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Digital Economy Pilot Zones and Firm Innovation: Evidence from a Quasi-Natural Experiment in China

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Abstract: The digital economy and market-oriented reforms of data as a factor of production are reshaping firms' resource allocation and governance boundaries, creating new drivers and pathways for innovation. Using data on Chinese A-share listed firms from 2016 to 2022, this study treats the establishment of National Digital Economy Innovation and Development Pilot Zones as an exogenous policy shock and develops a multiperiod difference-in-differences (DID) and event-study framework to systematically assess its causal and dynamic effects on firm innovation. The results show that the pilot zone policy significantly improves firm innovation. This finding remains robust to a range of checks, including PSM-DID, industry-by-year fixed effects, an alternative count model, the exclusion of pandemic years, cluster-robust standard errors, and controls for concurrent policies. Mechanism analysis indicates that the policy operates primarily through three channels: alleviating financing constraints, advancing firms' digital transformation, and enhancing their investment value. Heterogeneity analysis reveals that the benefits are more pronounced among non-state-owned firms, firms located in regions with more advanced industrial structures, and firms with lower total factor productivity. This study contributes by identifying the net effect and stage-specific dynamics of market-oriented data factor reforms and providing firm-level evidence on the finance–digitalization–value transmission chain. The findings offer theoretical and empirical support for stimulating firm innovation through institutional provision in the digital economy.

Keywords: National Digital Economy Innovation and Development Pilot Zones; Innovation; Difference-in-differences model; Parallel trends test

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1. Introduction

Digital technologies are developing rapidly, and firms are changing how they produce goods, manage their activities, and run their businesses; these changes make the digital economy an important source of economic growth and industrial upgrading. For firms, digital transformation can bring lower costs and better use of resources; it also makes knowledge easier to share, providing better conditions for innovation in technology, organization, and management.

China introduced the National Digital Economy Innovation and Development Pilot Zones to link firm

innovation with the development of the digital economy. Within these zones, data are allocated through the market as a factor of production, and digital infrastructure is improved; efforts are also made to achieve breakthroughs in key digital technologies and take firms' digital transformation further. Through these measures, the zones seek ways to develop institutional innovation together with innovation in firms.

The effects of the pilot zones on firms still need to be examined using data. Policy implementation may vary with local digital foundations, industrial structures, and governance; firms' responses may also differ according to the resources they possess and their stage of development. The analysis therefore needs to consider the overall policy effect, the ways in which the policy works, and the conditions needed for it to work.

Research on the National Digital Economy Innovation and Development Pilot Zones has examined their effects at both the micro and macro levels. At the firm level, fiscal support and R&D innovation are the channels through which Zeng found that the policy significantly promotes digital transformation [1]. Li *et al.* focused on firm innovation; their findings show that the zones significantly encourage innovation through lower transaction costs, the attraction of talent, and digital transformation [2]. Firms' environmental, social, and governance (ESG) performance is examined by Zhang *et al.* using machine learning methods; they report significant improvements following the establishment of pilot zones, with digital transformation and technological upgrading playing particularly important roles [3]. Zhou and Zhou used a difference-in-differences approach to study risk-taking by firms. Their results show that the zones increase risk-taking by reducing financing constraints and agency costs; this effect is more pronounced in capital- and technology-intensive regions [4]. In their study of private firms, Shang and Wang reported a significant increase in collaborative innovation after pilot zones are established; faster digital transformation and a better ability to absorb knowledge help explain this increase [5].

At the macro level, Xia *et al.* considered new quality productive forces. Their study finds that these forces are significantly strengthened by the zones through technological innovation, the concentration of talent, and digital and intelligent transformation [6]. Song and Liu examined digital economic development and regional innovation output using provincial-level analysis; they find that expansion of the digital economy significantly increases regional innovation output, with improvements in industrial structure and reduced financing constraints among the channels involved [7].

These studies provide a basis for understanding the innovation effects of pilot zones. Further discussion is still needed on changes in policy effects over time, the composition of production factors within firms, and the different roles played by regional conditions; this study examines these issues through the links among financing, digitalization, and investment value. It also considers how firm characteristics and regional industrial structures affect firms' responses to the policy. This study uses data on A-share listed firms from 2016 to 2022; difference-in-differences and event-study methods are applied to examine the policy's effects on innovation and their changes over time. The mechanism analysis covers financing constraints, digital transformation, and investment value. Differences in the effects are then examined by firm ownership, regional industrial structure, and firm-level total factor productivity (TFP); the results provide evidence for adapting policy implementation to different conditions across pilot zones.

2. Theoretical analysis and research hypotheses

2.1. The effect of pilot zone establishment on firm innovation

In recent years, China has continued to test new institutional arrangements for the digital economy; in 2016, it had already introduced comprehensive big data pilot zones. These zones aimed to open up and share

government data, improve digital infrastructure, and encourage firms to use big data in management and R&D, helping firms use data and carry out digital transformation to some extent. However, higher-level institutional innovation and reforms in factor allocation were still lacking; unclear data rights and incomplete arrangements for data transactions and income distribution limited the role of data in firm innovation [8].

China built on this earlier initiative by introducing the National Digital Economy Innovation and Development Pilot Zones in 2019, with the aim of further developing market-based data allocation and institutional innovation. These regions have priority in reform tasks and policy support compared with areas outside the zones; this support covers clearer data rights, data transactions, flows of data across regions, and upgrades to digital infrastructure. Fiscal subsidies, tax incentives, innovation platforms, and support for R&D in key technologies allow the government to further reduce institutional barriers and resource difficulties in firm innovation. The zones also attract digital firms and highly skilled workers; their presence helps knowledge spread and strengthens connections within innovation networks. Compared with areas outside the zones, these regions therefore have more developed digital ecosystems and more favorable conditions for innovation [9,10].

As a new factor of production, data have several characteristics: they can be copied, are non-excludable, and have substantial effects beyond those who use them directly [11]. Under conventional institutional arrangements, firms often face restrictions on data access; data property rights are also unclear, and transactions do not receive enough institutional protection. These difficulties prevent firms from making effective use of data for innovation. In the pilot zones, different arrangements are tested to clarify data rights, make data flows easier, and realize the value of data; firms can then make greater use of these resources in R&D, production improvements, and business model innovation, significantly improving their productivity and ability to innovate.

The support that pilot zones provide for firm innovation concerns both resources and institutions; it comes from better allocation of data, improved institutional arrangements, and stronger innovation ecosystems. This analysis leads to the following hypothesis:

H1: Establishing pilot zones increases innovation by firms located in the designated regions.

2.2. Mechanisms linking pilot zone establishment to firm innovation

The effects of pilot zones on firm innovation can be considered as a process that passes through different stages and involves connections across scales; this explanation draws on the adaptive cycle and Panarchy frameworks in ecology [12,13]. In the rapid growth phase, known as the r phase, firms receive policy support and funding as external energy inputs to the system; these inputs reduce early financing constraints and help firms start technological R&D and enter the market quickly. Firms then move into the K phase, or accumulation phase. Their size and processes become more stable during this period, although dependence on existing paths and difficulties in changing their structures may also develop. Support from the zones for data flows, digital infrastructure, and institutional arrangements then brings about release and reorganization in the Ω–α phases; with digital transformation at the center of this process, firms rearrange their resources and organizational structures to overcome existing constraints and improve operating efficiency and coordination.

Connections between levels are described in Panarchy as memory and revolt; regional institutions and resources hold memory that helps firms retain effective practices during reorganization. At the lower levels, changes in technology and business models put pressure on higher levels and increase innovation outcomes; the process then reaches a new K phase at a higher stable state. Firms still benefit from the pilot zone policy at this stage, and their rising value brings in further investment from outside. The proposed process therefore begins

with reduced financing constraints, followed by digital transformation and structural adjustment in the medium term; over the longer term, firms become better able to sustain innovation. Through these stages, the zones increase firms' long-term investment value and continue to support their innovative development.

2.2.1. Financing constraints

Easier access to financing is one way in which pilot zones support innovation in firms. Pecking order theory explains that information asymmetry affects the order in which firms choose their funding sources; internal funds are preferred, borrowing comes next, and equity financing is used only as a last option. Firms facing financing constraints often have difficulty raising enough money from outside, especially when information is not equally available. Their ability to innovate and develop is directly affected by this problem; technological innovation projects are particularly exposed because they require substantial investment and involve high risks. Without enough funds, firms may be unable to invest sufficiently in R&D, leaving their innovation potential limited.

The National Digital Economy Innovation and Development Pilot Zones address these difficulties through several policy measures. Financial institutions are encouraged to develop new products suited to small and medium-sized enterprises; examples include technology financing guarantees and financing backed by intellectual property, which reduce financing requirements and help firms obtain funds. Low-interest loans and direct financial assistance are provided through innovation funds and risk compensation funds; this support eases funding pressure, particularly when firms undertake technological innovation or expand their markets. Tax incentives also leave firms with more money for R&D and market development by reducing the taxes they pay, supporting their investment in innovation.

Cooperation between financial institutions and capital markets is encouraged within the zones, giving firms different ways to meet their funding needs, including equity and debt financing. The government also directs private capital toward the digital economy and supports financing through initial public offerings and bond issuance; firms can therefore raise funds more flexibly and at a lower cost. Stronger credit systems make financing conditions more transparent and standardized; improved credit information platforms allow financial institutions to judge firm risk more accurately and provide flexible financing at lower cost. Taken together, these measures reduce both financing costs and innovation delays caused by funding shortages. When cheaper funds are available, firms can devote more attention to technological innovation and market expansion, with better conditions for carrying out innovation activities [14].

2.2.2. Accelerating digital transformation

Firms can improve their innovation performance through digital transformation and use innovation to achieve high-quality development. Several measures under the National Digital Economy Innovation and Development Pilot Zone policy help firms carry out this transformation [15]. First, policy guidance and overall institutional arrangements provide conditions for combining the digital and real economies; they also support digital transformation in traditional industries. The *Implementation Plan for the National Digital Economy Innovation and Development Pilot Zones* was issued in 2019; it supports firms' transformation through better data allocation and more sharing of government data, providing both policy assistance and institutional protection.

Second, digital infrastructure is expanded in the zones, alongside wider use of 5G, cloud computing, and big data. Xiong'an New Area provides an example: a strong urban computing system has been developed using the Xiong'an Cloud platform and 5G deployment; government services become more efficient, while firms gain

access to technical support and face fewer technical barriers during transformation. The cost of transformation is also reduced through fiscal subsidies and tax incentives. In Chongqing, dedicated funds and a data exchange center have been established to provide financial assistance and make data flows easier; these measures give further support to digital transformation in firms [16].

Third, the zones train and attract people with digital skills to provide the innovation capabilities needed for transformation; Chongqing has developed a digital economy talent market and offered digital skills training, giving firms stronger support in human resources. Finally, successful practices are shared, and demonstration projects are used to help regions develop in a coordinated way; Zhejiang Province has set up regular exchanges to share good digital economy practices as examples for development throughout the province. Policy support, infrastructure, financing, and talent development therefore help the zones advance digital transformation in firms and support high-quality economic development.

2.2.3. Enhancing firms' investment value

A firm's value represents the present value of the wealth it is expected to create in the future, reflecting expected profitability and growth potential [17]. Tax benefits, research funding, and other incentives offered by the pilot zones attract leading scientists, engineers, designers, and other highly skilled people from both China and abroad [18]; bringing these people together improves firms' R&D capabilities and strategic positions in innovation, and also raises their overall value. Higher investment value also reflects signals from the external environment, as positive signals from the wider market increase firms' influence in industrial chains and innovation ecosystems. Higher value gives firms a better reputation, helping them gain the trust of strategic partners and obtain more external resources for innovation; it also reduces possible difficulties in transactions and information asymmetry, allowing firms to get external capital and technical support at a lower cost and strengthen their ability to innovate. Over time, increases in value supported by the policy bring more outside resources into firms and provide a firm basis for continued growth in value. The study therefore puts forward the following hypothesis:

H2: Establishing pilot zones increases firm innovation by easing financing constraints, supporting digital transformation, and raising firms' investment value.

3. Research design

3.1. Sample selection and data sources

The initial sample comprises A-share listed firms from 2016 to 2022. Firms designated ST or *ST, firms in the financial and insurance sectors, and observations with missing values for relevant variables are excluded. The main continuous variables are winsorized at the 1st and 99th percentiles, yielding 12,979 valid observations. Data are obtained from the CSMAR, CNRDS, and Wind databases, as well as provincial and municipal statistical yearbooks.

3.2. Model specification

This study treats the establishment of the National Digital Economy Innovation and Development Pilot Zones as a quasi-natural experiment and uses the following difference-in-differences model to examine the effect of the policy on firm innovation:

Here, DID is a dummy variable capturing the policy shock, and its coefficient measures the effect of pilot zone establishment on firm innovation. Controls denote the set of control variables. The model includes year, industry, and firm fixed effects to account for common time trends and individual differences, together with a stochastic error term.

3.3. Variable definitions

1. Dependent variable. Following Liu *et al.*, this study measures firm innovation (innovation) using the proportion of R&D personnel, defined as the number of R&D employees relative to the firm's total workforce [19]. This measure is adopted for three reasons. First, R&D personnel are central to innovation activities. Their share directly reflects the intensity of firms' innovation-related factor inputs and resource allocation priorities, capturing human resource capacity and organizational commitment in activities such as technological R&D and product iteration. Second, compared with financial measures such as R&D expenditure, the R&D personnel share can partly avoid measurement bias arising from differences in R&D cost accounting across industries and firms of different sizes, providing a more stable indicator of the structural characteristics of innovation capability. Third, the measure captures both firms' long-term strategic commitment to innovation and the accumulation of human capital as a core factor of production in the innovation process. It is therefore closely aligned with the role of knowledge and technological breakthroughs in firm innovation in the digital economy and provides a reliable observable dimension for capturing the effect of pilot zone establishment on innovative behavior.

2. Core explanatory variable. National Digital Economy Innovation and Development Pilot Zone policy is measured using a dummy variable that equals 1 when a firm's registered location is within a designated pilot zone and the observation falls in the post-implementation period, and 0 otherwise [20].

3. Control variables. Drawing on the approach of Li *et al.* and considering other potential influences on firm innovation [17], this study includes leverage (lev), the fixed asset ratio (fixratio), firm size (size), return on equity (roe), and cash holdings (cash) at the firm level. At the macro level, it controls for economic agglomeration (agglo), fiscal decentralization (fiscal), urbanization (urbanization), financial development (financial), and science and technology expenditure (technology). Detailed definitions are provided in **Table 1**.

Table 1. Definitions and measurement of control variables

Level	Variable	Symbol	Measurement
Firm level	Leverage	lev	Total liabilities / total assets
	Fixed asset ratio	fixratio	Net fixed assets / total assets
	Firm size	size	Natural logarithm of total assets
	Return on equity	roe	Net profit / average net assets
	Cash holdings	cash	Cash and cash equivalents / total assets
Macro level	Economic agglomeration	agglo	Employment density in the secondary and tertiary sectors of the region
	Fiscal decentralization	fiscal	Generally, local fiscal expenditure / (local fiscal expenditure + central fiscal expenditure)
	Urbanization	urbanization	Urban population / total population
	Financial development	financial	Commonly, outstanding deposits and loans of regional financial institutions / regional GDP
	Science and technology expenditure	technology	Local fiscal expenditure on science and technology / total local fiscal expenditure

4. Empirical analysis

4.1. Descriptive statistics

The descriptive results in **Table 2** give a mean of 18.965 and a standard deviation of 14.156 for the firm innovation measure; its minimum is 0.610, and its maximum is 74.070, showing large differences among firms. For DID, the mean is 0.257, and the standard deviation is 0.437; the variable takes either 0 or 1 to indicate the policy treatment status of each firm-year observation.

Table 2. Descriptive statistics

Variable	*N*	Mean	Std. dev.	Minimum	Maximum
innovation	12979	18.965	14.156	0.610	74.070
DID	12979	0.257	0.437	0	1
lev	12979	0.375	0.191	0.052	0.862
fixratio	12979	0.183	0.130	0.005	0.585
size	12975	21.983	1.282	19.336	25.971
roe	12948	0.070	0.115	-0.535	0.349
cash	12975	0.236	0.163	0.025	0.756
agglo	12979	9.462	1.301	6.237	11.996
fiscal	12979	0.718	0.193	0.216	1.063
urbanization	12945	0.786	0.130	0.471	1.007
financial	12979	1.830	0.638	0.587	3.569
technology	12979	0.050	0.028	0.004	0.131

4.2. Baseline regression

The baseline estimates give a significantly positive DID coefficient with each set of control variables; the direction stays the same when only fixed effects are included, when firm or regional variables are added separately, and when both sets are included. With all controls included, the coefficient is 0.6237. These results support H1, since the positive effect of establishing pilot zones on firm innovation holds across different choices of controls. See **Table 3**.

Table 3. Baseline regression results

	(1)	(2)	(3)	(4)
Variable	**innovation**	**innovation**	**innovation**	**innovation**
DID	0.6118***(3.008)	0.6078***(2.984)	0.6284***(2.934)	0.6237***(2.908)
lev		-3.7154***(-4.830)		-3.8054***(-4.933)
fixratio		-0.9340(-0.974)		-0.9279(-0.964)
size		0.3680*(1.651)		0.3713*(1.663)
roe		-0.0201(-2.048)		-0.0208(-2.120)
cash		0.0676(0.100)		0.0267(0.039)
agglo			-0.5747(-1.433)	-0.6318(-1.534)
fiscal			0.7641(0.792)	0.6962(0.720)
urbenization			5.5569**(2.282)	5.1638**(2.116)
financial			0.5499*(1.653)	0.5947**(1.771)
technology			1.0186(0.214)	1.1217(0.235)

	(1)	(2)	(3)	(4)
Variable	**innovation**	**innovation**	**innovation**	**innovation**
_cons	18.8983***(285.011)	12.3696**(2.530)	18.3652***(5.770)	12.6176**(2.242)
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
N	12388	12354	12348	12314
adj.R^2	0.906	0.907	0.906	0.907

4.3. Parallel trends test

Before the policy takes effect, the parallel trends test checks whether innovation changes differ significantly between the treatment and control groups; the coefficients shown for this period are not significantly different from zero, which supports the parallel trends assumption. Once the policy is implemented, the estimates stay positive and fairly stable, showing that the two groups' innovation performance begins to differ. See **Figure 1**.

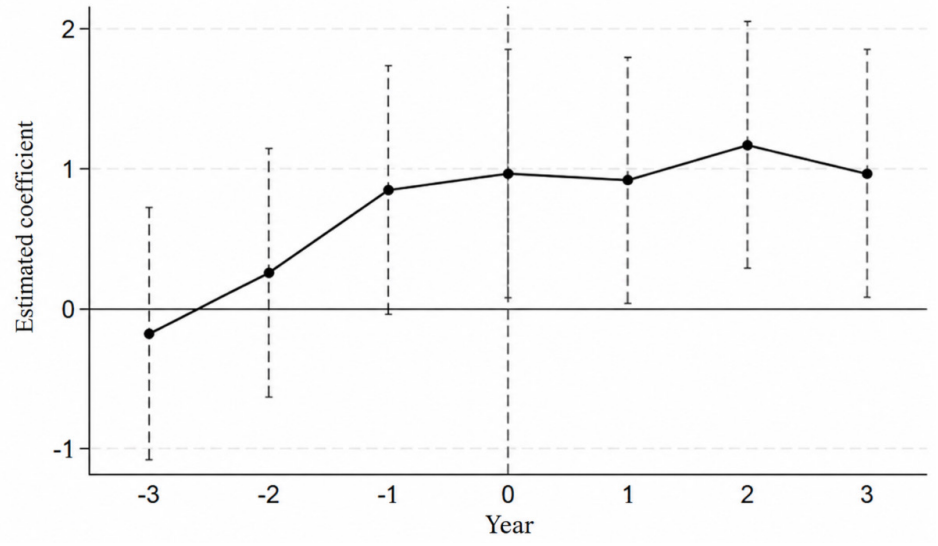


Figure 1. Parallel trends test

4.4. Placebo test

For the placebo test, artificial policy shocks are constructed, and the resulting coefficients are examined; their kernel density distribution lies mainly around zero, without a systematic shift towards positive values. Such artificial treatments are therefore unlikely to produce a consistent positive effect, and this result gives further support to the baseline findings. See **Figure 2**.

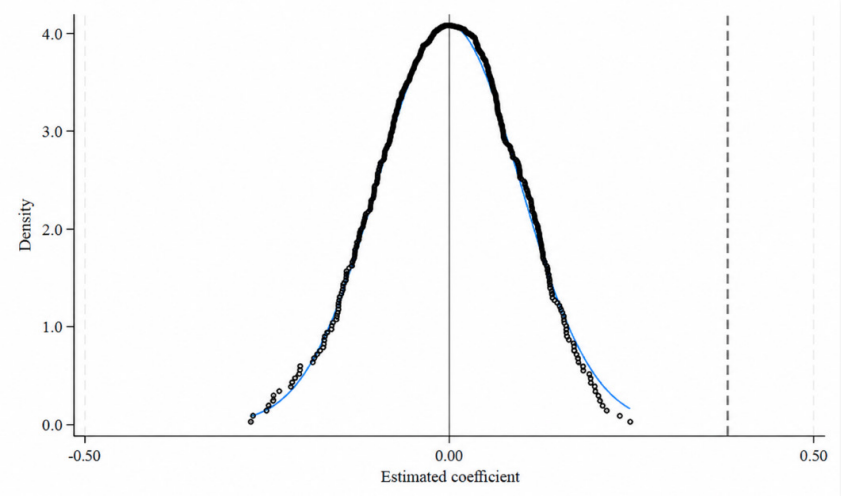


Figure 2. Placebo test

4.5. Additional robustness checks

The robustness checks consider sample selection, common shocks, the specification of the model, and the error structure; DID remains significantly positive with radius matching and entropy balancing. Its coefficient is also significant at the 1% level after adding industry-by-year fixed effects and when using Poisson regression; excluding pandemic years gives significance at the 10% level, while clustering standard errors by firm gives significance at the 5% level. Positive policy coefficients are found throughout these checks, suggesting that the baseline results have a degree of stability. See **Table 4**.

Table 4. Robustness checks

	PSM-DID					
Variable	**Radius matching**	**Entropy balancing**	**Industry-by-year FE**	**Poisson regression**	**Excluding pandemic years**	**Firm-clustered SEs**
DID	1.2581*** (3.116)	0.6237*** (2.908)	0.6279*** (2.752)	0.0375*** (3.585)	0.4024* (1.873)	0.6237** (2.195)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-year FE	No	No	Yes	No	Yes	Yes
N	5504	12314	12222	12910	7435	12314
adj.R^2	0.913	0.907	0.907	0.922	0.918	0.907

4.6. Accounting for concurrent policies

The study checks the influence of policies introduced during the same period by adding indicators for Broadband China Demonstration Cities, Innovative City Pilots, Smart City Development, and National Comprehensive Big Data Pilot Zones one at a time; it then includes all four indicators together. In each specification, the DID coefficient is positive, significant at the 1% level, and close to the baseline estimate; thus, after these other policies are taken into account, the pilot zones still have a positive effect on firm innovation. See **Table 5**.

Table 5. Tests controlling for concurrent policies

	(1)	(2)	(3)	(4)	(5)
Variable	**innovation**	**innovation**	**innovation**	**innovation**	**innovation**
DID	0.6023*** (2.781)	0.6231*** (2.904)	0.6220*** (2.901)	0.6447*** (3.007)	0.6209*** (2.865)
Broadband China Demonstration Cities	-1.2014 (-0.927)				-1.5768 (-1.134)
Innovative City Pilots		-1.7179 (-1.444)			-1.9193 (-1.377)
Smart City Development			-0.5058 (-0.441)		0.6231 (0.465)
National Comprehensive Big Data Pilot Zones				1.3335 (1.079)	1.5196 (1.068)
Controls	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
N	12314	12314	12314	12314	12314
adj.R^2	0.807	0.901	0.812	0.815	0.907

4.7. Mechanism tests

The mechanism analysis adopts the two-step approach of Jiang [21]; this method is used to identify the specific channels through which the policy affects the dependent variable. With other influences controlled for, the approach clarifies how the core explanatory variable relates to the mechanism variables and how those variables relate to the dependent variable, helping explain how the policy works. The analysis considers financing constraints, firms' digital transformation, and their investment value as mechanism variables. The KZ, WW, and SA indices are commonly used to measure financing constraints; KZ and WW contain financial variables, including cash flow and leverage, so they may be affected by endogeneity. The SA index is used here to measure financing constraints and avoid this interference [22]. A composite score using indicators such as spending on digital technologies and the share of digital business activities can measure digital transformation [23]; for firms' investment value, the measure is Tobin's Q [24], which divides market value by the replacement cost of assets. Market value is usually calculated by adding equity market capitalization to the book value of liabilities; the replacement cost of assets is estimated from asset data in the balance sheet.

The mechanism estimates give DID coefficients of −0.0064 for financing constraints, 0.0243 for digital transformation, and 0.1326 for investment value; each is significant at the 1% level. These findings indicate that the zones ease funding pressure and thus support R&D, help firms improve processes and operating efficiency through digital transformation, and raise investment value to attract resources from outside; the three channels together connect financial support, support through technology, and improvements in value. See **Table 6**.

Table 6. Mechanism tests

	(1)	(2)	(3)
Variable	Financing constraints	Digital transformation	Investment value
DID	-0.0064***(-3.577)	0.0243***(15.940)	0.1326***(2.968)
Controls	Yes	Yes	Yes

	(1)	(2)	(3)
Variable	Financing constraints	Digital transformation	Investment value
Industry FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
N	11878	12314	11548
adj.R^2	0.982	0.951	0.588

4.8. Heterogeneity analysis

4.8.1. Heterogeneity by ownership

In the ownership subsamples, the policy coefficient for non-state-owned firms is significant at the 1% level; local state-owned enterprises also show a significant positive effect, but the effect for central state-owned enterprises is not statistically significant. Non-state-owned firms face more market competition and can make decisions and allocate resources with greater flexibility, so they can more easily use policy support for R&D investment. State-owned enterprises already have some advantages in obtaining resources, and their procedures for making innovation decisions are more complex; additional policy support may therefore have a relatively limited marginal effect.

4.8.2. Heterogeneity by external industrial structure

For firms in regions with a higher level of industrial structure development, the policy coefficient is 1.0422 and is significant at the 1% level; for the lower-level group, it is 0.3483 and is not statistically significant. Better-developed industrial chains, technological services, and cooperation between industry, universities, and research institutions help digital technologies spread, and innovation resources come together, allowing the policy to work under more favorable conditions. Where industrial support systems are weaker, a lack of complementary resources and innovation services may limit how firms respond to the policy.

4.8.3. Heterogeneity by Internal Total Factor Productivity

The low-TFP group has a policy coefficient of 0.9051, significant at the 1% level; the high-TFP group's coefficient is 0.4313 and is not statistically significant. Firms with low TFP have more room to improve their use of technology, production management, and resource allocation, giving them a greater need for the technical and managerial support available in the pilot zones. Firms with high TFP already have relatively mature systems for production and innovation; for these firms, extra policy resources may make a smaller marginal contribution. See **Table 7**.

Table 7. Heterogeneity analysis

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Variable	**Central SOEs**	**Local SOEs**	**Non-SOEs**	**Higher industrial structure level**	**Lower industrial structure level**	**High TFP**	**Low TFP**
DID	1.4061 (1.486)	0.8244* (1.838)	0.6125*** (2.583)	1.0422*** (2.820)	0.3483 (1.239)	0.4313 (1.273)	0.9051*** (2.855)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable	**Central SOEs**	**Local SOEs**	**Non-SOEs**	**Higher industrial structure level**	**Lower industrial structure level**	**High TFP**	**Low TFP**
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	893	1847	8706	6179	5828	6469	4706
adj.R^2	0.833	0.906	0.928	0.923	0.856	0.900	0.930

5. Conclusion and implications

Using data on A-share listed firms from 2016 to 2022, this study applies a difference-in-differences approach to examine the effect of pilot zone policy on firm innovation. The findings show that the establishment of pilot zones significantly promotes firm innovation, and the results remain valid after robustness checks and controls for concurrent policies. The policy operates primarily by alleviating financing constraints, advancing digital transformation, and enhancing investment value, forming a logical chain of financial support, technological enablement, and value enhancement. Policy responses are more pronounced among non-state-owned firms, firms in regions with more developed industrial structures, and low-TFP firms, reflecting differences in firm characteristics and regional conditions.

The government should improve financial support, digital infrastructure, and talent development systems within the pilot zones; enhance the financing environment for small- and medium-sized enterprises; improve digital public services; and strengthen regional policy coordination. Support measures should be differentiated according to firm characteristics, industrial support conditions, and production efficiency so that policy resources are aligned with innovation needs. Firms should use the institutional and resource conditions offered by the pilot zones to integrate digital transformation into production, management, and strategic decision-making, improve the allocation of R&D resources, and develop sustained innovation capabilities.

Disclosure statement

The author declares no conflict of interest.

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