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Article

# The impact of digital infrastructure on organizational digital innovation in China

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**Abstract:** With the rapid development of digital technology, the digital infrastructure enables the rapid formation, modification and refactoring of digital products through continuous experimentation and implementation, reduces the cost of innovation, and facilitates the implementation of digital innovation. To solve the problem that the technical scope of digital innovation is relatively concentrated and the knowledge flow between the achievements of digital innovation is insufficient, this study investigates the impact of digital infrastructure on organizational digital innovation in China. The cross-sectional study was conducted from November 2023 to March 2024 among 384 employees and managers in the core industries of the digital economy, as well as enterprises in traditional industries in China. Data were collected using closed-ended questionnaires adapted from previous literature. Structural equation modelling (SEM) was employed to analyze the data using SPSS 28 and AMOS 28. The results reveal that both the information infrastructure and the innovation infrastructure have a positive and direct effect on organizational digital innovation in China, as well as an indirect effect through data flows. Converged infrastructure has only an indirect impact on organizational digital innovation through the flow of data.

**Keywords:** digital innovation; data flows; digital infrastructure; information infrastructure; converged infrastructure; innovation infrastructure

## 1. Introduction

As digital technologies such as big data, cloud computing, and artificial intelligence have gradually changed the fundamentals of the industrial economy, modern society has entered the era of digital economy (Yoo et al., 2010). Digital technologies have changed the basic form of the original product, the way the production process of the new product, the business model (Nambisan et al., 2017), and the way firms innovate (Lee and Berente, 2012). Based on this, digital innovation that uses digital technology as an integral part or supporting part to change the original product, process or business model has gradually attracted attention. In recent years, China has made remarkable achievements in digital innovation, and a number of excellent digital innovation platform companies such as Alibaba, JD.com, Tencent, and Haier have emerged (Li et al., 2023). In terms of volume, China's digital innovation has grown significantly in recent years, with the total amount in 2020 being about 32 times that of 2000 (Zhang and Ma, 2023). From the perspective of innovation participants, enterprises are the main body of China's digital innovation (Zhang and Liu, 2023). According to the data from China's Ministry of Science and Technology, among the more than 860 projects approved under the National Key R&D Program in

2021, more than 680 projects were led or participated in by enterprises, accounting for 79% (Zhang and Liu, 2023). From the perspective of the technical characteristics of digital innovation, edge computing, 5GTSN, 5GLAN, and 5GNPN have become hot spots in the patent layout, and the number of major patents of "5G + Industrial Internet" accounts for 40% of the world, maintaining a leading position in the world (CAICT, 2023). From the perspective of the industrial distribution, China's digital innovation patents are mainly concentrated in the fields of communication technology, computer technology and electronic engineering (CAICT, 2023).

However, there are still challenges. Specifically, the technical scope of digital innovation is relatively concentrated, and the knowledge flow between the digital innovation achievements is insufficient. According to the World Intellectual Property Indicators 2022 (WIPO, 2022), China's patents in the field of digital innovation are mainly concentrated in areas such as communication technology, computer technology, and electronic engineering. The knowledge flow between digital innovation achievements in China is mainly generated within the same technical field, and the knowledge flow between innovation achievements is insufficient (Cao, 2023). Taking the patent application for the invention of digital innovation in the new generation of the information technology industry as an example, nearly 70% of the patent citations come from the industry (Zhang and Ma, 2023). This may lead to the unbalanced development of industrial digitalization, which is not conducive to the improvement of the knowledge spillover effect of digital technology, and reduces the efficiency of the deep integration of digital technology with the real economy (Zhang and Ma, 2023). The existing literature found that digital infrastructure can significantly reduce the cost of information transmission and knowledge dissemination, accelerate technology diffusion and knowledge spillover (Xue et al., 2020), enhance the ability of enterprise information acquisition and expand the boundaries of enterprise innovation (Goldfarb and Tucker, 2019; Shen et al., 2023), motivate enterprises to increase R&D investment, and promote enterprise independent innovation and industrial collaborative innovation (Zhang and Fu, 2021; Zhang et al., 2022; Zheng, 2023). To solve the problem that the technical scope of digital innovation is relatively concentrated and the knowledge flow between the achievements of digital innovation is insufficient, this study investigates the impact of digital infrastructure on organizational digital innovation in China.

Theoretically, this study advances digital innovation research by offering a fresh perspective: a digital infrastructure-driven organizational digital innovation. Practically, this study investigates the combined impact of digital infrastructure, that is, information infrastructure, converged infrastructure and innovation infrastructure, on organizational digital innovation in enterprises in the core industries of the digital economy, as well as enterprises in traditional industries in China. This study aims to fill the research gap by examining what and how digital infrastructure in the external business environment can foster organizational digital innovation in China. Previous studies have defined digital innovation as both a process and a result (Zhang et al., 2023). Digital innovation as a process includes initiating, developing, and implementing digital innovation (Kohli and Melville, 2019; Liu et al., 2020a). The digital innovation process is influenced by digital technologies such as the Internet of Things, big data, cloud computing, and more (Nambisan, 2017). Digital innovation as outcomes is also influenced by multiple factors, such as the industrial Internet (Wang et al., 2022), employees (Opland et al., 2022), data-rich environment (Troilo et al., 2017), and government innovation policies (Liang and Li, 2023). However, existing research on digital innovation mainly focuses on the elaboration of the conceptual connotation, basic characteristics, theoretical framework, governance mechanism, etc., and needs to be further studied on what and how digital infrastructure in the external business environment influences organizational digital innovation. By filling this gap, this study seeks to shed light on the complex dynamics between the three types of digital innovation, providing valuable insight into their joint impact on organizational digital innovation. Furthermore, this study explores the impact of the external data environment on enterprise digital innovation, which is helpful in deepening the understanding of the core elements of the digital economy, giving full participation to the multiplier effect of data elements, and empowering economic and social development. This study can also provide a reference for the decision making for innovation activities of digital enterprises, digital transformation of traditional enterprises, and the development of emerging and future industries.

## 2. Literature review

### 2.1. Organizational digital innovation

Currently, scholars define digital innovation from the perspective of innovation outcome (Yoo et al., 2012), innovation process (Nambisan, 2017), and holistic perspective (Liu et al., 2020a). According to Yoo et al. (2012), digital innovation refers to the creation of new products, business processes, and business models through the use of digital technologies. Nambisan (2017) argued that digital innovation refers to the use of digital technologies in the process of innovation. Because it is difficult to separate the process and outcome of digital innovation, this study agrees with the holistic perspective in defining digital innovation. In the current study, digital innovation refers to the adoption of digital technologies in the innovation process to bring about new products, production process improvements, organizational model changes, and the creation and change of business models (Liu et al., 2020a; Nambisan, 2017; Yoo et al., 2010). Digital innovation is characterized by convergence (Nambisan, 2017), self-growth, multi-agent interaction, dependence on the flow of data elements, and digital technology empowerment (Yan et al., 2021). Digital technology factors such as digital infrastructure (Zhang et al., 2023), internal factors such as educational background, ICT skills and related training of enterprise employees, internal factors such as the employment structure of enterprise employees (Opland et al., 2022), digital talent environment factors such as the number of scientific research institutions in the location of enterprises, the number of universities offering ICT-related majors, and the number of digital human resource market service institutions (Pan et al., 2023), and institutional factors such as the promulgation and implementation of policies related to the digital economy and government supervision (Shao et al., 2023) and environmental factors such as data flow and security (Buhe and Chen, 2022) will affect the digital innovation of enterprises.

In recent years, some scholars have studied the digital innovation of enterprises from the perspective of the digital innovation ecosystem. The digital innovation ecosystem emphasizes the synergistic symbiosis between digital innovation subjects due to the introduction of digital elements, which leads to the reorganization of factors and the logical change of system behaviour (Beltagui et al., 2020). Producers, consumers, enablers, operators, and researchers in the digital innovation ecosystem have established a close cooperative game relationship of risk sharing and benefit sharing and realized the continuous exchange of materials, energy, information, and data with the ecological environment (Liu et al., 2023). Through the interaction between digital subjects, system efficiency can be improved, information sharing can be facilitated, and intra- and inter-agent collaboration can be enhanced (Teece, 2018). Existing studies have carried out a series of discussions on the influencing factors of organizational digital innovation, and some scholars have studied digital innovation ecosystem. However, these studies have not yet explored the influencing factors and their mechanisms of organizational digital innovation from the perspective of the digital innovation ecosystem.

## 2.2. Digital infrastructure

Digital infrastructure refers to unbounded, heterogeneous, shared, and evolving socio-technical systems that include a wide variety of digital technology capabilities, user bases, operations, and design communities (Tilson et al., 2010). Digital infrastructure includes not only hardware devices such as computers, mobile devices, and application platforms, but also a wide range of software, such as digital technologies such as cloud computing, Internet of Things, and 3D printing, as well as digital community-related organizations and governance such as open standards (Liu et al., 2020a). Digital infrastructure can be enterprise-level, industry-level, national-level, or even global-level (Constantinides et al., 2018). According to the definition, digital innovation is based on digital technology, so the process of digital innovation is inseparable from the digital infrastructure of the organization itself and the ecosystem in which it is located (Liu et al., 2020a). Exisiting research have found that digital infrastructure enables rapid iteration of digital products (Tee and Gawer, 2009) and greatly increases the speed of innovation. Further, the support of digital infrastructure makes all aspects of the production process of enterprises very transparent, and suppliers and customers can be more deeply involved in value creation activities including product development, testing, marketing, etc., which is conducive to more efficient production and manufacturing (Li et al., 2024). In addition, digital infrastructure can build a bridge for the flow of innovation information, reduce the cost of innovation information transfer, and create an environment where technical knowledge can fully spill over, which in turn positively affects enterprise innovation. First, digital infrastructure can break the spatial barrier of information transmission (Wang et al., 2023), facilitate cross-regional collaboration in the innovation processes of enterprises (Tian and Lu, 2023), and can help companies identify innovation opportunities with higher R&D value (Thanasopon et al., 2016). Second, a sound digital infrastructure can reduce the cost of information search and transmission (Xu et al., 2019), accelerate the dissemination and exchange of knowledge and information, and provide rich innovation resources for enterprises' digital innovation (Huang et al., 2019). Finally, digital infrastructure can facilitate the spillover, dissemination, and transfer of knowledge, becoming an important spillover channel for enterprise innovation (Wang et al., 2023), which is conducive to the generation of high-quality "breakthrough" innovations (Liu et al., 2020c).

Although some studies focus on the enabling effect of digital infrastructure on organizational digital innovation, they ignore the heterogeneous impact of different type of digital infrastructure construction. According to the interpretation of China's National Development and Reform Commission for new infrastructure, digital infrastructure or so-called "new infrastructure" in China, including information infrastructure, converged infrastructure, and innovative infrastructure (Liu et al., 2020b). Information infrastructure is an infrastructure system formed by the evolution, integration and overlay iteration of a new generation of information technologies such as 5G network, Internet of Things, industrial Internet, artificial intelligence, cloud computing, and data center (Zhang, 2019). The existing research mainly analyzes the impact of information infrastructure from the perspectives of economic development, industrial structure, and production mode. For example, "Internet+" can promote economic development by optimizing labor allocation, expanding market capacity and economic surplus, and increasing per capita income (Huang et al., 2019). It is found that AI will promote the transformation of industrial structure and have an impact on distribution efficiency and exchange patterns while improving workers' skills and stimulating technological innovation (Acemoglu and Restrepo, 2018). However, current research mainly focuses on the impact of information infrastructure at the macro level, and at the micro level, there are few studies on the role and mechanism of information infrastructure on enterprise digital innovation. According to Wang et al. (2023), information infrastructure has become an important spillover channel for enterprise innovation. Mechanism test shows that information infrastructure can magnify technology spillover effect of cooperate innovation (Wang et al., 2023).

According to the interpretation of China's National Development and Reform Commission, converged infrastructure mainly refers to the in-depth application of technologies such as the Internet, big data, and artificial intelligence to support the transformation and upgrading of traditional infrastructure, and then form converged infrastructure. For example, industrial Internet of Things (IIoT), intelligent transportation infrastructure, smart energy infrastructure, smart cities, etc. Open innovation theory believes that firms can promote innovation through effective selection and access to external information, technology, and knowledge (Laursen and Salter, 2006). From the perspective of enterprise innovation model, with the rise of the mobile communication industry, vertical and horizontal integration has emerged in the industry, which can provide more complex forms of services (Ballon, 2007). For example, the application of the industrial Internet enables real-time interaction between various systems such as operation management, product production, quality assurance and user feedback, realizes digital, controllable and flexible production of production processes, and transforms the enterprise value creation model from a simple product supply model to a digital service manufacturing model of "product + service" (Iivari, et al., 2016), thereby promoting value creation. In addition, enterprises can leverage the wealth of information and resources obtained by converged infrastructure to achieve business goals (Zhuang et al., 2020), thereby promoting enterprise digital innovation.

Innovation infrastructure mainly refers to the infrastructure with public welfare attributes that supports scientific research, technology development, and product development, such as major scientific and technological infrastructure, science and education infrastructure, and industrial technology innovation infrastructure. Justman and Teubal (1986) pointed that regional innovation needs to be supported by government innovation infrastructure, and that a good infrastructure environment is an important driving force for regional innovation. Fuman et al. (2002) believed that a country's innovation capacity depends on the level of the country's innovation infrastructure, the innovation environment of major industrial clusters, and the strength of the linkages between the two. Scholars have conducted extensive research on the relationship between innovation infrastructure and regional innovation, and generally agree that innovation infrastructure can affect regional innovation (Fuman et al., 2002; Keeley, 2013). However, there is still a lack of research on the impact of innovation infrastructure on firms' innovation behavior. Innovation infrastructure can gather innovation resources and create an innovation environment (Zhang et al., 2023), thereby nurturing future industries (Huang et al., 2024). From the perspective of different types of innovation infrastructure, major scientific and technological innovation platforms such as high-level laboratories and innovation centers can provide necessary technical reserves for future industrial development in a forward-looking manner, thereby giving birth to disruptive innovation; Proof-of-concept centers, industrial parks and other infrastructure for the transformation of achievements can help the transformation of preface technology achievements; Supporting infrastructure, such as major scientific and technological infrastructure and public technical service platforms, can support the development of applied technologies, realize the transformation of cutting-edge scientific and technological achievements, and realize the iteration of industrial technologies (Huang et al., 2024).In line with these findings, Hypothesis 1 ($H_1$), Hypothesis 2 ($H_2$) and Hypothesis 3 ($H_3$) was established.

$H_1$: There is a direct relationship between information infrastructure and digital innovation.

$H_2$: There is a direct relationship between converged infrastructure and digital innovation.

$H_3$: There is a direct relationship between innovation infrastructure and digital innovation.

## 2.3. Data flows

According to the theory of digital innovation ecosystem constructed by Buhe and Chen (2022), data flows within the ecosystem in the form of innovation elements, thus activating, connecting, and aggregating the innovation activities of multiple subjects. Data flows are the flow of data-based knowledge and value in the digital space among multiple subjects participating in the whole life cycle of data (Liu and Xie, 2022). The flow of data drives the flow of information and promotes the accumulation and creation of knowledge (Liu and Xie, 2022). By providing the sharing of information, data flows help match supply and demand, address problems caused by information asymmetry, reduce market failures, and reduce detention in trade transactions

(González and Jouanjean, 2017). The agglomeration of data elements can promote the digital transformation of enterprises, accelerate the flow of labor factors, improve the level of regional human capital and the activity of innovation and entrepreneurship, and ultimately affect the employment scale and employment structure of enterprises (Liu et al., 2024). However, only when data flows reasonably and adequately can the innovative behaviour of innovation subjects be activated and the purpose of value spillover can be achieved (Teece, 2018). Thus, the flow and circulation of data is not completely accompanied by application demand or flows freely, but is affected by many aspects such as data production, flow and national security corresponding laws, regulations, and systems. By referring to the existing literatures, we propose Hypothesis 4 ($H_4$).

$H_4$: Data flows significantly affect organizational digital innovation.

The continuous deepening construction of digital infrastructure provides a good hardware foundation for data flow (Liu and Xie, 2022), which profoundly affects the flow rate and flow direction of production and innovation factors, especially will promote the flow and agglomeration of digital innovation resources to the region, which is conducive to the improvement of innovation level (Zhang et al., 2023). The interconnection and sharing of digital infrastructure accelerate the coding of knowledge information, real-time exchange at almost zero marginal cost, breaks down the temporal and spatial barriers of information exchange, improves the efficiency of knowledge flow, and promotes the spread of innovative elements between cities and industries (Yu and He, 2023). Information infrastructure is the physical foundation of the existence of digital space and the hardware support for data flow. Information infrastructure can help to build a bridge for data circulation and reduce the cost of data transmission (Zheng, 2023). Converged infrastructure can help enterprises dig deeper into the value of data resources, build a production system with data resources as the core, and give full play to the value of data resources (Li et al., 2017). Innovation infrastructure can help promote the sharing and opening of various data-based achievements to enterprises, and promote the efficient transformation of future technologies (Huang et al., 2024). These studies provide a platform to develop Hypothesis 5 ($H_5$), Hypothesis 6 ($H_6$) and Hypothesis 7 ($H_7$).

$H_5$: Information infrastructure significantly affects data flows.

$H_6$: Converged infrastructure significantly affects data flows.

$H_7$: Innovation infrastructure significantly affects data flows.

In the process of mutual reinforcement of digital technologies and innovation networks, digital infrastructure provides an "information superhighway" for data flows (Guo and Zhu, 2023). The interconnection and sharing of digital infrastructure accelerate the coding of knowledge information, real-time exchange at almost zero marginal cost, breaks down the temporal and spatial barriers of information exchange, improves the efficiency of knowledge flow, and promotes the spread of innovative elements between cities and industries (Yu and He, 2023). In this process, the flow of data becomes a link between the external environment and the subject of digital innovation, facilitating the sharing and flow of knowledge, technology and information, and stimulating new cooperation models and business opportunities. More specifically, the following hypotheses, hypothesis 8 ($H_8$), hypothesis 9 ($H_9$), and hypothesis 10 ($H_{10}$) are expressed.

$H_8$: Data flows mediate the relationship between information infrastructure and digital innovation.

$H_9$: Data flows mediate the relationship between converged infrastructure and digital innovation.

$H_{10}$: Data flows mediate the relationship between innovation infrastructure and digital innovation.

# 3. Methodology

## 3.1. Conceptual framework

This study focuses on the impact of digital infrastructure on organizational digital innovation in China. Based on the literature review mentioned above, the conceptual framework is shown in **Figure 1**.

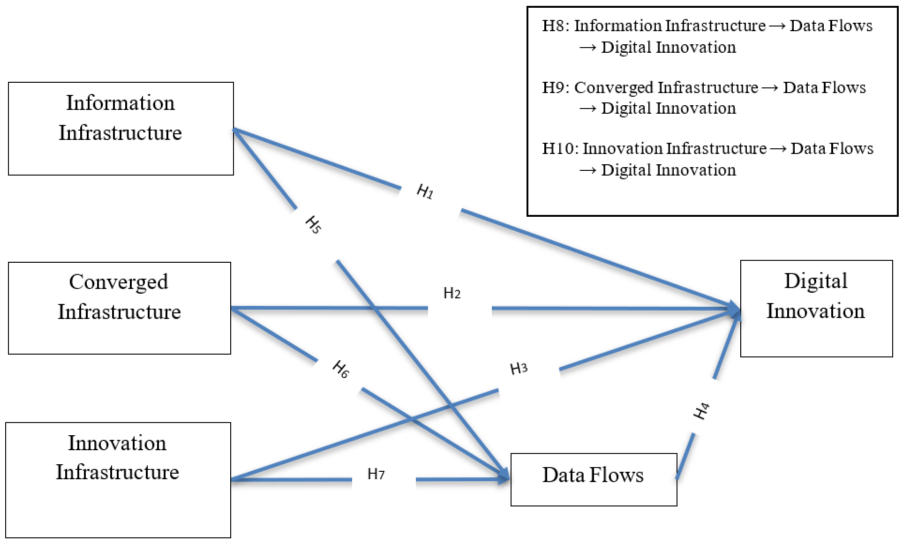


**Figure 1.** Conceptual framework.

## 3.2. Sample and data collection

Digital technology has rapidly penetrated into all aspects of society and economy, and has given rise to new economic formats and comprehensive industrial and consumption transformations. In this transformation, not only Internet companies, but also traditional industries, such as biological, chemical, pharmaceutical and textile manufacturing enterprises, are also experiencing the baptism of new business models and new formats triggered by the Internet economy. Therefore, the study population is made up of enterprises in the core industries of the digital economy, such as Internet platforms, Internet wholesale and retail and Internet finance, as well as traditional industries in China that already carried out or intend to carry out digital innovation. From this, the specific size of the target population is not available at present. Considering the availability of data, we chose convenience sampling to collect data. This study selected top managers and ordinary employees as the survey objects. The sample of both top managers and employees was appropriate as study objects, as top managers know how new technological breakthroughs can be adopted to address organizational problems and needs, while 'ordinary employees', ranging from the

R&D or ICT professionals to middle managers within the enterprise, as well as employees in other positions, such as employees in the departments of human resources, finance and accounting, are recognized as key contributors to the innovation process.

Data collection started from November 2023 to March 2024 consisting of two stages. In the first stage, data was collected face to face on the second Global Digital Trade Expo held in Hangzhou, China from 23 to 27 November 2023. Seven people, including members of the research group, participated in the distribution of the questionnaire. A total of 300 questionnaires were distributed and 183 were responded, with a 61% response rate. As the face-to-face questionnaires were delivered in print-out surveys, some respondents had not answered all the items in the questionnaire. To transfer the data from the collected questionnaires to the computer, templates for all constructs were prepared in the SPSS 28, which can enter, edit, and view the contents of the data file so that analysis can be performed to extract information. Each row of the data editor represents a respondent, and each column represents a construct. While entering data non-responded items were kept blank. According to Sekaran and Bougie (2016), if the number of submitted questionnaires was high and a few items out of over 30 items in the questionnaire were left blank, referring to the maximum and minimum values, frequency tables and outliers can overcome omissions. As the number of responses with missing items were only seven, and the missing items were only two or three while the number of submitted questionnaires was high, we use the mean value of a single construct to fill the blank to overcome the missing data. After removing invalid questionnaires, 166 were valid and used for further data analysis. The second stage started from 18 January to 3 March 2024 with data collected online through social platforms such as WeChat, Ding talk, etc. Online questionnaires were designed via the platform named Questionnaire Star, and delivered personally to 443 potential respondents, including managers and employees of enterprises that the research group has ever worked with, and friends or relatives and who are working in China's core industries of the digital economy or enterprises in traditional industries carrying out digital innovation. As questionnaires were distributed through Questionnaire Star and if there were any unfinished options, the system would automatically remind respondents to ensure that respondents completed all the questionnaire items. So, there is no missing data in this stage. After removing the questionnaires that responded too quickly or repeated too many answers, 218 of the 345 questionnaires recovered were valid for further data analysis. Therefore, this two-stage survey collected 384 valid sample and then the distribution of questionnaires was discontinued. The total response rate is 71%, and the total valid sample recovery rate is 52%. Respondents were anonymized in the survey for this study. All respondents were accompanied by a letter stating the anonymity and data were collected for study use only. Details of demographics are shown in **Table 1**.

**Table 1.** Demographic information.

| **Respondent Profile (*n* = 384)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Attributes** | **Distribution** | **Frequency** | **(%)** | **Attributes** | **Distribution** | **Frequency** | **(%)** |
| Position | Senior manager | 61 | 15.9 | Education level | Vocational or Basic | 11 | 2.9 |
| | Middle manager | 118 | 30.7 | | Undergraduate | 220 | 57.3 |
| | R&D personnel | 31 | 8.1 | | Masters' | 110 | 28.6 |
| | ICT staff | 50 | 13.0 | | PhD | 7 | 1.8 |
| | Other | 124 | 32.3 | | Other | 36 | 9.4 |
| Firm Age (Year) | Less than 5 years | 58 | 15.1 | Annual turnover (CNY) | Less than 2 million | 39 | 10.2 |
| | 5–10 years | 108 | 28.1 | | 2–5 million | 30 | 7.8 |
| | 11–20 years | 101 | 26.3 | | 6–10 million | 38 | 9.9 |
| | More than 20 years | 117 | 30.5 | | More than 10 million | 277 | 72.1 |
| Number of employees | Below 100 | 130 | 33.9 | Industry | Digital efficiency improvement | 126 | 32.8 |
| | 101–200 | 46 | 12.0 | | Digital products manufacturing | 58 | 15.1 |
| | 201–500 | 41 | 10.7 | | Digital technology application | 46 | 12.0 |
| | 501–1000 | 41 | 10.7 | | Digital factors driving | 78 | 20.3 |
| | More than 1000 | 126 | 32.8 | | Digital products service | 76 | 19.8 |

### 3.3. Constructs measurement

Information Infrastructure (INFO), Converged Infrastructure (CONV), Innovation Infrastructure (INNO), Data Flows (DTFL), and Digital Innovation (DIIN) are the five latent constructs in this study. INFO, CONV and INNO are three first-order constructs with three items measuring the scale, cost, equality, and government incentives of accessing to information infrastructure, converged infrastructure and innovation infrastructure, respectively. DTFL is a first-order construct and refers to the flow of data-based knowledge and value in the digital space among multiple subjects participating in the entire life cycle of data elements (Liu and Xie, 2022). DTFL measures the mobility and security of data elements within the digital innovation ecosystem. Five items were used to access the responses on DTFL. DIIN is another first-order construct and refers to both the process and outcomes of digital innovation in companies. DIIN measures the process and achievement of organizational digital innovation by five items (as shown in Appendix). All items of the questionnaire were adapted from past research and measured using the 5-point Likert Scale with "1" represents strongly "disagree" and "5" represents "strongly agree".

## 4. Results

### 4.1. Common method variance

To test the Common Method Variance (CMV), we employed Harman's Single-Factor Test. Results show that the unrotated first factor explained only 39.495% of the total variation (given in **Table 2**), which is less than the 50% threshold, which indicated that there were no significant Common Method Bias (CMB) in the study data (Podsakoff et al., 2003).

**Table 2.** Total variance explained (*N* = 384).

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative% | Total | % of Variance | Cumulative% |
| 1 | 7.504 | 39.495 | 39.495 | 7.504 | 39.495 | 39.495 |
| 2 | 2.256 | 11.871 | 51.366 | 2.256 | 11.871 | 51.366 |
| 3 | 1.856 | 9.769 | 61.135 | 1.856 | 9.769 | 61.135 |

## 4.2. Measurement model

SPSS 28 and Amos 28 were employed to access and analyze the measurement model. Three types of validity were measured in the measurement model: the convergent validity, the construct validity, and the discriminant validity. The Average Variance Extracted (AVE) and factor loadings (as shown in **Table 3**) were employed to access the convergent validity. The AVE values for every construct are more than 0.5, while the factor loadings are more than 0.6, indicating that convergent validity is achieved (Hair et al., 2016). By running the Confirmatory Factor Analysis (CFA) using AMOS 28, the fitness indexes for each construct and the pooled-CFA achieved the required level (ChiSq/df = 2.315 < 3, CFI = 0.951 > 0.9, and RMSEA = 0.059 < 0.08), indicating the validity of the construct achieved. The heterotrait-monotrait test was used to access the discriminant validity. The values for all components were significantly below 1 (as shown in **Table 4**), indicating the discriminant validity is achieved (Dijkstra and Henseler, 2015).

The reliability of the measurement model in this study was evaluated using Cronbach's alpha and Composite reliability (CR). Cronbach's alpha was performed using SPSS 28. The CR values of all the constructs in this study are more than 0.7 (given in **Table 2**), indicating that the reliability and internal consistency of each latent construct are achieved (Gefen et al., 2000).

**Table 3.** Reliability and validity.

| Constructs | Items | Loading > 0.6 | Alpha > 0.7 | CR > 0.7 | AVE > 0.5 |
|---|---|---|---|---|---|
| INFO | INFO1 | 0.74 | | | |
| | INFO2 | 0.77 | 0.792 | 0.788 | 0.553 |
| | INFO3 | 0.75 | | | |
| CONV | CONV1 | 0.77 | | | |
| | CONV2 | 0.79 | 0.824 | 0.814 | 0.593 |
| | CONV3 | 0.78 | | | |
| INNO | INNO1 | 0.76 | | | |
| | INNO2 | 0.78 | 0.826 | 0.765 | 0.523 |
| | INNO3 | 0.62 | | | |

**Table 3.** (*Continued*).

| Constructs | Items | Loading > 0.6 | Alpha > 0.7 | CR > 0.7 | AVE > 0.5 |
|---|---|---|---|---|---|
| DTFL | DTFL1 | 0.74 | | | |
| | DTFL2 | 0.82 | | | |
| | DTFL3 | 0.78 | 0.878 | 0.870 | 0.573 |
| | DTFL4 | 0.74 | | | |
| | DTFL5 | 0.70 | | | |
| DIIN | DIIN1 | 0.84 | | | |
| | DIIN2 | 0.78 | | | |
| | DIIN3 | 0.75 | 0.874 | 0.876 | 0.588 |
| | DIIN4 | 0.80 | | | |
| | DIIN5 | 0.65 | | | |

**Table 4.** Discriminant validity (HTMT).

| | INFO | CONV | INNO | DTFL | DIIN |
|---|---|---|---|---|---|
| INFO | | | | | |
| CONV | 0.750 | | | | |
| INNO | 0.774 | 0.820 | | | |
| DTFL | 0.536 | 0.466 | 0.395 | | |
| DIIN | 0.600 | 0.500 | 0.590 | 0.441 | |

## 4.3. Structural equation modelling (SEM)

The structural equation model in this study explains the hypothesized relationships between constructs. **Table 5** shows the results of the hypotheses testing for $H_1$ to $H_7$, which represent the direct relationships. As shown in **Table 4**, INFO and INNO are positively, directly and significantly related to Digital Innovation, since the standardized beta estimate for direct effects of these two exogenous variables on DIIN is 0.325 and 0.292 respectively. The critical ratio (C.R.) value is 2.751 and 2.069 (> 1.96) respectively while the $p$ values are 0.006 and 0.039, both less than 0.05, which is significant at the 95% confidence interval, confirming the significance of the relationship and supporting Hypothesis 1 ($H_1$) and Hypothesis 3 ($H_3$). The result from Hypothesis 2 ($H_2$) indicated that the value of S.T.D. (β) is −0.059, the C.R. value is −0.467 and the $P$ value is 0.641 > 0.05, which is not significant and has no practical implications. Therefore, $H_2$ is not supported. The findings from the path analysis for Hypothesis 4 ($H_4$) show that the value of S.T.D. (β) is 0.179, the C.R. value is 2.744 > 2.58 and the $P$ value is 0.006, less than 0.05, which is significant at the 95% confidence interval, indicating that $H_4$ is supported. The results of Hypothesis 5 ($H_5$) show that S.T.D. (β) is 0.473, the C.R. value is 3.858 > 2.58 and the $P$ value is less than 0.001, which is significant at the 99% confidence interval, indicating that $H_5$ is supported. The results for Hypothesis 6 ($H_6$) show that S.T.D. (β) is 0.326, the C.R. value is 2.428 > 1.96 and the $P$ value is 0.015 < 0.05, which is significant at 95% confidence interval, indicating that $H_6$ is supported. The result of Hypothesis 7 ($H_7$) indicated that the value of S.T.D. (β) is −0.243, the C.R. value is −1.608 and the $P$ value is 0.108 > 0.05, which is not significant and has no practical implications. Therefore, $H_7$ is not supported.

**Table 5.** Results of the hypothesis testing ($H_1$ to $H_7$).

| Hypothesis | Path | S.T.D. (β) | C.R. | *p*-Value | Results |
|---|---|---|---|---|---|
| $H_1$ | Information Infrastructure → Digital Innovation | 0.325** | 2.751 | 0.006 | Supported |
| $H_2$ | Converged Infrastructure → Digital Innovation | −0.059 (NS) | −0.467 | 0.641 | Not Supported |
| $H_3$ | Innovation Infrastructure → Digital Innovation | 0.292* | 2.069 | 0.039 | Supported |
| $H_4$ | Data Flows → Digital Innovation | 0.179** | 2.744 | 0.006 | Supported |
| $H_5$ | Information Infrastructure → Data Flows | 0.473*** | 3.858 | *** | Supported |
| $H_6$ | Converged Infrastructure → Data Flows | 0.326* | 2.428 | 0.015 | Supported |
| $H_7$ | Innovation Infrastructure → Data Flows | −0.243 (NS) | −1.608 | 0.108 | Not Supported |

Note: ***$P < 0.001$ **$p < 0.01$ *$p < 0.05$.

As to the mediating effect, bootstrapping procedure was performed to verify the mediation of DTFL on the relationship between INFO, CONV, INNO, and DIIN. By using AMOS 28, the researcher chose to obtain a 2000 bootstrap sample, resulting in the Bias-corrected percentile method at the 95% confidence interval. As shown in **Table 6**, the results from the Bootstrap method for Hypothesis 8 ($H_8$) show that the Bootstrap estimate of indirect effect is 0.082, S.T.D. (β) is 0.085, and the *P*-value (two-tailed significance of bootstrap confidence) is 0.021, which is less than 0.05, indicating that the mediating effect of DTFL on the relationship between INFO and DIIN exists at 95% confidence interval, thus, $H_8$ is supported. Similarly, the results from the Bootstrap method for Hypothesis 9 ($H_9$) show that the Bootstrap estimate of indirect effect is 0.053, S.T.D. (β) is 0.058, and the *P*-value (two-tailed significance of bootstrap confidence) is 0.049, which is less than 0.05, indicating that the mediating effect of DTFL on the relationship between CONV and DIIN exists at the 95% confidence interval, thus, $H_8$ is supported. However, the results of the Bootstrap method for Hypothesis 10 ($H_{10}$) show that the bootstrap estimate of indirect effect is −0.52, S.T.D. (β) is −0.043, and the *P*-value (two-tailed significance of bootstrap confidence) is 0.105, which is not significant and has no practical implications, indicating that the mediating effect of DTFL on the relationship between INNO and DIIN does not exist, thus, $H_{10}$ is not supported. The results of SEM are given in **Figures 2** and **3**.

**Table 6.** Results of hypothesis testing ($H_8$ to $H_{10}$).

| Hypothesis | Path | S.T.D. (β) | *p*-Value | Results |
|---|---|---|---|---|
| $H_8$ | Information Infrastructure → Data Flows → Digital Innovation | 0.085* | 0.021 | Supported |
| $H_9$ | Converged Infrastructure → Data Flows → Digital Innovation | 0.058* | 0.049 | Supported |
| $H_{10}$ | Innovation Infrastructure → Data Flows → Digital Innovation | −0.043 (NS) | 0.105 | Not Supported |

Note: ***$P < 0.001$ **$p < 0.01$ *$p < 0.05$ NS = Not significant.

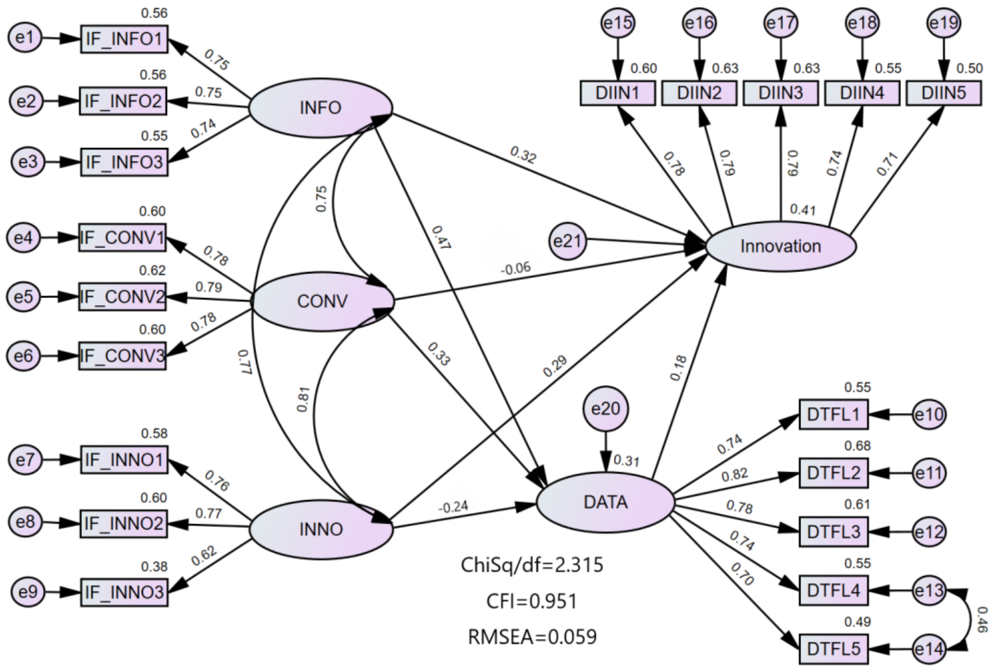


**Figure 2.** Structural equation model results.

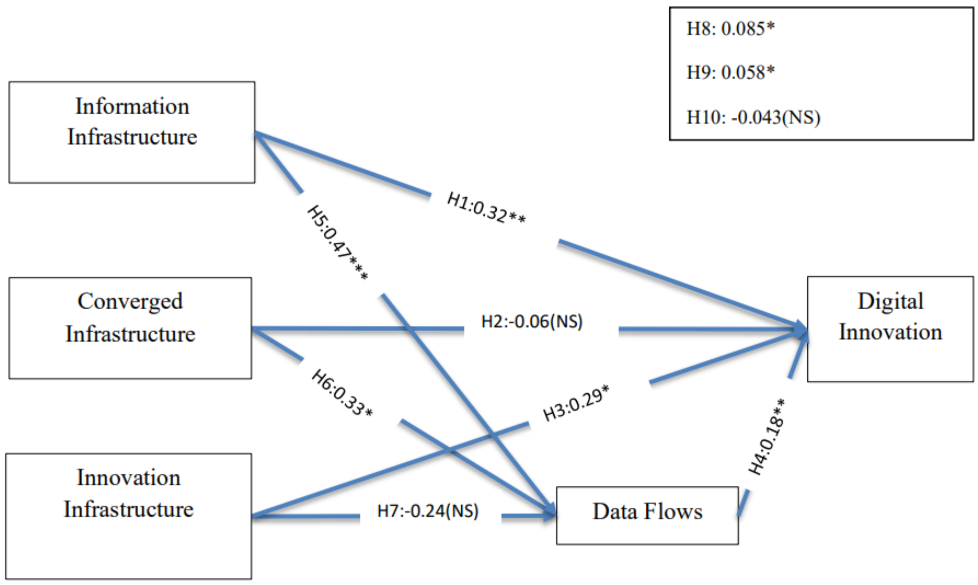


**Figure 3.** Structural equation model results with beta measure and significance.

Note: ****P* < 0.001 ***p* < 0.01 **p* < 0.05 NS = Not significant.

## 5. Discussion

### 5.1. Findings

This study constructs a research framework on the relationship between digital infrastructure and organizational digital innovation. The findings show that both the information infrastructure and the innovation infrastructure are positively, significantly, and directly related to the organizational digital innovation in China, thus supporting $H_1$ and $H_3$ in the conceptual framework of this study. Information infrastructure is an infrastructure system formed by the evolution, integration and overlay iteration of a new generation of information technologies such as 5G networks, IoTs, artificial intelligence, and data centers. Innovation infrastructure refers to major scientific and technological infrastructure, scientific and educational infrastructure, etc. The essence of organizational digital innovation is the innovation of technological capabilities. Information infrastructure and innovation infrastructure, as a vehicle for creative destruction of technology, is triggering a major change in the "techno-economic" paradigm. The construction and application of information infrastructure and innovation infrastructure will increase the demand for technical resources of enterprises, and the more R&D resources, the greater the development space for R&D and technological innovation. This will lead to the improvement of innovation capabilities, so there are more opportunities to create more competitive advantages for companies and promote upgrading of companies. However, the result of Hypothesis 2 ($H_2$) is not significant and has no practical implications, indicating that $H_2$ is not supported. Converged infrastructure includes intelligent transportation infrastructure, smart energy infrastructure, etc. These facilities are not accessible or accessible to companies in all industries, which may be why the results of this survey show that there is no direct relationship between converged infrastructure and enterprise digital innovation. Combined the results of Hypothesis 9 ($H_9$), converged infrastructure can only affect organizational digital innovation through the mobility of data. The use of smart transportation and smart energy infrastructure will generate massive amounts of data. It is suggested that the government should use more incentives and data security guarantees to enhance the willingness of data subjects to share data, so as to promote the flow and sharing of data and stimulate the vitality of digital innovation of enterprises.

Findings show that both information infrastructure and converged infrastructure are positively and significantly related to the flow of data while data flows can foster organizational digital innovation, thus the indirect effect of information infrastructure and converged infrastructure on orgainizational digital innovation may exist, supporting $H_4$, $H_5$, and $H_6$. The mediating effects of data flows are confirmed by the Bootstraping procedure. Thus, $H_8$ and $H_9$ were also confirmed. These results are consistent with the inferences of previous research that the interconnection and sharing of digital infrastructure accelerate the coding of knowledge information, real-time exchange at almost zero marginal cost, breaks down the temporal and spatial barriers of information exchange, improves the efficiency of knowledge flow, and promotes innovation (Yu and He, 2023). The findings of this study provide empirical support for the predictions of existing studies about the mediating effect of data flows on the relationship between digital infrastructure and organizational digital innovation. However, the result for Hypothesis 7 ($H_7$) and the bootstrap results for Hypothesis 10 ($H_{10}$) are not significant and have no practical implications. Thus, $H_7$ and $H_{10}$ are not supported, and the mediating effect of data flows between innovation infrastructure and organizational digital innovation does not exist. This may be because innovation infrastructure only improves the level of digital innovation in the stage of technology research and development, but it has no impact on the transformation of research results into technological innovation. Data flows mainly affect organizational digital innovation through the knowledge flow in the process of achievement transformation, thus data flows is not a mediation between innovation infrastructure and enterprise digital innovation. Therefore, combined with the above analysis of the direct relationship, innovation infrastructure only has a direct effect on enterprise digital innovation. In the future, the government can take innovation infrastructure as the starting point, focus on the innovation needs of enterprises and the key links in the transformation of technological achievements, continue to promote the construction of pilot test bases, industrial research experimental bases, and achievement transfer and transformation platforms, continuously improve the scientific and technological innovation service chain, and empower enterprises to improve their digital innovation performance.

### 5.2. Contributions and implications

Theoretically, this study explores the influencing factor of organizational digital innovation from the perspective of digital infrastructure, analyses the heterogeneous effects of different types of infrastructure, and enriches the research in digital infrastructure and organizational digital innovation. This study also reveals the mediating effect of data flows on the relationship between digital infrastructure and digital innovation, and opens up the black box of enterprises from integrating and allocating the external resources to facilitate digital innovation. Most of the theoretical perspectives of existing studies have focused on the theory of resource-based view (RBV) and study organizational internal resources. This study enriches the research and provides empirical evidence for the theory of digital innovation ecosystem. Practically, this study helps to provide a decision-making basis for enterprises in the core industries of the digital economy, as well as traditional industries in China, to effectively integrate external resources and facilitate digital innovation.

Enterprises should closely integrate the actual situation of China's digital economy and make good use of the basic resources from the external environment. On the one hand, the digital infrastructure and digital-related policies and regulations in the digital context are crucial for enterprises to carry out digital innovation, which means that enterprises should fully grasp and explore the changes and opportunities of external factors. On the other hand, in the digital ecosystem, Internet enterprises have the leading advantage of digital background and can achieve vertical collaboration with local traditional industries, such as the industrial Internet is the "integration" and "superposition" between traditional industrial technology and digital technology, which also provides a decision-making reference for how to implement industrial digitalization represented by "Internet + manufacturing".

### 5.3. Limitations and suggestions for future research

However, although this study looks for the factors that affect the digital innovation of enterprises from the perspective of digital infrastructure, in reality, there are many such influencing factors, and more influencing factors should be included to explore the digital innovation of enterprises in the future.

## 6. Conclusion

This study explores the research framework on the relationship between digital infrastructure and organizational digital innovation in China. Hypotheses were developed based on theoretical and empirical support from previous literature. An empirical investigation was carried out using data collected from 384 enterprises in the core area of digital industries as well as enterprises in traditional industries in China, exploring the heterogeneous effects of different types of digital new infrastructure on organizational digital innovation. The following conclusions are drawn from this study: First, the construction of digital infrastructure is an important starting point for empowering enterprises to improve their digital innovation level. Second, from the perspective of heterogeneity analysis, information infrastructure can not only directly affect enterprise digital innovation, but also indirectly affect enterprise digital innovation by affecting the flow of data within the innovation ecosystem. Converged infrastructure can only improve the digital innovation performance of enterprises by facilitating data flow. The impact of information infrastructure on enterprise digital innovation has only a direct effect, and there is no mediation.

This research provided evidence for the influencing effect of the data environment on organizational digital innovation in China. The findings and results can help to solve the research problem that the technical scope of digital innovation is relatively concentrated and the knowledge flow between digital innovation achievements is insufficient to provide the basis for evaluating market potentials and business environment towards digital innovation for future investment. The results and conclusions in this study can also provide references for governments to formulate and implement digital-related policies and regulations such as data flow restrictions. According to the conclusion of this paper, the government should further expand the coverage and depth of the construction of new digital infrastructure, so as to lay a good foundation for enterprise technological innovation. It is necessary to continue to strengthen the construction of information infrastructure, understand the innovation needs of enterprises, continue to promote the construction of pilot test bases, industrial research experimental bases, and achievement transfer and transformation platforms, continuously improve the scientific and technological innovation service chain, reduce the digital divide between regions, continue to promote the formulation of laws related to data rights confirmation, stimulate enterprises' willingness to share data, and maximize the potential of enterprises' digital innovation.

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# Appendix

**Table A1.** Constructs and items.

| Constructs | Variable code | Items | Sources |
|---|---|---|---|
| INFO | INFO1 | Scale of local information infrastructure (5G, Internet of Things, industrial Internet, artificial intelligence, data centres, etc.), construction is large with fast progress. | Sun, L. (2022) |
| | INFO2 | The cost (time, expense) of connecting information infrastructure for enterprises is in line with expectations. | |
| | INFO3 | Fiscal incentives are in place to accelerate the development of information infrastructure (e.g., accelerated depreciation for connectivity infrastructure investments, tax credits for research and development, or loans or subsidies for connectivity infrastructure). | World Bank Group. (2019) |
| CONV | CONV1 | Scale of local converged infrastructure (intelligent transportation, smart energy, etc.) construction is large with fast progress. | Sun, L. (2022) |
| | CONV2 | The cost (time, expense) of connecting converged infrastructure for enterprises is in line with expectations. | |
| | CONV3 | Fiscal incentives are in place to accelerate the development of converged infrastructure (e.g., accelerated depreciation for connectivity infrastructure investments, tax credits for research and development, or loans or subsidies for connectivity infrastructure). | World Bank Group. (2019) |
| INNO | INNO1 | Scale of local innovative infrastructure (major science and technology, science and education, and industrial technology innovation, etc.) construction is large with fast progress. | Sun, L. (2022) |
| | INNO2 | The cost (time, expense) of connecting innovative infrastructure for enterprises is in line with expectations. | |
| | INNO3 | Equal access is available to local innovative infrastructure. | |
| DTFL | DTFL1 | Data controllers/processors are required to comply with the relevant provisions on data retention periods. | ECIPE. (2019) |
| | DTFL2 | Data controllers/processors must comply with the relevant restrictions imposed on online content (e.g., approval and filtering of web content, bandwidth requirements, etc.). | |
| | DTFL3 | Data intermediaries (e.g., social media platforms) must comply with relevant intermediary liability provisions (e.g., notice-takedown regimes, etc.). | |
| | DTFL4 | Data controllers/processors must comply with administrative procedures established by regulators to lawfully process personal data. | |
| | DTFL5 | Data controllers/processors must comply with the relevant security requirements for the automatic collection of personal data. | |
| DIIN | DIIN1 | Digital technologies are automating your firm's processes. | Xu, Y. (2022) |
| | DIIN2 | The introduction of digital technology in your firm enhances management communication inside and outside the organization. | |
| | DIIN3 | Your firm updates the data or related information carried by infrastructure (such as data centers), production equipment, R&D tools, etc. in a timely manner. | |
| | DIIN4 | Your firm can continuously and in real time obtain various internal and external information through digital technology. | |
| | DIIN5 | Your firm is improving its products or services based on digital technologies. | |