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How external factors influence organisational digital innovation: Evidence from China

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ABSTRACT

Although the digital economy has developed remarkably in recent years, the - motivation for organisational digital innovation is still lacking, and the existing data market size is far below its real value. Most previous studies proposed factors influencing digital innovation mainly from an organisational perspective, and the impact of external environmental factors has been ignored to a certain extent. To explore the impact of external factors such as digital infrastructure and the regulatory environment, this study surveyed a sample of 346 enterprises in China operating in both the core industries of digital economy and traditional industries and analysed using SPSS and AMOS. The findings reveal that digital infrastructure and the regulatory environment positively and significantly a digital innovation. The flow of data elements within a digital innovation ecosystem mediates the relationship between external factors and organisational digital innovation. Our findings enrich the theory of digital innovation ecosystems and provide a reference for enterprises to seize external resources, and for policymakers to focus on policies and regulations that facilitate the flow of data.

1. Introduction

Digital technology, such as 5G, artificial intelligence, cloud computing, and big data, promoted the arrival of intelligent interconnections among all things, gradually changing the fundamentals of the industrial economy [1], business model [2], and how firms innovate [3], and produced a new paradigm of organisational innovation, namely digital innovation [4]. In the context of digital environment, a traditional business model may no longer be viable [5]. Digital innovation, as an important means of digital transformation, continuously reshapes product and service design, market models and business models through digital technology [6]. In this process, the construction of digital infrastructure accelerates the flow of information and reduces the cost of acquiring and exchanging information [7], whereas government support, like policy support for new industries or national strategic industries through special government investment, is closely associated to the regulatory environment of the digital economy [8]. For example, 'Digital Strategy 2025' in Germany, and 'Outline of Digital Economy Development Strategy' in China [9]. In 2022, the United States enacted the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act, aiming to provide subsidies and corresponding tax breaks for chip manufacturers [10] to facilitate the development of digital innovation in the United States. During the process of promoting digital innovation, data elements are important drivers [11]; thus, data accessibility and mobility are central to sustained growth and innovation among digital businesses [12].

Data element, just like capital and labour, can be a factor of production [13]. Data element refers to data resources that are electronically recorded during social production and business activities, integrating with other factors of production, and continuously iterating to bring economic and social benefits to users or owners [14]. Data element has important economic-technical characteristics such as non-competitiveness, non-exclusivity, low replication costs, externalities, permeability, dependence, virtual substitution, and self-organisation [15]. Data flow refers to the transfer and interaction of data elements among different regions, fields, and departments [16]. There are approximately three ways to realise the flow of data: data openness, data trading, and data exchange [17]. The flow of public-sector data mainly adopts the method of data openness, and government agencies that have access to public data resources

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selectively open data to the public on the premise of fully assessing data security and other factors. Private-sector data flows through data transactions and data exchanges by micro-enterprises that own data resources. Among them, data exchange is essentially a special form of data exchange, similar to bartering in commodity trading [18]. The flow of data elements between regions, departments and enterprises has made the digital innovation ecosystem gradually emerge and become the soil for innovation in the digital era [19].

The emergence of digital innovation has provided enterprises with unprecedented opportunities; however, not all businesses are able to seize these opportunities, and some are still struggling and mired in digital transformation [20]. One reason is that in the digital era, it becomes extremely difficult to benefit from innovation because of the nature of digital technologies (e.g. digital technologies are very easy to imitate) [21]. Besides, as technologies required for R&D of digital innovation become more sophisticated, so to do the costs and risks of engaging in innovation activities [22], especially the digital infrastructure that underpins innovation, are complex to build and evolve owing to its layered modular architecture [1]; organisations need to quickly improve or iterate on digital infrastructure to respond to changes in response to external demands for flexibility and agility [23].It is difficult for most companies that are short-term profit seekers to plan and implement original innovation activities that require opportunity costs and long R&D cycles [24]. In addition, companies need to adapt to changes in the digital environment while overcoming the associated societal barriers [25], as disputes in data ownership, data rights and interest distribution, data value assessment privacy protection, and national security increased [26–28], accompanied by the generation and circulation of data. Therefore, owing to the high complexity, uncertainty, and high risk of organisational digital innovation, the external environment such as regional digital infrastructure construction and government policy guidance and support are particularly important for companies to carry out digital innovation [29]. Furthermore, in current digital economy practices, as the flow of data elements is far from reaching a state of full sharing, the existing data market size is far less than the real value of the data elements [18].

Previous studies proposed multiple factors that influence digital innovation, most of which were proposed from an organisational or micro perspective [30]. From the theoretical perspective, most existing research focuses on the theory of resource base view (RBV), such as analysing relational networks [31], organisational agility [32], digital culture [33], and ambidextrous innovation ability [34]. However, these studies somewhat ignore the impact of external factors on organisational digital innovation and the multiplier effect of data elements, which have the characteristics of low replication cost, non-competition, and externality on labour, capital, and technological factors [35]. According to the theory of the digital innovation ecosystem, as an element of innovation, data can transcend the limitations of physical space and flow freely in the digital innovation ecosystem [36], thus activating, connecting, and aggregating the innovation activities of multiple subjects [19]. Digital infrastructure can help data elements exchange information beyond geographical restrictions, making the transmission of information more efficient, whereas an appropriate regulatory environment can ensure safe and effective data sharing. These external factors can further improve an enterprise's willingness to engage in digital innovation.

The Chinese context is fertile ground for exploring theories related to the construction and governance of digital innovation ecosystems. In recent years, China's digital innovation has grown significantly [24], and many outstanding digital platform enterprises have emerged, such as Tencent, Haier, JD.com, and Alibaba [37]. Additionally, China has a good foundation for the construction of digital infrastructure. These resources provided a rich basis for this study. Furthermore, China's institutional environment and market environment are extremely complex and unique [38]. Under the logic of 'crossing the river by feeling the stones', many new digital platforms have 'grown savagely' in the context of institutional void, which provides rich research materials for exploring the construction and governance of the digital-related regulatory environment. In addition, the lack of motivation for enterprises to engage in digital innovation, especially for original breakthrough [24, 37], and not realizing the full value of data elements [18,39] are also perplexing China. Exploring the construction and governance of digital innovation ecosystems in the Chinese context to contribute to existing theories and guides Chinese management practices.

From the perspective of digital innovation ecosystems, this study integrates the two critical external influencing factors of organisational digital innovation: digital infrastructure and the regulatory environment, exploring the mediating role of data flows, aiming to form synergistic digital innovation ecosystems, strengthen the dominant position of enterprises in scientific and technological innovation, motivate enterprises to carry out digital innovation, and promote the flow and sharing of data elements. The main contributions of this study are as follows. First, unlike most existing studies based on the RBV researching the influence of organisational internal resources on digital innovation [40,41], this study is based on digital innovation ecosystem theory, taking digital infrastructure and the regulatory environment as the external environment of the ecosystem, and taking the flow of data elements as a link between the external environment and the behaviour of innovation subjects. Second, the results show that sound digital infrastructure construction outside the enterprise and the support of the government in the regulatory environment have a direct role in promoting the digital innovation activities of enterprises. This is conducive to stimulating the willingness of innovation subjects to carry out digital innovation activities from the outside and provides ideas to solve the problem of insufficient subjective initiative of innovation subjects to carry out digital innovation from different perspectives. Third, this study finds that the flow of data elements significantly promotes enterprises' digital innovation and that the external environment can also indirectly affect enterprises' digital innovation activities through data flows. These findings highlight the importance of data flows, providing a basis for the introduction of policies to promote the flow and sharing of data elements, and are conducive to giving full play to the multiplier effect of data elements. Finally, unlike existing studies [8,42] that often use partially publicly available secondary data from institutions or governments, this study confirms that sound digital infrastructure and government support have become new drivers of China's digital innovation ecosystem through primary data from the Chinese context. The conclusion of this study suggests theoretical guidance for policymakers to explore and formulate policies and regulations related to innovation cultivation and provide a decision-making reference for enterprises' innovation activities to enhance their competitiveness in the digital era. Hence, this study builds a research framework on the relationship between digital infrastructure, the regulatory environment, and organisational digital innovation through the mechanism of data flows. Specifically, this study attempts to answer the following questions.

RQ1. What is the impact of digital infrastructure and the regulatory environment on organisational digital innovation?

RQ2. How do digital infrastructure and the regulatory environment affect organisational digital innovation?

2. Literature review and hypothesis development

2.1. Digital innovation

In recent years, digital innovation has become a popular topic in innovation research. Digital innovation is defined from the perspectives of innovation outcomes [43], innovation processes [2], and holistic perspectives [44]. In this study, digital innovation is considered from a holistic perspective, which refers not only to new products or services integrated in digital technology, but also to the adoption of digital technology in the innovation process, which brings about the improvement of production processes or the transformation of business models as well as novel organisational arrangements [1,2,44]. According to this definition, digital innovation can be further divided into digital product innovation [45], digital process innovation [46], digital organisational innovation [47], and digital business model innovation [48]. Digital innovation is characterised by convergence [2], self-growth [48], multi-agent interactions, dependence on the flow of data elements [49]. Digital technology [50], internal organisational [51], digital talent [52], institutional [53], and data environment factors [19] can affect organisational digital innovation. The theoretical perspective of most existing literature focuses on RBV, such as studies in relational networks [31], organisational agility [32], digital culture [33], and ambidextrous innovation capabilities [34]. Many scholars use the Technology-Organization-Environment (TOE) framework [54] to explain the multi-factor synergistic linkage mechanism of the digital innovation process, such as studying the impact of TOE factor linkage on enterprise digital innovation [29,50].

In recent years, scholars have used the idea of biological evolution to study digital innovation activities from an ecosystem perspective. Some scholars argue that the digital innovation ecosystem is a social ecosystem composed of digital innovation-related industrial entities based on competition and cooperation [55]. A digital innovation ecosystem can be recognised as a fusion of 'digital innovation' and the 'innovation ecosystem' [55]. Beltagui et al. contend that, owing to the introduction of digital elements, the elements of innovation are reorganised, and the logic of system behavior also changes, leading to a synergistic symbiosis between digital innovation subjects [56]. Within digital innovation ecosystems, the convergence attribute of digital technology, as an important infrastructure, effectively improves the efficiency of resource allocation and data processing in the process of digital innovation, and enables the cross-border flow of digital innovation resources [57].

The digital innovation ecosystem has the characteristics of the digitization of innovation elements, virtualisation of participants, and ecology of inter-subject relationships [58]. The formation of a digital innovation ecosystem is guided by value creation, which emphasises the interdependence of technology [59]. With the introduction of data elements, organisational boundaries under the traditional business model are further dissolved, the concept of boundaries within and between enterprises has become blurred, industrial boundaries have been gradually broken, and the operating logic of business activities is changing dynamically [60]. In summary, most prior studies on the factors influencing enterprises' digital innovation are based on the RBV. The impact of external resources on organizational digital innovation behaviour through ecological thinking has been ignored to a certain extent, and the mechanism by which the external environment affects enterprise digital innovation behaviour remains unclear.

2.2. Digital infrastructure

Digital infrastructure refers to the basic digital technology, organisational structure, and related services or facilities that support the operation of enterprises or industries, and in the form of a shared, unbounded, heterogeneous, open and evolving socio-technical system, including diverse digital technology capabilities and user installation, operation and design communities [31]. Digital infrastructure is positively related to enterprise innovation [61,62], and this driving effect exhibits strong structural characteristics, particularly for non-state-owned and high-tech enterprises [63]. Robust digital infrastructure, including internet connectivity and all types of information networks, can help enterprises take the lead in newer production methods and successfully conduct innovation programmes [64]. However, because of the hierarchical and modular architecture of digital infrastructure [1], which makes it extremely complex to build and evolve, organisations need to quickly improve or iterate on digital infrastructure to respond to changes in response to the external demands for flexibility and agility [23]. It is difficult for most companies that are short-term profit seekers, to plan and implement original innovation activities that require opportunity costs and long R&D cycles [24]. Therefore, external support, such as regional digital infrastructure construction, is particularly important for companies to carry out digital innovation [29]. However, existing research focuses on the relationship between digital infrastructure and enterprise innovation, focusing on digital infrastructure at the enterprise level, and ignores, to some extent, the impact of external digital infrastructure construction on the organisation's digital innovation activities, such as local information infrastructure (5G network, Internet of Things (IoT), industrial Internet, data centers, etc.), converged infrastructure (industrial IoT (IIoT), intelligent transportation infrastructure, etc.), and innovation infrastructure (large-scale scientific research platforms, science and education infrastructure, etc.).

According to digital innovation ecosystem theory, firms are willing to innovate using open external contracts rather than closed vertical integration; thus, the trajectory of value creation shifts from inside to outside the business [65]. This shift makes digital innovation process inseparable from the digital infrastructure within the organisation and the ecosystem in which it operates [44]. Digital infrastructure can be at the industry, national, or even global level [66]. At the industry level, the digital infrastructure outside these enterprises is part of the innovation environment that enables smooth flow and rational allocation of innovation and innovation resources, breaks down the original enterprise and industry barriers [60], promotes cross-industry and cross-field cooperation, and promotes the integration of innovation subjects through mutual learning and resource sharing to form a close innovation network relationship [67]. The construction of digital infrastructure has reduced the cost of acquiring and exchanging information and enabled innovative actors to easily and quickly access the most advanced technological information [7], improving the efficiency of innovation [68,69], providing the core competencies needed for digital innovation by enterprises within the ecosystem [70,71]. Regionally, digital infrastructure can break down spatial barriers to information transmission, promote cross-regional cooperation in innovation processes, and help enterprises identify innovation opportunities with higher R&D value [72]. Digital infrastructure such as digital communication platforms can mitigate the impact of uncertainty propagation [73], and help governments understand the entire business ecosystem [74]. Based on existing literature, we propose hypothesis H_1.

H1. The construction of sound digital infrastructure that outside enterprises positively related to organisational digital innovation.

2.3. Regulatory environment

The regulatory environment reflects the local government's support for digital technology, digital markets, and digital talent, the government's supervision of the collection and use of user data by digital market entities, and unfair competition in the digital market [75]. The flow of data elements, the empowerment of digital technology, and the organisation of digital platforms make digital innovation completely different from traditional technological innovation, showing an ecological structure and operational characteristics [19], and bringing new challenges to the innovation activities of enterprises. The generation and circulation of data activate the innovative behaviours of many different types of subjects but also increase the complexity of data ownership relations [26], data rights and interest distribution [26,27], data value assessment [26], privacy protection [28], and national security [76]. The rise of digital platforms and markets has also brought great challenges to regulators, stimulating the need to regulate issues such as antitrust and the abuse of dominance [77]. Digital innovation policies formulated and implemented by governments are conducive to the circulation and sharing of information, reduces transaction costs, and improves regional innovation performance [78]. Government support can increase start-ups' willingness to engage in knowledge strategy activities by enabling them to access resources such as capital and legitimacy [79]. Specific policies such as the information consumption pilot policy and tax reduction policy can significantly promote the development of the digital economy through innovation promotion effect [37,80].

In view of this,we propose H2 as follows.

H2. *The regulatory environment positively related to organisational digital innovation.*

2.4. Data flows

2.4.1. Definition of data flows

In the book Data Journeys in the Sciences, Leonelli and Tempini [81] defined journeys of data as designating the movement of data from their production site to many other sites where they are processed, mobilised and re-purposed. In addition, many scholars studied data flows from a technical perspective, and discussed data flows in the context of specific research questions. For example, in the data warehouse (DW) context, the extract-transform-load (ETL) process enables data integration. Generally, an ETL process represents a data-intensive flow (or data flow). The ETL process extracts, cleanses, and transforms data from multiple heterogeneous sources for further analysis [82]. From a technical perspective, the flow of data improves the liquidity of data in the digital space through physical operations such as data transmission, access, storage, and editing, as well as the optimisation of algorithms and systems. Data flows can occur internally, or externally, regionally, nationally, or even globally as well as from technical and application systems, data networks, and physical and data spaces. The homogenisation of data comes with the emergence of new media that separate content from the medium offering it. Thus, the content can be stored or displayed on any device [83]. However, it is impossible for any system to open all data without restrictions. Therefore, there will be an uneven flow and sharing of data in space, that is, the generation of nodes in a specific space [84]. At the technical level, it is helpful to identify and describe the status and characteristics of data flows in practical application scenarios, such as cross-border access, transmission, transfer and use of data in the process of cross-border data flow, and to provide a specific focus for specific policy formulation of data governance. Although the definition of technology is widely recognised and applied, it does not account for the value creation of the digital economy in the process of data flow and iteration at the technical level.

Ecological thinking is more in line with the dynamic, cyclical and adaptive characteristics of the mutual transformation between data, knowledge and value in the process of data flow. From an ecological perspective, data flows are actually data cycles with data value creation, data value transmission and data creation as the main links, which have an ecological structure and operation characteristics and constitutes the basic operational mechanism of data ecology [19]. In the process of data flow, the lack of a data flow link will restrict data circulation, which in turn will lead to an imbalance in the data ecosystem. According to ecological thinking, data flows are the flow of data-based knowledge and value among multiple subjects engaged in the full data life cycle, which can be deconstructed into three levels: digital data streams, flows of knowledge. and value flows [85]. Digital data streams are the continuous encoding and transmission of data related to events, including time, people, places, facts, methods, causes, and effects [86]. Knowledge flow refers to the transfer of data, information, and knowledge between individuals and systems, including sets of processes, events, and activities [87]. Value flows refer to the value-added difference generated by the data element market players, including the producers of raw data, producers of data sets and data analysts who participate in the collection, storage, analysis and application of data. They guide the value flow to form a closed loop of the value chain with a positive feedback effect [85]. From the perspective of data circulation, knowledge and ideas are generated from data. Digital data streams are fundamental, drive the flow of information, and promote the accumulation and creation of knowledge. The digital era offers a new mean for dynamic open innovation in widespread ecosystems [88].

Data elements can break through the boundaries of time and space and flow efficiently as innovation elements, creating favorable conditions for open innovation through which innovation subjects break through organisational boundaries and integrate internal and external innovation resources [43]. The flow of data elements can break the boundaries between innovation subjects, expand the innovation network space, render enterprises no longer the only innovation subjects, strengthen collaboration between innovation subjects, promote cross-field and cross-regional collaborative innovation of various innovation subjects, and continuously form a pattern of integrated development of multiple innovation subjects [60]. Purposeful managed knowledge flows across organisational boundaries during data flows [89] and value is increasingly co-created in digital ecosystems and marketplaces [90].

Combining the digital innovation ecosystem perspective [19] and the view of decomposing data flows into digital data streams, knowledge flows, and value flows [85], we believe that data flows are the transfer and interaction of data elements between different regions, fields, and departments. Through the transformation from 'data stream' to 'knowledge flows' and then to 'value flows', the value creation of data is finally realised.

2.4.2. Digital infrastructure and data flows

Based on the definition of data flow, mobility is a prerequisite for realizing the value of data. The rapidly development of digital infrastructure provides a good foundation for data flows [85], which profoundly affects the rate and direction of flow of data and promotes the agglomeration of digital innovation resources [91]. The sharing and interconnection of digital infrastructure accelerate the real-time exchange of information at almost zero marginal cost, improve the efficiency of knowledge flow, and promote the spread of innovative elements between industries cities [92]. More specifically, information infrastructure, such as 5G network, IoT, and data centers, can help reduce the cost of data transmission and build a bridge for data circulation [61]. Converged infrastructure, such as the IIoT, can help enterprises build a production system with data resources as its core and dig deeper into the value of data resources [93]. For example, the industrial Internet can transform the value creation model of enterprises from simple product supply to "product + service", and realise real-time interaction between multiple systems such as product production, quality assurance and user feedback [94], thereby promoting value creation. Innovation, science, and education infrastructure, can help promote the sharing of various data-based achievements among enterprises and the efficient transformation of future technologies [95]. Based on the available literature, H_3 is proposed as follows.

H3. Digital infrastructure positively relates to data flows.

2.4.3. Regulatory environment and data flows

By integrating and optimizing resource allocation, data elements can drive the economy and society in a more efficiently and intelligently. This process requires the guidance and support of policies. The government and relevant institutions provide favorable conditions for digital technology innovation and ecosystem construction by formulating policies to encourage digital innovation, providing innovation financial support, and building innovation service platforms. Simultaneously, by establishing a reasonable intellectual property protection mechanism and fair market access rules, digital innovation achievements can be protected and more enterprises and individuals can be incentivised to participate in innovation activities [96]. In this process, the data sharing mechanism and open platform established by the government have become key, providing channels for the cross-border flow of data resources and ensuring that data can safely and effectively enter the innovation ecosystem as an unlimited supply of production factors [97]. Conversely, because the nature of data is different from that of factors of production such as land and capital, a series of institutional changes developed and introduced by governments around data privacy, security, property rights, and restrictions on cross-border flows can also affect data flows within ecosystems [19], but stricter data policies are expected to adversely affect industries that rely on data in their production processes [98]. Based on the literature, we propose H_4 as follows.

H4. : The regulatory environment positively relates to data flows.

2.4.4. Data flows and digital innovation

Traditional innovation is based on the input and reorganisation of traditional production factors such as human resources and capital, and reconstructs the production function to achieve innovation. In the digital era, data elements are used as new production and innovation factors in innovation activities to, optimise resource allocation and promote the evolution of innovation models [99]. On the one hand, the development of digital technologies such as big data and cloud computing has derived a large amount of data resources, which become data elements and can become innovation elements after the process of mining, collection, and cleaning, enriching the innovation element system. On the other hand, data elements can break through economic boundaries, achieve deep integration with other innovation factors, reconstruct a combination of production factors, and improve production and innovation efficiency. Specifically, in the decision-making process, the integration of data elements and human capital factor can accurately capture innovation information and improve the efficiency and quality of decision-making with big data as the carrier [100]. In the R&D process, data elements break the limitations of time and space, enable multiple subjects to participate in innovation activities across time and space, reduce the constraints of innovation activities, and improve the efficiency of innovation activities [101]. In terms of the application of achievements, the empowerment of data elements can shorten the cycle of achievement transformation and improve the efficiency of achievement transformation.

Data elements can break through the boundaries of time and space and flow efficiently in the digital innovation ecosystem as innovation elements. The flow of data elements can cross the boundaries between innovation subjects, expand the innovation network space, and promote cross-field and cross-regional collaborative innovation among innovation subjects [60]. In this process, the agglomeration of multiple innovation subjects constitutes an innovation ecosystem, and realises the overall evolution of the innovation model. The flow of data elements in a digital innovation ecosystem can drive the concentration of knowledge, technology, capital, and talent to more efficient areas and improve resource misallocation [102]. Consequently, data flows enable synergies by consolidating and optimizing resource allocation, thereby fostering digital innovation. Therefore, data elements can transcend the limitations of physical space and flow freely in the digital innovation ecosystem, reflecting a strong geospatial spillover effect [36], thereby promoting cross-industry, cross-field and even cross-border cooperation and communication to increase the output of digital innovation. Among these, the openness of public data enables governments, enterprises, research institutions and other entities to share important data in the fields of society, economy, environment and other fields, and the data flow between enterprises enables different enterprises to share each other's data resources, achieve synergies, and promote product and service innovation. This kind of cooperation is not limited to the same industry, but also stimulates the generation of new business models and innovative ideas across industries, and the international data flow can help to achieve the efficient allocation of global resources and promote international cooperation and exchange [96]. These studies provide a platform to develop Hypothesis 5 (H_5).

H5. Data flows positively relate to digital innovation.

2.4.5. Mediating effect of data flows

In the process of digital infrastructure indirectly influencing organisational digital innovation, data flows become a link between the external environment and the digital innovation subjects. First, the construction of digital infrastructure reduces the real-time exchange cost and breaks down the spatial barriers of information exchange [92], which significantly reduce the cost of data flows, promote the free flow of data elements as innovation elements in the digital innovation ecosystem, and enable an all-round breakthrough from factor monopoly to reasonable sharing [61]. On this basis, data elements are gathered on different platforms through flow, and by applying innovation to different scenarios, the product value space is continuously expanded, and the performance of enterprise digital innovation is improved. Simultaneously, various platforms provide new channels for the cross-space dissemination and diffusion of data elements with the help of the network-link advantages of industrial digitalisation, thereby achieving continuous increase in marginal benefits and improving the digital innovation performance of enterprises. Second, the flow of data elements through digital infrastructure is conducive to fully exploiting the multiplier effects of data elements, exploring innovative models and industrial formats suitable for the sustainable and high-quality development of the local economy, and promoting the integration of data elements and the real economy. The flow of data elements can continuously promote the transformation of the production modes and organizational forms of traditional industries and empower the innovation and development of the real economy and digital industry [103]. Third, the construction and operation of digital infrastructure can form digital innovation ecosystems by enabling the agglomeration of industrial space. According to the theory of digital innovation ecosystems, the innovation and application of digital technology need to be supported by a good ecological environment. Building an open ecosystem that supports digital innovation and fosters cooperation involves breaking down industry barriers, promoting cross-industry and cross-sector cooperation, and forming an interconnected and resource-sharing digital innovation network. This type of ecosystem can not only provide broader application scenarios and richer resources for digital innovation, but also promote the flow of knowledge and rapid iteration of technology, and accelerate the transformation and application of innovation achievements [96]. In addition, through the flow of data, enterprises in a system can easily obtain advanced general digital technologies, improve the level of technology spillovers, and realise the complementarity of digital technologies. Technology complementarity is conducive to reducing uncertainty in digital innovation activities, thereby improving an enterprise's digital innovation performance [104]. Based on previous literature, we propose H_6 as follows.

H6. Data flows mediate the relationship between digital infrastructure and digital innovation.

The regulatory environment can influence the functioning of innovation systems and the interaction between innovation elements [105], thereby indirectly affecting firms' innovation activities. Owing to the high complexity and uncertainty of digital innovation, the R&D risk of enterprises is greater; therefore, government policy guidance and support are particularly important for organisational digital innovation [29]. The flow of data elements can promote the effective transmission of information between the market and the government and between government departments [106], and encourage the government to make better use of digital economy-related policies, which are an important tool for scientific and technological innovation, simplifying the process procedures of digital enterprises, providing enterprise services, and pooling the creativity of talent, so that digital economy-related policies can better release the incentive energy of innovation [107]. The flow of data elements can simultaneously promote the interconnection and interoperability of real information, greatly reducing the cost of information search and reprocessing caused by the uncertainty of external economic policies [108] and thus improving the digital innovation performance of enterprises. Therefore, H_7 was proposed as follows.

H7. *Data flows mediate the relationship between regulatory environment and digital innovation.*

The conceptual framework shows the above hypotheses (as shown in Fig. 1).

3. Methodology

3.1. Sample and data collection

This study employed structural equation modeling (SEM) to analyse the relationships among constructs. SEM is widely used to simultaneously estimate a range of interrelationships between latent structures in a model [109]. Digital technologies have rapidly permeated every aspect of society and the economy, giving rise to new economic forms and comprehensive industrial and consumer transformations. In this revolution, both Internet-based companies, and companies in traditional industries, such as textile manufacturing and pharmaceuticals, are implementing new business models and formats triggered by the digital economy. Therefore, the research objectives of this study include not only companies in the core industries of the digital economy but also enterprises that have carried out or plan to carry out digital innovation in traditional industries. For companies that meet these requirements, it is not yet possible to determine the exact size of the target group. According to data released by the National Bureau of Statistics of China (NBSC), more than 1,000,000 enterprises fit within the scope of the target population.

In addition, as digital innovation has the characteristics of convergence, multi-agent interaction, and self-growth [2], the measurement of digital innovation is still in the exploratory stage. At present, the NBSC has a relatively clear definition of the digital economy and its core industries, and in 2021 published the *Statistical Classification of the Digital Economy and Its Core Industries* (2021) standard. This standard accurately and comprehensively classifies the scope of the digital economy into five categories: digital product manufacturing, digital product services, digital technology applications, digital factor-driven industries, and digital efficiency improvement industries. The first four categories are defined as the core industries of the digital economy and represent the digital industrialisation part of the digital economy. Enterprises in the core industries of the digital economy have inherent advantages in digital innovation, which can be better reflected in their operations. These enterprises rely entirely on digital technology and data elements to conduct various economic activities and provide digital technologies, products, services, infrastructure, and solutions for the digital development of industries, which is an important supporting foundation for promoting digital technology innovation and digital business model transformation [110]. For example, enterprises in the digital product manufacturing industry of electronic components and equipment manufacturing, or enterprises in the digital product retail or digital product maintenance digital product service industry are important components of digital industrialisation, which are knowledge-intensive, networked, digital, and platform-based [111].

The fifth category of the digital efficiency improvement industry belongs to the industrial digitalisation part, which refers to the application of digital technology and data resources to increase the output and efficiency of traditional industries. It is the integration of digital technology and the real economy, covering all traditional industries that can be combined with the digital economy, such as smart agriculture, intelligent manufacturing, intelligent transportation, and smart logistics. The application of digital technologies to various enterprises in digital efficiency improvement industries can optimise production processes, improve resource allocation efficiency, and enhance market responsiveness [110], which is an important embodiment of digital process innovation and digital organisational innovation (the

Table 1
The basic scope and classification of digital [1]economy.

Basic scope	Subordinate industry categories	Subordinate industry in the class
Digital industrialisation part	Digital product manufacturing industries	Electronic components and equipment manufacturing, communication and radar equipment manufacturing, intelligent equipment manufacturing, etc.
	Digital product service industries	Digital product wholesale and retail, digital product leasing, digital product maintenance, etc.
	Digital technology application industries	Software development, telecommunications, radio and television and satellite transmission services, etc.
	Digital elements driving industries	Internet finance, Internet platform, digital content and media, data resources and property rights transactions, etc.
Industrial digitization part	Digital efficiency improvement industries	Smart manufacturing, smart transportation, smart logistics, Smart agriculture, etc.

Source: Introduction of Digital Economy Statistical Monitoring System in China[2]

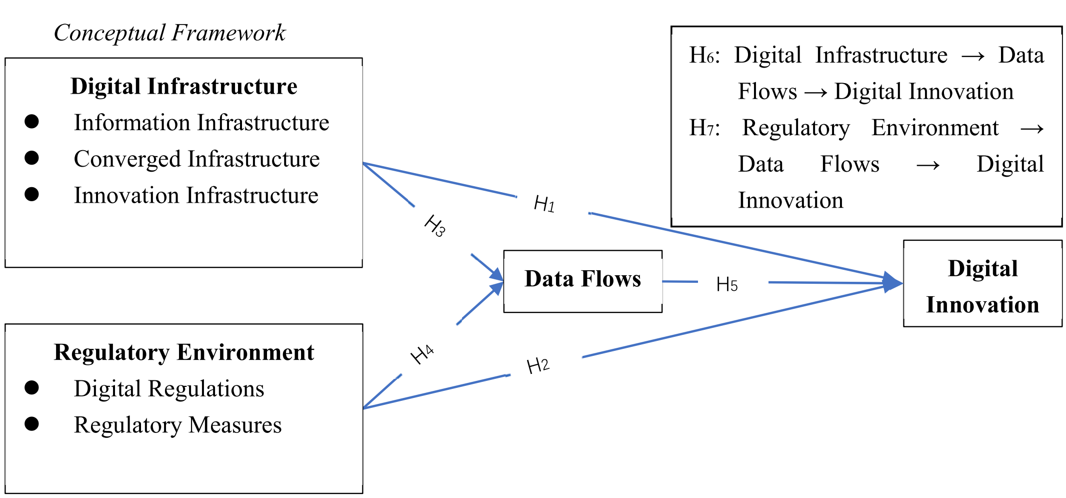

Fig. 1. Conceptual framework.

Table 2
Demographics.

Respondent Profile *(n = 346)*							
Attributes	Distribution	Frequency	(%)	Attributes	Distribution	Frequency	(%)
Position	Senior manager	52	15.0	Education level	Vocational or Basic	5	1.4
	Middle manager	109	31.5		Undergraduate	205	59.2
	R&D personnel	26	7.5		Masters'	96	27.7
	ICT staff	46	13.3		PhD	7	2.0
	Other	113	32.7		Other	33	9.5
Firm Age (Year)	Less than 5 years	52	15.0	Annual turnover (CNY)	Less than 2 million	32	9.2
	5–10 years	98	28.3		2-5 million	24	6.9
	11–20 years	89	25.7		6-10 million	34	9.8
	More than 20 years	107	30.9		More than 10 million	256	74.0
Number of employees	Below 100	109	31.5	Industry	Digital efficiency improvement	115	33.2
	101–200	40	11.6		Digital products manufacturing	51	14.7
	201–500	40	11.6		Digital technology application	37	10.7
	501–1000	40	11.6		Digital factors driving	75	21.7
	More than 1000	117	33.8		Digital products service	68	19.7

classification is shown in Table 1).

Considering the accessibility and availability of samples, we chose convenience sampling to collect data. Although commonly used, convenience sampling may cause potential bias in the results [112] because respondents who are not involved in digital innovation are ignored. To minimise the impact of potential bias on the results, we selected managers, R&D staff, ICT staff and other employees who could be accessed by the research team as respondents. Both middle and senior managers and ordinary employees were suitable for this study. Top management understands the organization's need to apply new technological breakthroughs to solve problems [113], while ordinary employees are considered key contributors to the organisation's innovation process [51]. Ordinary employees range from R&D or ICT professionals to middle managers within the company, as well as employees in other positions, such as HR, finance, and accounting.

Primary data from the managers and employees of 346 enterprises in China were collected using questionnaires because the survey method is more convenient and flexible for collecting data, and the survey can be carried out in various forms, such as on-site answers, mailing, and entrusting a third party. Considering the availability of data, to ensure the quantity and quality of questionnaire distribution and collection, this study made full use of resource channels, such as schoolmates, relatives, friends, and acquaintances of the research team and group, to contact the target group. This study used a combination of online and offline methods to carry out research. Specifically, the first step was to complete the on-site distribution and completion of questionnaires in the field research and face-to-face negotiation of the research team members. Second, Questionnaire Star platform was used to edit the online questionnaire and send the questionnaire through Ding Talk, WeChat, and email. Enterprises that do not respond for more than two weeks will be invited to participate in the survey again by phone or email. Data collection was conducted from November 2023 to February 2024 and comprised two stages. In the first stage, data were collected face to face on the second Global Digital Trade Expo held in Hangzhou, China from 23rd to November 27, 2023. A seven-person team was responsible for face-to-face data collection. A total of 300 closed-ended questionnaires were distributed, of which 183 were turned back, with a 61 % response rate. After careful checking, 166 questionnaires were deemed valid and used for data analysis. The second stage began on 18th January and last to 15th February collecting data online through WeChat, Ding Talk, and emails. Online questionnaires used Questionnaire Star platform and delivered to 400 managers and employees of enterprises in China. A total of 302 responses were collected, 180 of which were valid for data analysis. The overall response rate (ORR) was 69 %. Table 2 presents the demographic characteristics of the 346 respondents.

3.2. Constructs measurement

Digital Infrastructure (IF), Regulatory Environment (RE), Digital Innovation (DIIN), and Data Flows (DTFL) are the four variables and latent constructs in this study. IF and RE are second-order constructs with subdimensions and their respective items. All the items in the survey were adapted from existing literature and were measured by 5-point Likert Scale with '5' represents 'strongly agree' and '1' represents strongly 'disagree'. Appendix 1 provides the details of the constructs and relevant references.

Digital Infrastructure (IF) measures cost, scale, and government incentives to access digital infrastructure. IF is a second-order construct with 3 dimensions. According to the National Development and Reform Commission's interpretation, digital infrastructure including information infrastructure (IoT, cloud computing, artificial intelligence, etc.); converged infrastructure (smart energy infrastructure and intelligent transportation infrastructure, etc.), and innovation infrastructure (technological education infrastructure, major technology infrastructure, etc.) [114]. Three first-order constructs (INFO, CONV, and INNO) measured IF from these aspects. INFO is the first dimension of IF and has four items that measure the scale and how easily enterprises access information infrastructure. CONV is the second dimension, with four items measuring the scale the scale and how easily enterprises access converged infrastructure that integrates digital technology into the traditional infrastructure. The INNO is the third dimension with four items measuring the scale, cost, and government incentives of enterprises accessing innovation infrastructure.

Regulatory Environment (RE) is another second-order construct that measures a firm's external regulatory environment. RE is measured using two first-order constructs: namely Digital Regulations (DGRG) and Regulatory Measures (RGMS). The DGRG is the first dimension, measuring the enactment of government policies and regulations in digital-related aspects, whereas the RGMS is the second dimension, measuring the supervision and governance of digital-related economic activities by local governments. Both the DGRG and RGMS have three items.

Data Flows (DTFL) is a first-order construct that measures the relevant restrictions and provisions regarding the mobility and security of data elements which required to be comply with. Five items were used to tap responses to the DTFL.

Digital Innovation (DIIN) is another first-order construct that measures firms utilising and integrating digital technology in organisational arrangements, production, and business models using five items.

[2] https://unstats.un.org/bigdata/events/2024/measuring-digital-economy/presentations/day3/3.%20Introduction%20of%20digital%20economy%20statistical%20monitoring%20system%20in%20China_Chen%20Hang.pdf.

Table 3
Total variance explained (N = 346).

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative%	Total	% of Variance	Cumulative%
1	9.645	38.579	38.579	9.645	38.579	38.579
2	2.202	8.809	47.388	2.202	8.809	47.388
3	1.953	7.814	55.202	1.953	7.814	55.202
4	1.476	5.903	61.105	1.476	5.903	61.105

Table 4
Common method bias test results (N = 346).

Compared Models	ChiSq/df	CFI	RMSEA
Original Model	1.729	0.958	0.046
Model with CMV factor	1.673	0.962	0.044

4. Results

4.1. Common method variance

Common method bias (CMB) can occur in the data collection process when the required data comes from a single source and self-presentation is the only way to respond [115]. To minimise the impact of CMB on the results of empirical research, this study not only explained the purpose and main research content of the questionnaire in the instructive part, but also made an anonymous commitment to the respondents, and clarified the estimated time and response requirements of the questionnaire. The protection of respondents' personal private information is conducive to the expression of their true feelings and thus enhances the authenticity of the data obtained. Informing respondents about the length of the questionnaire will also help them allow enough time to answer the questionnaire and try to avoid the phenomenon of filling in the questionnaire due to time constraints. SPSS and AMOS were also used to evaluate the common method variance (CMV) of the samples to ensure the authenticity and validity of the empirical results. First, we employed Harman's single-factor test using SPSS 28 to test CMV. The first unrotated factor explained only 38.58 % of the total variation (Table 3), which was less than the 50 % threshold. This result indicated that there was no significant common method bias in the study data [116].

Second, according to Jordan and Troth [117], confirmatory factor analysis (CFA) was used to further test the common method bias of the sample by comparing the fit of the benchmark model with the addition of a common method factor. As shown in Table 4, compared with the original model, the change of the model fitting index after adding the common method factor is small, and the goodness of fit does not change significantly ($\Delta\chi^2/df = 0.056$, $\Delta CFI = 0.004$, $\Delta RMSEA = 0.002$), indicating that there is no serious common method bias in the sample data.

Furthermore, VIF is tested and all the values of VIF as reported in Table 5 are between 1.355 and 2.328, all less than five, indicating that there is no serious multicollinearity problem of [118].

4.2. Measurement model

The measurement model was analysed before we modeling the interrelationships of the latent constructs in SEM. We checked the Cronbach's alpha using SPSS 28 and the composite reliability (CR) using AMOS 28 to assess the reliability of the questionnaire. Table 6 shows the results of Cronbach's alpha and CR. All the Cronbach's alpha and CR values were more than 0.7. These results meet the requirement for reliability and internal consistency for each latent construct [119].

Three types of validity were used to assess the validity of the items in the measurement model. The average variance extracted (AVE) and factor loading were used to assess convergent validity. In Table 3, all AVE values were greater than 0.5, and all factor loadings of each item were greater than 0.6, indicating that convergent validity was achieved [120]. We used AMOS to conduct the CFA. In the pooled CFA results, $ChiSq//df = 1.729 < 3$, $CFI = 0.958 > 0.9$, and $RMSEA = 0.046 < 0.08$, meet the requirement for model fitness The results indicated the construct validity is achieved. We employed the Fornell-Larcker criterion to assess the discriminant validity. The results are summarised in Table 7. The correlation between the constructs was smaller than the square root of the AVE represented in the same column, indicating that the measurement model met the requirements of discriminant validity [121].

Table 5
Results of VIF.

Constructs	Collinearity Statistics	
	Tolerance	VIF
Information Infrastructure (INFO)	0.519	1.929
Converged Infrastructure (CONV)	0.474	2.109
Innovation Infrastructure (INNO)	0.440	2.273
Digital Regulations (DGRG)	0.430	2.328
Regulation Measures (RGMG)	0.570	1.754
Data Flows (DTFL)	0.738	1.355

4.3. Structural equation modeling results (SEM)

SEM explains the hypothesised relationships between constructs in this study. Tables 8 and 9 present the hypothesis testing results. Digital Infrastructure was positively and significantly related to Digital Innovation at the 95 % confidence level, with a standardised beta estimate of 0.319. The critical ratio (C.R.) value was 2.726, larger than 1.96, and the p value is 0.006, which is less than 0.05. Another exogenous variable, Regulatory Environment is also positively and significantly related to Digital Innovation at the 95 % confidence level, with a standardised beta estimate of 0.255, a critical ratio (C.R.) value of $2.152 > 1.96$, and a p value of $0.021 < 0.05$. The relationships between these two independent variables and the mediating variable, Data Flows, are also positive and significant. The standardised beta estimate for Digital Infrastructure and Regulatory Environment on Data Flows was 0.302 and 0.284 respectively. The critical ratio (C.R.) values were 2.313 and 2.140 (>1.96), respectively, while both the p values were less than 0.05, confirming a significant relationship at the 95 % confidence level. Table 8 shows a significant positive correlation between Data Flows and Digital Innovation ($S.T.D.\beta = 0.168$, $C.R. = 2.719 > 1.96$, $p = 0.007 < 0.05$).

Bootstrapping (performed with 2000 bootstrapping samples, resulting in the bias-corrected percentile method at the 90 % confidence level) via AMOS 28 was employed to test the mediating effect of Data Flows in the conceptual framework of this study. As shown in Table 9, the indirect standardised beta estimate of H6 is 0.051, with a p value of $0.042 < 0.05$, indicating that the mediating effect of Data Flows mediate the relationship between Digital Infrastructure and Digital Innovation. Similarly, the indirect standardised beta estimate of H7 is 0.048, with a p value of $0.042 < 0.05$, indicating that Data Flows mediate the relationship between the Regulatory Environment and Digital Innovation. The direct effects of Digital Infrastructure and Regulatory Environment on Digital Innovation are also significant ($p = 0.085$ and 0.077, respectively) at the 90 % confidence level, indicating that a partial

Table 6
Reliability and validity.

Constructs		Items	Loading >0.6		Alpha >0.7		CR >0.7		AVE >0.5	
RE	DGRG	DGRG1	0.75	**0.95**	0.785	**0.854**	0.814	**0.875**	0.594	**0.779**
		DGRG2	0.81							
		DGRG3	0.75							
	RGMS	RGMS1	0.72	**0.81**	0.806		0.808		0.584	
		RGMS2	0.79							
		RGMS3	0.78							
IF	INFO	INFO1	0.75	**0.85**	0.799	**0.890**	0.797	**0.928**	0.568	**0.811**
		INFO2	0.75							
		INFO3	0.76							
	CONV	CONV1	0.70	**0.92**	0.828		0.789		0.556	
		CONV2	0.71							
		CONV3	0.82							
	INNO	INNO1	0.63	**0.93**	0.767		0.776		0.538	
		INNO2	0.76							
		INNO3	0.80							
DTFL		DTFL1	0.72		0.872		0.867		0.562	
		DTFL2	0.68							
		DTFL3	0.75							
		DTFL4	0.82							
		DTFL5	0.77							
DIIN		DIIN1	0.84		0.868		0.871		0.577	
		DIIN2	0.78							
		DIIN3	0.75							
		DIIN4	0.79							
		DIIN5	0.62							

Note: Results of 2nd order constructs are shown in bold.

Table 7
Fornell-Larcker criterion.

	RE	IF	DTFL	DIIN
RE	**0.883**			
IF	0.822	**0.901**		
DTFL	0.532	0.536	**0.750**	
DIIN	0.607	0.619	0.475	**0.760**

mediating effect exists. Fig. 2 shows the SEM results with standardised beta measures and their significance.

5. Discussion

5.1. Findings

This study explores the impact of digital infrastructure and the regulatory environment on organisational digital innovation. The findings show that digital infrastructure is positively related to digital innovation, thereby supporting H1 within the conceptual framework. This result is consistent with the previous research [64,122], confirming that digital infrastructure is the core competitiveness of maintaining innovation in the digital ecosystem [123]. It enables the design of new products and services, enhances the ability to acquire enterprise information, and expands the boundaries of enterprise innovation [124], thereby promoting organisational digital innovation. This finding provides evidence that digital infrastructure construction that outside enterprises can impact organisational digital innovation. Compared with traditional infrastructure, digital infrastructure includes digital technologies and intelligent platforms that break the boundaries of enterprise design, R&D, production, sales and other links, and can provide the necessary technical resources for enterprises' digital innovation activities.

The findings of this research show that in the digital era, the regulatory environment also has a direct impact on organisational digital innovation, including policies that related to data elements, the digital market and digital talents and relevant regulatory measures regulating digital market competitions. Thus, H_2 in the conceptual framework is supported, which is compatible with previous literature [125,126]. Government subsidies and tax incentives can effectively incentivise relevant enterprises to carry out digital innovation activities through financial subsidies such as loan discounts, project subsidies, and

Table 9
Hypothesis 6-7 results (bootstrap).

Hypothesis	Path	Direct effect	Indirect effect	Result
H6	Digital Infrastructure→Data Flows→Digital Innovation	0.319* ($p = 0.085$)	0.051** ($p = 0.042$)	Supported (Partial mediation)
H7	Regulatory Environment→Data Flows→Digital Innovation	0.255* ($p = 0.077$)	0.048** ($p = 0.042$)	Supported (Partial mediation)

Note: *** = $P < 0.01$; ** = $p < 0.05$; *$p < 0.10$.

Table 8
Hypothesis 1-5 results.

Hypothesis	Path	S.T.D. (β)	C.R.	p-Value	Results
H1	Digital Infrastructure→Digital Innovation	0.319***	2.726	0.006	Supported
H2	Regulatory Environment→Digital Innovation	0.255**	2.152	0.031	Supported
H_3	Digital Infrastructure→Data Flows	0.302**	2.313	0.021	Supported
H4	Regulatory Environment→Data Flows	0.284**	2.140	0.032	Supported
H5	Data Flows→Digital Innovation	0.168***	2.719	0.007	Supported

Note: *** = $P < 0.01$; ** = $p < 0.05$; *$p < 0.10$.

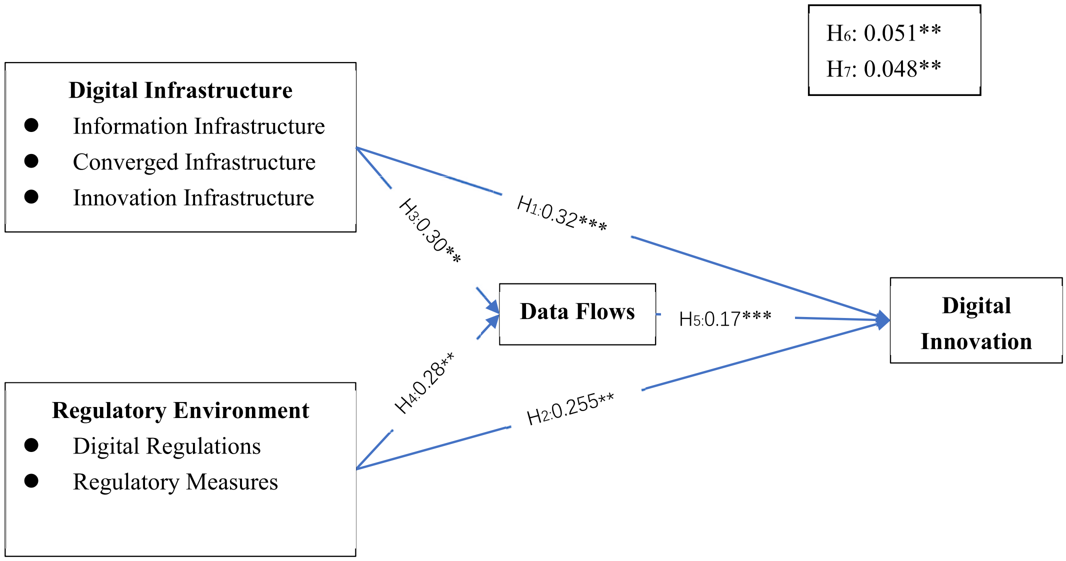

Fig. 2. SEM results with beta measure and significance.

post-incentives.

The findings also show that both digital infrastructure and the regulatory environment are positively and indirectly related to digital innovation through data flow, thus supporting H3, H4 and H5. The construction of digital infrastructure can provide a technical foundation and promote the spread of data elements, which will promote organisational digital innovation. Existing research reports that digital infrastructure can support design, production, and even products and services across organisations and their value chains and that digital platforms and ecosystems can share more data and processes across organisational boundaries [60,127] and allow information to travel across spatial distances [58]. Thus, the construction of digital infrastructure can boost data flows within the digital innovation ecosystem. Governments are an important component of the digital innovation ecosystem. The development and implementation of digital-related regulations by governments to create a regulatory environment for various innovative activities in the digital innovation ecosystem affect the mobility and security of data flow within the ecosystem.

The bootstrap results confirm the mediating effect of data flows, supporting H6 and H7. Existing research on the role of data flows between external factors and organisational digital innovation focuses only on conceptual and theoretical perspectives, and there is still a lack of empirical research. The results of this study provide evidence of the mediating role of data flows from the perspective of the digital innovation ecosystem. The flow and deformation of data elements have the potential to generate new value and innovative applications. Data flows within the digital innovation ecosystem in the form of innovation elements, thereby activating, connecting, and aggregating the innovation activities of multiple subjects. Digital infrastructure, as a ‘highway’ for data flow, facilitates the flow of innovation elements and intellectual capital within and between enterprises. The formulation and implementation of policies related to the digital economy enabled data to flow within the ecosystem, thereby encouraging enterprises to actively carry out digital transformation. In turn, the flow of data elements can promote the effective transmission of information between the market and government and between government departments so that the government can better provide services for relevant enterprises, and the relevant policies of the digital economy can better release the incentive energy for innovation, thereby stimulating the digital innovation of enterprises. This result is consistent with existing research [128], which confirms that by establishing a reasonable intellectual property protection mechanism and fair market access rules, digital innovation achievements can be protected and more enterprises and individuals can be incentivised to participate in innovation activities.

5.2. Theoretical contributions

First, this study considers digital infrastructure and the regulatory environment as the external environment from the perspective of the digital innovation ecosystem and explores the flow of data elements as a link between the external environment and the behaviour of innovation subjects, enriching the research on innovation ecosystem theory. In contrast to most existing studies based on internal business and management aspects [31–34], this study combines research on the theory of the digital innovation ecosystem with the unique characteristics of digital innovation activities. This includes the organisation, elements, and technology, with a focus on the impact of external factors on enterprise digital innovation activities, and take data elements as innovation elements in the digital innovation ecosystem to explore the mediating effect of data flows on the relationship between digital infrastructure, the regulatory environment, and digital innovation. The results of this study show that the sound construction of digital infrastructure and the support of the government in the regulatory environment play a direct role in promoting the digital innovation activities of enterprises, which can encourage innovation subjects to carry out digital innovation activities from the outside and helps solve the problem of insufficient subjective initiative of innovation subjects to carry out digital innovation to a certain extent.

Second, most of existing research on the digital innovation ecosystem focuses on the theoretical analysis of the connotations and approaches of digital innovation, and there is a lack of empirical support. The findings provide empirical evidence for digital innovation ecosystem theory. Moreover, the construction and governance of digital ecosystems in the Chinese context deserve in-depth study. If digital innovation ecosystems are regarded as adaptive systems in complex environments, then the Chinese context is fertile ground for exploring theories related to the construction and governance of digital innovation ecosystems. On the one hand, China’s institutional environment and market environment are extremely complex and special [38]. On the other hand, exploring the construction and governance of digital innovation ecosystems in the Chinese context, contributes to existing theories and guides Chinese management practices.

Moreover, most existing digital innovation-related studies use second-hand data provided by government agencies or investigating organisations and employ data such as the number of patented inventions to characterise digital innovation. Primary data obtained from enterprises that invest in digital innovation are rare and challenging. This study introduces digital infrastructure, the regulatory environment, and data flows into the framework of research on digital innovation, employes a quantitative survey to collect data from China, and identifies the external factors that influence organizational digital innovation and the mechanisms of their impact.

5.3. Practical contributions

First, the results of this study show that sound digital infrastructure and a supportive regulatory environment play a direct role in promoting the digital innovation activities of enterprises and stimulating the willingness of innovation subjects to carry out digital innovation activities from external factors. To some extent, this can help overcome the insufficient motivation for enterprises conducting digital innovation to a certain extent. This study can provide a decision-making basis for enterprises by identifying the external environment that affects organisational digital innovation. Enterprises could explore and seize the favorable factors in the institutional environment in a timely manner, which is the key to obtaining the expected benefits of digital innovation. For internet enterprises, which have the leading advantage of digital background, the results of this research can help them achieve vertical collaboration with local traditional industries, such as implementing industrial Internet or 'Internet + manufacturing'. For traditional industries, such as farming and manufacturing, the results can help enterprises carry out digital transformation and help latecomers catch up with opportunities by focusing on the cultivation of digital-related capabilities and readiness. Therefore, this study can provide a decision-making reference for the conducting innovation activities of internet-based enterprises, implementing digital transformation of traditional enterprises, and the development of emerging and future industries, motivate innovation subjects to increase digital innovation output, enhance the collaborative development of enterprises in the digital innovation ecosystem, and improve the competitiveness of enterprises.

Second, the results show that the flow of data elements significantly promotes digital innovation, and the external environment can also indirectly affect digital innovation activities through data flow. This conclusion highlights the importance of data flows and provides theoretical guidance for governments to explore and formulate relevant policies and regulations to promote the flow of data elements, thereby releasing the value of data elements and creating a regulatory environment for the benign flow of data. To improve the flow environment of regional data elements, policymakers should strengthen the construction of regional digital infrastructure, formulate a comprehensive and systematic development plan for the flow of data elements, strengthen the standardisation of supporting facilities such as market laws and regulations, establish a platform for data element trading and open sharing, promote the safe and efficient flow of data elements, and stimulate initiative digital innovation within enterprises. On the one hand, it is necessary to strengthen regional digital infrastructure, rationally plan and deploy digital infrastructure according to the characteristics of different regions and industries, and improve the coverage and applicability of digital infrastructure. New-generation information technologies such as 5G, cloud computing, and big data should be promoted; the level and coverage of digital infrastructure improved; and the necessary technical support and guarantees for the value of data elements provided. On the other hand, the establishment of data element trading and open sharing platforms, focusing on the development of the digital economy and the wide regional radiation driving effect of the region, and the construction of industry characteristics of the industry data trading platform can promote the integration and sharing of data in the industry. Platforms should be interconnected and move beyond regional and industry barriers. This would include unified data transaction circulation rules, perhaps with a unified national quotation and decentralised transaction data trading venue system. Simultaneously, with the rapid growth of digital innovation, the overall intensity of government subsidies for digital innovation should be increased, and financial resources should be used to leverage digital enterprises' own R&D investments and social capital supplements to form a diversified innovation investment system.

5.4. Limitation

Considering the availability of data, this study used the convenience sampling method to collect samples, which has some shortcomings: first, the researcher's work area is one of the most developed regions in China's digital economy, and with the support of favorable factors such as a broader space for digital development in the region and an exemplary and leading role of digital benchmarking enterprises, it is easier for enterprises to achieve positive results in digital innovation. However, in fact, there are great differences in the development of the digital economy in different regions of China, and future research can divide the digital development level of enterprises in the regions where enterprises are located into high, medium and low levels, and compare the characteristics of digital innovation of enterprises at different levels, as well as the differences in the role of the external environment on the digital innovation of enterprises to explore new discoveries. Second, the total sample size is small, and an attempt should be made to expand the sample size in the future to enhance the reliability and accuracy of the research conclusions. As this study is limited to enterprises in China, samples from other countries or regions and larger sample size can be taken to cross check this relationship in future investigations. Third, digital innovation is developing quickly, and new influencing factors and mechanisms could be investigated.

6. Conclusion

These findings provide evidence that the external environment, such as digital infrastructure and the regulatory environment, directly and indirectly affects organisational digital innovation. Data flows within the digital innovation ecosystem connects the external environment to innovative activities. The flow of data elements is limited by the digital infrastructure and regulatory environment, which also influence organisational digital innovation. Digital infrastructure can provide the necessary technical resources for enterprises' digital innovation activities and promote the flow of knowledge and innovation elements within and between organisations. The regulatory environment around data flows has a vital impact on the mobility and security of data elements and ultimately influences organisational digital innovation. The findings and conclusions of this study can provide guidance for enterprises to successfully transform and achieve digital innovation performance using digital technologies, and can also provide a basis for government decision-making such as restrictions on cross-border data flows.[2]

CRediT authorship contribution statement

Yue Xia: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Md Gapar Md Johar:** Supervision.

Consent for publication

All the authors read and agreed to publish this article.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1

Measurement items.

Constructs		Items	Item contents	Sources
IF	INFO	INFO1	Scale of local information infrastructure construction is large with fast progress.	Sun [129]
		INFO2	The cost (time, expense) of connecting information infrastructure for enterprises is in line with expectations.	Sun [129]
		INFO3	Fiscal incentives are in place to accelerate the development of information infrastructure.	World Bank Group [130]
	CONV	CONV1	Scale of local converged infrastructure (intelligent transportation, smart energy, etc.) construction is large with fast progress.	Sun [129]
		CONV2	The cost (time, expense) of connecting converged infrastructure for enterprises is in line with expectations.	Sun [129]
		CONV3	Fiscal incentives are in place to accelerate the development of converged infrastructure.	World Bank Group [130]
	INNO	INNO1	Scale of local innovative infrastructure construction is large with fast progress.	Sun [129]
		INNO2	The cost (time, expense) of connecting innovative infrastructure for enterprises is in line with expectations.	Sun [129]
		INNO3	Equal access is available to local innovative infrastructure.	World Bank Group [130]
RE	DGRG	DGRG1	The local government actively explores and formulates relevant policies for data elements such as data collection, openness, trading, use, and protection.	Zhang and Ma [75]
		DGRG2	Local governments are actively exploring and formulating relevant policies and regulations that are conducive to competition in the digital market, such as setting up digital free trade zones, cross-border e-commerce comprehensive pilot zones, and encouraging digital small and micro enterprises to join the digital market.	Zhang and Ma [75]
		DGRG3	The local government is actively exploring and formulating policies related to digital talents, such as the introduction and cultivation of digital talents.	Zhang and Ma [75]
	RGMS	RGMS1	The local government has corresponding regulatory measures for existing unfair competition behaviors in the digital market such as platform monopolies.	Zhang and Ma [75]
		RGMS2	The local government has regulatory measures in place to regulate the quality of services and goods on online platforms.	Zhang and Ma [75]
		RGMS3	The local government has corresponding regulatory measures for the protection of online intellectual property rights, as well as corresponding regulatory measures for the security of personal information and data.	Zhang and Ma [75]
DTFL		DTFL1	Local data controller or processor must comply with the relevant provisions on the data retention period.	ECIPE [131]
		DTFL2	Local data controllers or processors are subject to a set of restrictions imposed on online content (e.g., restrictions on approving and filtering web content).	ECIPE [131]
		DTFL3	Local data intermediaries (e.g., various types of social media platforms) must comply with local intermediary liability provisions (e.g., notice of take-down regimes, etc.).	ECIPE [131]
		DTFL4	The local data controller or processor must comply with the relevant administrative processing procedures established by the local supervisory authority in order to lawfully process personal data.	World Bank Group [130]
		DTFL5	Local data controllers or processors must comply with relevant local security requirements regarding the automatic collection of personal data.	World Bank Group [130]
DIIN		DIIN1	Your company's processes are being automated by digital technologies.	Xu [132]
		DIIN2	Your company is introducing digital technologies that can enhance management communication inside and outside your organization.	Xu [132]
		DIIN3	Your company is up-to-date with data or related information stored in digital infrastructure (e.g. data centers), production equipment, and R&D tools.	Xu [132]
		DIIN4	Your company can continuously and in real time obtain various internal and external information through digital technology.	Xu [132]
		DIIN5	Your company is improving its products or services based on digital technologies.	Xu [132]

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techsoc.2024.102802.

Data availability

Data will be made available on request.

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