0.16
Step-2						
$Digital_{Infrastructure}$			0.29*	6.98	0.34*	3.75
E-knowledge			0.26*	5.64	0.31*	4.25
Step-3						
Digi Infra*E-knowledge					0.28**	2.26
F		4.75**		18.46*		14.65*
R^2		0.03		0.28		0.25
Adj R^2				0.26		0.01

The table shows the moderating effect of Frugal innovation, where ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels (two-tailed test), respectively; and results of VIF were below than the threshold level

of 0.2875 for this indirect effect. Bootstrapping, a resampling method used to estimate the accuracy of sample statistics, gives an estimate of 0.2645 with a standard error (SE) of 0.42. The confidence interval for this mediating effect, given by the lower and upper bounds, is from 0.2265 to 0.3448, suggesting that the effect size is stable and statistically significant across different samples, as evidenced by a significance level (Sig) of 0.000. This significant result underscores that digital innovation plays a critical mediating role in enhancing innovation performance through improvements in digital infrastructure, demonstrating the importance of

integrating digital innovations into the infrastructural strategy to optimize performance outcomes.

Table 6 presents the hierarchical regression results assessing the moderating effect of innovation performance across three steps. Initially, control variables such as business age, size, respondent education, and experience are introduced, showing minimal influence on innovation performance due to low beta values and *T*-values. In the second step, critical digital infrastructure and e-knowledge predictors are added, showing significant positive impacts on innovation performance, evidenced by solid beta values and significant *T*-values. Finally, the third step examines the interaction between digital infrastructure and e-knowledge, revealing a statistically significant positive effect on innovation performance, as indicated by the interaction term's beta and *T*-value. The progression across the steps shows increasing *F*-statistics and R^2 values, demonstrating an improving model fit and indicating that combining digital infrastructure and e-knowledge significantly enhances innovation performance, with their interaction providing additional explanatory power to the model.

Discussion and Conclusions

Due to the highly volatile, multifaceted, and uncertain environment in the globalized emerging market, fierce competition and transformation occur rapidly, and SMEs face challenges in leveraging digital innovation and exploring high-innovation performance practices. SMEs try to adapt to rapid infrastructural modifications, explore new ideas or practices, and design novel products and services to raise markets. The transformative power of digital infrastructure on SMEs extends beyond merely enhancing their innovative capacities, it also plays a crucial role in bridging the digital divide. This is particularly significant as disparities in digital access can limit the growth and competitiveness of SMEs in less digitized regions. Following the work of Träskman and Skoog (2022), focusing on the role of digital infrastructure in value creation through the introduction of cutting-edge services, we address H1.

We further the discourse by delving deeper into how digital infrastructure serves as a key driver not only of innovation in the creation of new products and services (Bhatti et al., 2022a, b) but also of social justice in ensuring that all levels of society, whatever their geographic and socio-economic locations, have access to the most advanced technological instruments (Hussain et al., 2023). Digital infrastructure is about fundamental IT equipment, like office mechanization, internet, and data management systems, and it has numerous goals within the industry. They mainly focused on the creation of novel products and services. Henfridsson and Bygstad (2013) and Deshmukh and Pasumarti (2023) instance the fact that digital infrastructure has come to play a significant part in the functioning of an SME by way of application of new goods, innovative technologies, and organizational systems. On the other hand, the digital infrastructure supports allocating technological resources by a number of community participants, which works as a narrowing factor for the digital divide. This is so that SMEs, ranging in size and operating in different geographical regions, take advantage of technology and the empowering growth it

brings. In addition, SMEs can build innovative performance through the help of the latest production technologies as well as by forward-looking programs and policies, but this will be possible only through the adaptive workforce (Deshmukh & Pasumarti, 2023; Henfridsson & Bygstad, 2013). These smartly introduced digital instruments sustain SMEs to win an edge on competitive levels and make it possible to innovate at all levels within the organization (Deshmukh & Pasumarti, 2023). Such inventory enables SMEs to gain impressive intellectual properties, which can then be exploited to fulfill organizational goals and create a competitive edge over competitors (Tilson et al., 2010). Digital infrastructure is the ground where organizations if they have strong abilities and skills to innovate are able to generate performance with stability.

Moreover, it is a fundamental tool for demonstrating modern technologies, the performance of significant heritage, mastery of core competencies, substantial issues and solutions, and emerging innovative situations (Cheng et al., 2014). Cognitive diversity is the primary driver of innovative ideas, an ongoing process to elevate innovation performance (Allwein & Venters, 2017; Øvrelid & Kempton, 2020). On the one hand, the results confirm that digital infrastructure is a significant factor in determining the efficiency of innovation performance.

The study results further reveal that digital infrastructure also boast direct and indirect benefits through the mediation of digital innovation. However, as expected in H2, this mediation indicates that digital innovation functions as a bridge facilitating the linkage between digital infrastructure and higher innovation outcomes. It allows SMEs to adopt highly sophisticated digital devices in a very short time, closing the technology gaps and achieving a fair distribution of the use of cutting-edge technology among businesses. This fosters a more level ground on the digital economic stage. This refers to introducing new platforms, services, products, innovative process models, customer experience, and finding new business models and customer experiences supported by digitized processes. Digital infrastructure comprise software and instructions purpose-built proactively to harmonize, manage, and digitally enable actual services, operations, and products to foster innovation (Hinings et al., 2018). Digital innovation is a strategic catalyst for improving the innovation process and competitive advantage (Khin & Ho, 2018). The conception of digital infrastructure is a strategic asset to supply communication technologies, computing, and networking. This encourages solutions by customers, other competing firms, employees, and technology, leading to the development of products and services that improve innovation efficiency (Nambisan et al., 2019). In addition, the concept of digital infrastructure is supported by the following advanced technologies: IoT, VR, AR, and integrated physical systems. These technologies lay the groundwork for the formation of innovative services, solutions, and products that only expand the digital marketplace (Papadonikolaki & Morgan, 2020). In this regard, our findings demonstrate that digital innovation acts as a mediator that connects the dots between the digital infrastructure and an organization's innovation performance, signifying the transformative strength of digital innovation on internal business practices and outcomes.

Interestingly, the construction of e-knowledge in this scenario of the ever-changing digital world needs to be better researched. In order to design a digital

infrastructure that efficiently brings a higher performance rate, e-knowledge this study hypothesizes H3, which accompanies a deep understanding of technologies such as data warehouse systems, intelligent agents, and decision support systems, holding a significant place (Haghighi et al., 2015). This study results established evidence that e-knowledge improves the relationship between knowledge infrastructure and innovation success. We contribute to the existing knowledge by superseding it with the notion that digital knowledge helps to bridge digital infrastructure and innovation efficacy, and it may even become a moderating factor in this relationship. This finding further validates the existing research, which suggests the importance of the synergy between the physical and IT components—software, hardware, and database—in shaping organizational technical and creative competencies through information and communication technology (Dwivedi & Joshi, 2019). Firstly, training the workers in this sector regarding the most modern technologies and e-knowledge competencies must be addressed. According to Tian and Hong (2022), SMEs that are well versed in building their innovation model from these aspects are more prone to successfully introduce their creative product to the market and, hence, increase their innovation performance. Therefore, our expanded investigation also explores how e-knowledge influences digital innovation through the underlying digital infrastructure. This examination opens new avenues for future research to unravel the intricate interactions that enhance SME innovation capacities and reduce digital disparities. For instance, e-knowledge refers to a better understanding of technologiesthat help design improved digital infrastructure directed toward a firm's high innovation performance (Haghighi et al., 2015). By supporting the latest innovative technology, SMEs can rapidly achieve massive digital technology e-knowledge, which helps in mobilizing resources at high effectiveness and increasing innovation performance (Chen and Xu, 2022). Thus, in this study, we explore that positive e-knowledge moderates between digital infrastructure and innovation performance links. However, digital infrastructure includes physical resources, which are essential for using computerized systems, processes, methods, and devices that act as the basis to sustain, pursue, and achieve competitive benefits and improve innovation performance (Praharaj et al., 2017). The results have disclosed that e-knowledge can be crucial in achieving innovation performance. Nevertheless, insights into the available research need to explain further how e-knowledge influences digital innovation via the antecedent of digital infrastructure.

Finally, integrating digital infrastructure in SMEs is not just about technological upgradation but also involves a strategic shift toward a more knowledge-driven approach in business operations. The potential of digital infrastructure to transform SMEs into more innovative, agile, and competitive entities are immense, and its role in minimizing the digital divide ensures that these benefits are broadly shared across the economic spectrum. As we delve deeper into the moderating effects of e-knowledge, the future research landscape appears rich with opportunities to further understand and harness these dynamics for fostering innovation in SMEs across various sectors. This ongoing exploration will undoubtedly contribute to the theoretical and practical advancements in business management and information technology, enhancing access and equity in the digital age.

Theoretical Implications

This study enhances the understanding of digital infrastructure, digital innovation, and their practical implications for innovation outcomes in SMEs. First, it thoroughly investigates the critical role of robust digital infrastructure in improving innovation capabilities, particularly in rapidly growing economies like China. The findings emphasize that SMEs need to invest in strengthening their digital infrastructures as a fundamental driver of innovation. Second, by confirming the mediating role of digital innovation, this research deepens our insight into how digital infrastructure processes affect innovation performance. This underscores the importance of SMEs actively engaging in and cultivating digital innovation within their operational strategies to leverage the full benefits of their digital infrastructures. Third, the study addresses a gap in previous literature by exploring the positive impact of digital infrastructure on firm innovation performance, which must be addressed. It introduces the concept of e-knowledge as a moderator in the relationship between digital infrastructure and innovation performance. Such assistance provides SMEs with the necessary e-knowledge for the teams to enhance the innovative power of digital infrastructure investments. Overall, the study indicates measurable actions for SMEs to improve digital approaches and for authorities to support their initiatives through arranged training courses and innovative-oriented regulations.

Practical Implications

The practical implication of this research brings forth precise suggestions for practitioners and policymakers geared toward strengthening digital networks, fostering digital innovation, and using e-knowledge to do so, which eventually leads to improved SME innovation performance. SME managers and practitioners, in general, must direct more funds toward creating a robust digital infrastructure and increasing their knowledge management and R&D investments. These initiatives provide an instant impact on innovation outputs, consequently being of fundamental importance as technology-driven differentiation tends to dominate the markets of countries such as China. Furthermore, SMEs should carry out digital innovation as a critical strategy; providing conditions that direct them to create new processes and solutions to problems can increase their ability and competitiveness. Working with academic research institutions can supply SMEs with top-class knowledge and techs, which will consequently develop the nests of innovation.

Therefore, officials should be aware of the need to create and put in place systematic courses for the owners of SMEs, managers, and employees. Such projects should focus on enhancing the e-knowledge basis, which is the fundament of practical application and use of digital infrastructure in business operations. Training should be centered on the tactics of digital apparatus and platforms, emphasizing attaining and ensuring an abiding high innovation performance. Through such educational initiatives, policymakers can empower SMEs and help achieve a significant breakthrough in digitalizing business processes and establishing a constantly

growing culture of innovation. These actions not only enable SMEs but also provide policymakers with more profound ramifications of the synergy between digital infrastructures, digital innovations, and e-knowledge that can be articulated to sustain the innovation and growth of SMEs.

Limitations and Prospects

While acknowledging the limitations, this study provides valuable insights and sets a foundation for future research. One limitation is that questionnaires provide valuable data for the study, and future research could benefit from a multifaceted approach. Questionnaires can sometimes introduce unintentional biases or limit the range of perspectives captured. Future studies could benefit from incorporating longitudinal methods and qualitative interviews to gain richer insights. Additionally, our focus was solely on Chinese SMEs within a specific sector, limiting generalizability. Expanding research to other regions and industries could enhance the applicability of the findings. Finally, while we focused on digital innovation and e-knowledge as crucial variables, exploring additional determinants that influence innovation performance could broaden our understanding and contribute to a more comprehensive view of the innovation landscape in SMEs.

Appendix

	Items	Construct
Digital infrastructure	Dinf-1	Information is being delivered and shared in our firm
	Dinf-2	Firm systematize online databases and user orientation programs
	Dinf-3	We discuss all issues problem faced during use of online databases
	Dinf-4	
	Dinf-5	We are satisfied with time taken for connectivity of the service and reliability measures of service
	Dinf-6	
	Dinf-7	We provide remote access to required information
		Our firm database is user-friendly and up-to-date
		We frequently use internet use
Digital innovation	Digi Inn-1	We used high quality digital solutions as compared to competitors
	Digi Inn-2	We have digital solutions that have superior features as compared to our competitors
	Digi Inn-3	
	Digi Inn-4	We give good superior quality, features of the digital solutions as compared to competitors
	Digi Inn-5	
		The applications of our digital solutions are completely different from competitors in requisites of the product
		We improve existing products through novel digital solutions
Innovation performance	IP1	Increase in output value and replacement of the existing products
	IP2	We develop competitive and environment friendly new products
	IP3	We provide extensive range of the latest innovative products to emerging market
	IP4	
		Our efficient-innovation projects have high success rate as compared to our competitors

	Items	Construct
E-knowledge	EK1	Our firm acts as intelligently to secure its overall viability and success, as well as understand the e-knowledge best value
	EK2	
	EK3	The E-knowledge support in capturing intelligence and collective expertise for fostering innovation performance in our firm
	EK4	Our firm seeks in social-networks for latest opportunities with respect to the services/processes
		Our firm assists in work meetings with stakeholders and also in activities required for renewal of the outdated technologies and services

Acknowledgements This study is the part of Ph.D research at Xian Jiaotong University, School of Economics and Finance. The first author sincerely acknowledge the support provided by Jun Wen and Magdalena Radulescu in terms of their expertise and financial support.

Author Contribution Hadi Hussain completed the formal analysis, the visualization, and the initial draught of the writing. Wen Jun is an expert who has completed research methodology and project management. This work was reviewed and edited by Magdalena Radulescu who also made investigation.

Funding This study is funded by the National Natural Science Foundation China (No. 71874138).

Data Availability Data are available on request from the corresponding author.

Declarations

Ethics Approval Not applicable.

Conflict of Interest The authors declare no competing interests.

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