The Impact of Digital Infrastructure Construction on Enterprise Innovation

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Abstract. By enhancing the efficiency of enterprise innovation, information acquisition and sharing, and collaborative capabilities, digital infrastructure increasingly amplifies and energizes enterprise innovation. Based on data from China's A-share listed companies from 2008 to 2021, this paper uses a bidirectional fixed effect model to empirically investigate the impact and mechanism of digital infrastructure on enterprise innovation. The study finds that digital infrastructure significantly promotes enterprise innovation, with the conclusions still holding after a series of robustness tests. Furthermore, mechanism analysis indicates that digital infrastructure primarily influences enterprise innovation through the dual paths of financing constraints and the aggregation of innovation elements. Additionally, both corporate ownership structure and digital infrastructure have a positive and significant impact on enterprise innovation and are substitutes for each other. Heterogeneity analysis reveals that digital infrastructure in the western region significantly affects its enterprise innovation, whereas the other three regions do not show significant effects. Similarly, digital infrastructure significantly impacts innovation in medium-sized enterprises, but not in large-scale or small-scale enterprises.

Keywords: Digital Infrastructure; Enterprise Innovation; Financing Constraints; Aggregation of Innovation Elements.

1. Introduction

In the post-pandemic era, traditional infrastructure faces challenges such as limited innovation and increased costs. Technologies like AI, big data, and blockchain are driving the need for digital transformation. Globally, countries, including China, are focusing on new digital infrastructure. China's "Digital China" plan, launched in 2023, aims for efficient digital infrastructure by 2025 and global leadership by 2035. This digital foundation is crucial for offering businesses new opportunities for innovation and growth.

Digital infrastructure is reshaping global resources, economic patterns, and competition by driving innovation and supporting the digital economy, making it essential for productivity and business innovation in the post-pandemic era.Today, within the important components of national economies, the future development of enterprises has become a critical point in promoting economic growth, creating employment opportunities, and tackling global challenges. Meanwhile, as a wave of digital transformation surges worldwide, Chinese enterprises must delve deeply into digital innovation and seize the opportunities and challenges brought about by this digital revolution. For the internal dynamic of enterprises, factors like company size, ownership structure, and executive incentives that impact corporate innovation have already been thoroughly analyzed(He Jun et al., 2016; Wu Yuankai et al., 2024)[1][2]. In recent years, as digitalization plays an increasingly larger role in life, society, and business, more scholars are turning their attention to studying the impact of digital infrastructure construction on enterprise innovation and its underlying mechanisms, ensuring that businesses can remain stable despite external turmoil.

As a new type of infrastructure system, the completeness of digital infrastructure lays the material and technological foundation for local enterprises to enhance the application of digital technology and accelerate digital transformation and upgrading. At the same time, by reducing the degree of information asymmetry through industrial agglomeration, it compresses the cost of technology spillover and implementation transactions between enterprises, promotes the co-construction and sharing of innovation resources, and injects new momentum into enterprise innovation. So, what is the impact of digital infrastructure construction on promoting the creative transformation and innovative development of enterprises? What is the intrinsic mechanism of action? Does the impact of digital infrastructure on enterprise innovation behavior vary with the ownership structure of the enterprises? A deep exploration of these questions is of great practical significance for leveraging the empowering role of digital infrastructure in enterprise innovation and enhancing core competitiveness, while also providing important theoretical insights for the country to form new productive forces.

2. Literature Review

With the rapid development of the digital economy, digital infrastructure construction plays a crucial role not only in enterprises, society, and the nation but also permeates all aspects of people's lives. Relevant research generally falls into the following areas: First, the impact of digital infrastructure on the macroeconomy. Studies show that digital infrastructure can promote dual-cycle economic development through optimizing economic structures and enhancing technological innovation. Specifically, digital infrastructure empowers urban-rural integration, accelerating economic construction and development, achieving balanced and coordinated spatial layout in terms of population flow and integration, and economic structure optimization and upgrading (Han Li et al., 2024)[3]. Additionally, digital infrastructure can effectively aid high-quality economic development, with a reverse spillover effect on empowering such development. Second, the impact on micro-level enterprises. Digital infrastructure can enhance total factor productivity by strengthening the agglomeration of innovation factors in regions (Xiu Guangli, 2024)[4] and can expand the boundaries of enterprise innovation by broadening access to market and technological information (Guo Feng et al., 2021)[5]. Third, influencing factors. The input of resources such as human capital and financial support is the basis and guarantee for fully leveraging the innovation empowerment effect of digital infrastructure construction (Guo Jinhua et al., 2023)[6].

Regarding research on enterprise innovation, existing literature mainly focuses on internal influencing factors. First, it considers cost control (Yu Liufang et al., 2024)[7], R&D investment (Chen Fang, 2024)[8], and effective corporate governance as key factors affecting enterprise innovation. Studies have found that good ESG performance helps improve innovation performance (Ding Yufang et al., 2024)[9]; customer stability positively promotes innovation (Liu Zhenhua et al., 2024)[10], and core employee equity incentives can boost innovation output (Wu Weihong et al., 2024)[11]. Second, from the perspective of external factors influencing innovation, research indicates that the main drivers of innovation include intellectual property protection systems and incentives from relevant industrial policies (Yu Minggui, 2024)[12].

Moreover, with policy support and the advent of nationwide digitalization, most scholars prefer to study the impact of external digital infrastructure construction on enterprise innovation. At the macro level, research shows that digital infrastructure construction enhances regional innovation activity by improving regional innovation levels and creating a favorable business environment (Li Qirong et al., 2024)[13]. It also facilitates urban-rural integration, promoting economic construction and development, population flow and integration, economic structure optimization and upgrading, and achieving balanced and coordinated spatial layouts (Han Li et al., 2024)[3]. Consequently, improved regional innovation and technological levels can drive the development of enterprise innovation capabilities. At the micro level, digital infrastructure construction helps enterprises overcome digital transformation challenges, enhancing innovation incrementally and efficiently, with a significant empowerment effect on innovation (Hua Yun, 2024; Guo Jinhua et al., 2023)[14][6]. Furthermore,

the "Internet+" strategy continuously promotes R&D investment in enterprises, with its impact increasing annually (Wang Fang et al., 2020)[15]. Lastly, some scholars have found that the development of internet technology reduces costs by improving productivity, reducing resource mismatch, and promoting innovation, thus acting as an engine for enhancing logistics efficiency and cost-effectiveness (Huang Qunhui et al., 2019; Lu Yahe, 2021)[16][17].

Research focuses on traditional impacts of digital infrastructure, like cost reduction and incentive optimization, while overlooking its role in driving digital transformation through model innovation and technology integration. Effects on resource optimization, efficiency, and cost reduction remain underexplored. Future studies should address its broader impacts on enterprise innovation.

The marginal contributions of this paper are as follows: First, it combines macro environment and micro enterprise perspectives to comprehensively analyze the digital processing and technological integration of enterprise innovation, total factor productivity, and resource allocation optimization by digital infrastructure construction. Second, it reveals the mechanisms through which digital infrastructure affects enterprise innovation, analyzing the mechanisms and impact paths from the perspectives of digital transformation, digital finance, and financing constraints. Third, it explores the moderating effect of digital infrastructure on enterprise innovation behavior based on the nature of enterprise ownership.

3. Theoretical Analysis and Research Hypotheses

3.1. The Direct Effects of Digital Infrastructure Construction on Enterprise Innovation

Digital infrastructure has become a driving force for business transformation in the global digital economy, particularly in high-tech industries, by enhancing resource allocation efficiency, upgrading industrial structures, and promoting industrial agglomeration, thus boosting innovation performance (Yang Zhian and Meng Siyu, 2024)[18]. It impacts enterprise innovation by reducing investment barriers through integrated infrastructure like cloud computing and big data, which provide access to computing and storage without large initial costs, enabling small businesses to experiment and analyze data for better market insights and innovation decisions. Computational infrastructure, such as high-performance computing and AI chips, increases innovative output by allowing complex simulations, shortening development cycles, and enhancing success rates. For instance, in new materials R&D, these tools can rapidly screen materials, improving efficiency and output. Additionally, network infrastructure like 5G and the industrial Internet facilitates the transition of innovations from lab to market by supporting remote collaboration and real-time control, speeding up product introduction. In smart manufacturing, this enables flexible production lines for quick product launches.

Based on the analysis above, this paper proposes Hypothesis 1.

Hypothesis 1: Digital infrastructure construction has a positive effect on promoting enterprise innovation.

3.2. The Intrinsic Mechanisms of How Digital Infrastructure Construction Affects Enterprise Innovation

(1) The Alleviating Effect of Digital Infrastructure Construction on Financing Constraints

Digital infrastructure significantly promotes enterprise innovation by alleviating financing constraints. It employs technologies like big data, cloud computing, and AI to improve transparency and reduce information asymmetry, thereby boosting investor confidence. This increased trust facilitates easier access to financial support, allowing companies to invest more in research and innovation. Financial institutions can leverage big data to monitor company information in real-time, assess credit risks accurately, and create personalized credit assessments, reducing bad debt risks and enhancing capital access (Mou Bin, Huang Hao, 2024)[19]. This financial backing enables firms to attract and retain top talent crucial for innovation. Additionally, digital infrastructure supports fintech development by optimizing payment systems and ensuring data security, offering diverse financing

channels. Online financing platforms and big data analysis simplify access to funding sources like bank loans, venture capital, and equity financing. These digital tools lower traditional funding barriers, enabling SMEs and startups to secure necessary capital. Adequate funding fosters interdisciplinary collaboration and the formation of diverse innovation teams, significantly boosting a company's innovative capacity (Yang Xiaomei, Pang Qiannan, 2023)[20].

Based on the above analysis, this paper proposes Hypothesis 2.

Hypothesis 2: Digital infrastructure construction can promote enterprise innovation by alleviating financing constraints.

(2) The Agglomeration Effect of Digital Infrastructure Construction on Innovation Elements

Digital infrastructure plays a significant role in promoting the aggregation of innovation elements. Firstly, this aggregation is reflected in the concentration of innovation funds, talent, environment, and outcomes (Zhao Ti, 2024)[21]. Digital infrastructure has a platform effect, facilitating the creation of well-established databases and network infrastructure that allow enterprises to share digital production elements via digital platforms. This forms a specialized factor supply market, broadens the channels and scope for enterprises to access resources, meets their demand for diverse innovation knowledge elements, and provides ample innovation resources and a favorable network sharing environment for research and development activities, thus promoting digital transformation (Xue Cheng et al., 2020)[22]. On the other hand, the aggregation of innovation elements promotes high-quality development in manufacturing through optimized allocation and economies of scale (Zhang Qing et al., 2024)[23]. Additionally, the application of digital technology shortens supply chain lengths, enhances supply chain efficiency, and reduces sunk costs in innovation activities, thereby fostering enterprise innovation behavior (Tu Lei et al., 2023)[24].

Based on the above analysis, this paper proposes Hypothesis 3.

Hypothesis 3: The construction of digital infrastructure can promote enterprise innovation by accelerating the agglomeration of innovative production factors.

3.3. The Moderating Effect of Corporate Ownership Structure

China is currently undergoing economic transition. As digitalization and market processes advance in areas where businesses operate, corporate ownership structures and governance improve. This significantly impacts owners, lowering financing costs, enhancing control and risk-resistance, and boosting company value. Research shows a symbiotic relationship between corporate ownership structure and innovation. Optimizing ownership structure improves the efficiency of various innovation activities, while innovation itself relies on a specific ownership structure (Xia Dong et al., 2005)[25]. From a corporate governance perspective, ownership structure determines not only the nature of the business but also its governance and management model, ultimately influencing managers' innovation tendencies, behavior, and risk management capabilities (Xu Ziyue, 2020)[26]. Both digital infrastructure and corporate ownership structure enhance innovation efficiency, but in areas with underdeveloped digital infrastructure and lower economic levels, limitations in hardware, a lack of skilled personnel, and insufficient awareness of digital technology come into play. In these cases, a well-structured ownership model can leverage internal funding, incentive alignment, and centralized management to help companies navigate resource scarcity and market instability more effectively. Conversely, for companies with less concentrated ownership, digital infrastructure can boost innovation through cost control, efficiency improvements, and digital transformation. Clearly, digital infrastructure and corporate ownership structure complement each other in driving enterprise innovation.

Based on the above analysis, this paper proposes Hypothesis 4:

Hypothesis 4: In regions with lower levels of digital infrastructure, the impact of corporate ownership structure on enterprise innovation is greater.

4. Research Design

4.1. Source of Sample Data

This thesis focuses on the analysis of China's Shanghai and Shenzhen A-share markets between 2011 and 2022. The number of patent applications and control variables at the enterprise level are mainly from the CSMAR database. The explanatory variable - digital infrastructure construction - is divided into inputs and outputs, based on data from China's Ministry of Industry and Information Technology's official list of model cities. At the same time, this study excluded companies with debt ratio greater than 1 and companies with unclear address information, and also excluded ST, *ST and listed companies in the financial industry. In order to avoid the influence of outliers, the continuous variables are Windsor treated by 1%.

4.2. Variable Explanation and Description

(1) Dependent Variable

Invention patents provide rich technical information and market insights, helping companies make more informed decisions during the innovation process. Based on this, the natural logarithm of the annual number of patent applications plus one is used as a measure of corporate innovation (rd_out) (Guo Jinhua et al., 2021)[27]. Specifically, considering the high difficulty of applying for invention patents, the total annual number of invention patents, utility model patents, and design patents is used to assess corporate innovation.

(2)Explanatory Variable

This study follows Wang Qin et al. (2023)[28], dividing explanatory variables into digital infrastructure input and output. Specifically, it categorizes fiber optic cable density, internet access ports per capita, and related workforce as digital infrastructure input (DID—input), while telecom business revenue, mobile phone penetration rate, and internet penetration rate are considered digital infrastructure output (DID—output). This dual perspective provides a more concrete and compelling measurement, enhancing the persuasive power of the results.

(3)Mediating Variable

This study selects mediating variables including financing constraints and innovation factor agglomeration. (1) Financing constraints (finan) are assessed by referencing Whited T M et al. (2006)[29], using a nonlinear GMM method to estimate Euler equation parameters, obtaining firm-level data such as total assets, long-term liabilities, and sales growth rate, measured through the WW index. (2) Innovation factor agglomeration can drive various resources and factors conducive to innovation, such as talent, capital, technology, information, and market demand, creating a more favorable environment for innovation and enhancing overall innovation capability and economic development. This study references Gao Panfeng (2024), selecting capital factor agglomeration (Capi) and talent factor agglomeration (per) as two dimensions for measurement. Specifically, capital factors are measured by (regional R&D funds/regional total population)/(national R&D funds/national total population), and talent factor agglomeration is measured by (regional R&D personnel/regional total population)/(national R&D personnel/national total population), assessing the essence of innovation factors from both talent and capital perspectives.

(4)Control Variable

Control Variables: To comprehensively and objectively analyze the impact of digital infrastructure on corporate innovation, it is necessary to control for variables that might affect corporate innovation behavior. This study, following the approach of Tao Yunqing et al.(2024)[23], controls for several important firm characteristics: firm size (Size), cash flow ratio (Cashflow), debt-to-equity ratio (ROE), dual roles (Dual), ownership nature (SOE), number of directors (Board), board independence (Indep), years listed (Age), and total asset turnover (ATO). Additionally, it also references Wang Lei et al.'s approach to control for important city characteristics: regional economic development level (Pgdp), financial development level (Fina), industrial structure (Stru), and government R&D investment (Govern).

(5)Moderating Variable

This paper selects the ownership structure of enterprises (Own) as a moderating variable to explore the internal logic of how digital infrastructure influences enterprise innovation. Currently, the shareholding ratio of the largest shareholder (Top1) is commonly used as a standard to measure the ownership structure of enterprises. Moreover, this ratio is a key indicator for assessing the concentration of company ownership, reflecting the distribution of control rights and governance structure. It not only indicates the distribution of control rights and governance structure but is also closely related to company performance.

4.3. Sample and Data

Table 1 shows the descriptive statistics for the variables. From Table 1, the average digital infrastructure is 0.081 with a standard deviation of 0.03, ranging from a minimum of 0.03 to a maximum of 0.16. This indicates quite a variation in digital infrastructure levels among companies, highlighting the need to enhance overall digital infrastructure. Additionally, the average corporate innovation stands at 1.724, with a standard deviation of 1.551, a maximum of 6.004, and a minimum of 0, suggesting significant differences in innovation capabilities among various companies.

Table 1: Descriptive Statistics

Variable	Ob	Mean	Std	Min	Max
Patentapplied	28721	1.724	1.551	0	6.004
DID	28721	0.081	0.030	0.030	0.160
SA	28721	-3.809	0.276	-5.888	-1.805
Capital element concentration	28721	0.653	0.405	0.005	2.380
Talent element concentration	28721	0.218	0.192	0.002	0.945
Size	28721	22.174	1.300	19.888	26.249
Lez	28721	0.399	0.206	0.043	0.875
ROE	28721	0.066	0.130	-0.651	0.351
Cashflow	28721	-0.116	0.517	-3.032	0.976
Dual	28721	0.290	0.454	0	1
Board	28721	2.123	0.199	1.609	2.708
Indep	28721	0.376	0.054	0.333	0.571
ATO	28721	0.141	0.105	0.008	0.591
SOE	28721	0.338	0.473	0	1
Age	28721	2.887	0.334	1.792	3.526
GDPGrowth	28721	10.110	0.654	7.833	10.882

5. Empirical Analysis

5.1. Baseline Regression Results

Table 2 presents the baseline regression results on the impact of digital infrastructure on corporate innovation. In column (1) of Table 3, no control variables are considered, only the time fixed effect is controlled. Column (2) adds individual fixed effects to column (1). Column (3) further includes all control variables based on column (2). Overall, columns (1) to (3) demonstrate that the regression coefficients of digital infrastructure (DID) on corporate innovation are significant and positive at the 1% and 10% levels, respectively, indicating a positive correlation between digital infrastructure and corporate innovation. This shows that digital infrastructure significantly promotes corporate innovation, validating Hypothesis 1.

Table 2: Baseline Regression

	(1)	(2)	(3)
Variable	Patentapplied	Patentapplied	Patentapplied
DID	1.7228***	0.6929*	0.6707*
	(5.0067)	(1.8286)	(1.7742)
Size			0.0761***
			(4.9552)
Lez			0.0251
			(0.5136)
ROE			-0.0220
			(-0.4865)
Cashflow			-0.0190*
			(-1.9284)
Dual			-0.0162
			(-0.9312)
Board			-0.0757
			(-1.2358)
Indep			0.0286
			(0.1501)
ATO			-0.2798***
			(-3.5090)
SOE			0.0093
			(0.2542)
Age			0.1225
			(1.2331)
GDPGrowth			0.0397
			(0.4974)
Constant	1.5852***	1.6683***	-0.5931
	(54.5106)	(53.9457)	(-0.6263)
Observations	28,721	28,721	28,721
R-squared	0.014	0.811	0.812

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2. Endogeneity Test

To mitigate the impact of endogeneity in the explanatory variables, this paper uses the first-order lag of DID (IV) as an instrumental variable for regression testing. Table 3 shows the test results. After controlling for individual and time-level variables, there is no direct relationship between the first-order lag of DID and enterprise innovation behavior, meeting the requirement for exogeneity. The endogeneity test validated the effectiveness of the baseline regression results. After re-estimating the model using the fitted values from the first stage, the regression results from the second stage show that the regression coefficient of the core explanatory variable DID remains significantly positive. From the weak instrument variable test, there is sufficient reason to reject the weak instrument variable hypothesis, suggesting that all instrumental variables are exogenous. Thus, after addressing the endogeneity issue, the original conclusion still holds, namely, that digital infrastructure construction can promote enterprise innovation behavior. The results of addressing the endogeneity issue are as follows:

Table 3: Instrumental Variable Test

Variable	Joint Fixed Effects	2SLS First Stage	2SLS Second Stage
DID	0.6897* (1.7742)		1.114*** (0.3883)
IV		0.8922*** (233.27)	
Control	YES	YES	YES
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	29246	25821	25821
Wald test			1825.18

5.3. Mechanism of Impact

(1) Financing Constraint Mechanism

Digital infrastructure enhances data transmission and communication, allowing companies to easily access and share information. This facilitates market research, technology exchange, and resource acquisition, reducing information asymmetry risks and boosting innovation. Additionally, advanced digital tools like cloud computing and AI improve resource allocation and project development efficiency, lowering innovation costs. As financial constraints ease, companies can invest more in R&D, enhancing competitiveness and driving industry-wide technological progress. This study uses the KZ index to measure the degree of corporate financing constraints; a higher KZ index indicates lower financing constraints. As shown in column (1) of Table 4, when financing constraints (KZ) are the dependent variable, the regression coefficient for digital infrastructure (DID) is 0.0805, significantly positive at the 1% level. This suggests that digital infrastructure can promote corporate innovation by alleviating financing constraints, thereby verifying Hypothesis 2.

(2)Innovation Element Aggregation Mechanism

Digital infrastructure creates fast and stable data networks, allowing companies to integrate resources and collaborate globally. This capability helps businesses quickly access innovation resources and exchange knowledge, accelerating innovation and enhancing capabilities. Additionally, through cloud computing and big data, companies can manage innovation activities more efficiently and optimize resources, reducing time and costs. This enables a focus on core innovations rather than basic infrastructure, boosting technological competitiveness and accelerating industry evolution and competition. This study uses the innovation talent mismatch index and the innovation capital mismatch index to measure corporate innovation aggregation. The lower the mismatch index, the higher the degree of innovation aggregation. The results are shown in column (2) and column (3) of Table 4. The regression coefficients for digital infrastructure (DID) are -2.4258 and -1.9037, respectively, significantly negative at the 1% level. This indicates that digital infrastructure significantly enhances overall corporate innovation capability through promoting innovation aggregation, thus confirming Hypothesis 3.

Table 4: Mechanism Test

Variable	(1) KZ	(2) Talent element concentration	(3) Capital element concentration
DID	0.0805***	-2.4258***	-1.9037***
	(-2.1074)	(-24.1105)	(-30.4517)
Constant	-3.4849***	1.0405***	0.6402***
	(-36.2026)	(2.6772)	(3.0234)
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Control	YES	YES	YES
Observations	28,721	28,721	28,721
R-squared	0.968	0.750	0.500

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.4. The Substitution Effect of Corporate Ownership Structure on Digital Infrastructure

The empirical results mentioned earlier indicate that digital infrastructure development positively impacts corporate innovation. To gain deeper insights into the causal relationship between the two, this study will further examine the moderating role of corporate ownership structure in the relationship between digital infrastructure development and corporate innovation.

To test Hypothesis 4, this study is based on the model.

Patentapplied=$\lambda_0 + \lambda_1$DID+λ_2Top1+λ_3DID*Top1+λ_4Controls+μ_i+ν_t+ϵ_{it}

The results are shown in Table 5. Columns (1) and (2) of Table 6 indicate that regardless of whether control variables are included, there is a significant positive relationship between corporate ownership structure and digital infrastructure development with corporate innovation. Specifically, both corporate ownership structure and digital infrastructure development show a significant positive correlation with corporate innovation at the 1% and 5% statistical levels, while their interaction term is significantly negatively correlated at the 5% statistical level. This result suggests that the impact of corporate ownership structure and digital infrastructure on corporate innovation is mutually permeating and substitutive. The reason lies in their different roles in resource allocation, decision-making mechanisms, incentive mechanisms, and corporate culture. Since both corporate ownership structure and digital infrastructure can effectively drive innovation, to some extent, companies may not rely solely on digital infrastructure investment, and vice versa. Moreover, companies can strengthen or substitute investments and structural designs in these two areas, thereby influencing their innovation capabilities to some extent. This finding supports Hypothesis 4.

Table 5: Results of the Moderating Effect of Corporate Ownership

Variable	(1) Patentapplied	(2) Patentapplied
DID	1.0135**	1.0104**
	(2.2761)	(2.2713)
top1	0.4699***	0.6571***
	(2.9488)	(3.9387)
interact	-7.7034**	-6.9210**
	(-2.2551)	(-2.0271)
Constant	1.5049***	-1.6754
	(23.9826)	(-1.4100)
Control	NO	YES
Year FE	YES	YES
Firm FE	YES	YES
Observations	20,400	20,400
R-squared	0.812	0.813

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Heterogeneity Test

6.1. Provincial Heterogeneity Analysis

Enterprises in different provinces and of varying sizes exhibit significant differences in terms of economic development level, policy environment, and resource accessibility. This study categorizes the sample based on provincial geographic locations into eastern, central, western, and northeastern regions, and by enterprise size into large, medium, and small-sized enterprises. The heterogeneous impact of digital infrastructure development on innovation performance across these different types of enterprises is examined, with results presented in Tables 6 and 7.

According to the results shown in Table 6, columns (1), (2), and (4) indicate that the regression coefficients for digital infrastructure development (DID) on corporate innovation (Patent applied) are not significant in these three regions. This suggests that the impact of digital infrastructure on corporate innovation in these areas is not notable. However, column (3) reveals a significant positive correlation between digital infrastructure (DID) and corporate innovation (Patent applied) at the 1% statistical level, indicating that digital infrastructure in the western region has a significant effect on corporate innovation.

Table 6: Results of Provincial Heterogeneity Analysis

Variable	(1) east Patentapplied	(2) center Patentapplied	(3) west Patentapplied	(4) northeast Patentapplied
DID	-0.0718	0.0090	3.1923***	0.9464
	(-0.1114)	(0.0127)	(2.9266)	(0.7585)
Constant	-0.1667	0.5478	0.1352	1.5261
	(-0.0990)	(0.4726)	(0.1102)	(0.7434)
Year FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
Control	YES	YES	YES	YES
Observations	20,319	4,015	3,967	930
R-squared	0.810	0.814	0.802	0.779

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6.2. Enterprise Scale Heterogeneity Analysis

There are significant differences in innovation drivers among enterprises of different sizes. Large companies focus on technology research and development and innovation, while small and medium-sized enterprises (SMEs), despite their relatively limited resources, tend to be more flexible and better able to adapt to market changes, excelling in specific areas such as innovative products. Analyzing the innovation performance of different-sized enterprises can reveal the varying impacts of digital infrastructure on the innovation capabilities of different types of businesses. According to Table 7, columns (1) and (3) indicate that their regression coefficients did not pass significance tests, suggesting that the impact of digital infrastructure is not significant. Similarly, for column (2), its regression coefficient shows a significant positive correlation at the 5% statistical level, indicating that digital infrastructure has a notable impact on the innovation of medium-sized enterprises. The reasons for this are that large enterprises typically already possess relatively mature digital infrastructure and technical capabilities, having invested heavily in information technology and automation projects early on. In contrast, while small enterprises are flexible, they often face limitations in funding, technology, and human resources. Lastly, medium-sized enterprises are generally in a growth and expansion phase, where their business needs, innovation motivations, and demands for digital transformation are more urgent, allowing them to keenly seize the opportunities brought by digital infrastructure. They leverage these new resources to enhance production efficiency, optimize business processes, and accelerate innovation, resulting in a significant impact from digital infrastructure.

Table 7: Results of Enterprise Scale Heterogeneity Analysis

	(1)	(2)	(3)
	Big	Middle	Small
Variable	paten_lnc	paten_lnc	paten_lnc
DID	-0.6186	0.9005**	-3.2559
	(-0.3037)	(2.2843)	(-1.3433)
Constant	-2.3377	-2.5913**	-7.5476*
	(-0.6592)	(-2.2535)	(-1.7013)
Control	YES	YES	YES
Year FE	YES	YES	YES
Firm FE	YES	YES	YES
Observations	1,315	26,297	1,433
R-squared	0.811	0.804	0.927

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7. Conclusions and Recommendations

This paper uses panel data from Chinese A-share listed companies between 2008 and 2021 to empirically analyze the impact and mechanisms of digital infrastructure construction on corporate innovation behavior, examining differences at the provincial and firm size levels. The findings are: (1) Digital infrastructure development promotes corporate innovation, a result that holds even after testing with alternative core explanatory and instrumental variables. (2) Digital infrastructure aids corporate innovation by easing financing constraints and facilitating the aggregation of innovation elements. (3) Heterogeneity analysis shows that while digital infrastructure has a diminishing marginal benefit for innovation in central and eastern regions, it has a more pronounced effect in the western regions. At the firm size level, medium-sized enterprises benefit most. (4) A more concentrated ownership structure enhances the promotion of corporate innovation.

Based on these conclusions, the paper suggests: First, accelerate network infrastructure to boost regional digital infrastructure and promote innovation, leveraging the role of digital infrastructure as an innovation driver and platform. Second, encourage the development of digital infrastructure to provide efficient, stable, and rapid data transmission and communication, reducing innovation costs and easing financing constraints for SMEs through more accessible financial services. Third, reinforce policy guidance for aggregating innovation elements such as talent and funds, building innovative cities to lower the time and cost of innovation. Fourth, encourage companies to concentrate ownership structures. Fifth, increase investment in digital infrastructure in weaker western regions to maximize the marginal benefits of corporate innovation. The government should emphasize the critical role of digital infrastructure in fostering corporate innovation by providing favorable external conditions to reduce inter-firm technology diffusion and innovation costs, and to create innovation platforms.

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