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Effect evaluation of national big data comprehensive experimental zone on financial science and technology innovation effect

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Aiming at the dynamic mechanism gap of financial technology innovation in the global digital transformation, this study focuses on the national big data comprehensive experimental zone policy, and explores its systematic impact on the development of financial technology through the three-dimensional path of resource allocation efficiency optimization, environmental supervision system reconstruction and technology integration intensity (TII) improvement. Based on the panel data of 279 prefecture-level cities in China from 2012 to 2024, this study innovatively adopts a framework integrating the Difference-in-Differences (DID) model and event study method. It controls for endogenous interference through instrumental variable methods and employs multi-level mediation tests to analyze the transmission mechanism. The empirical findings indicate that the construction of pilot zones significantly promotes the expansion of regional fintech enterprises, and this effect is statistically significant and continues to strengthen as the policy deepens; The verification of the three mechanisms shows that the policy forms a chain conduction by improving the efficiency of resource allocation, strengthening the efficiency of environmental supervision and promoting the quality of green innovation, especially promoting the "overtaking in corners" in underdeveloped areas. The research further reveals that the policy design should set the differential trigger threshold according to the endowment of regional digital base. It is recommended that indicators such as "freedom of cross-border data flow" and "distance of digital sovereignty systems" be included in the policy evaluation framework. These indicators can help promote a new paradigm of international digital governance that balances inclusive development and innovation-driven competition.

KEYWORDS
efficiency of environmental supervision, efficiency of resource allocation, financial science and technology innovation, national big data comprehensive experimental zone, technology integration intensity (TII)

1 Introduction

Amidst the profound transformation characterized by the accelerated reconstruction of the global digital economy governance system, China's national-level big data comprehensive pilot zones, as carriers of institutional innovation at the national level, are providing crucial exploration for the paradigm shift in global digital finance development through their unique policy design logic. Compared to the EU's "Digital Market Act," which focuses on the compliance burden imposed on enterprises by the data sharing obligations of "gatekeeper platforms," or the US's "California

Consumer Privacy Act," which restricts the reuse of commercial data through individual empowerment, the core breakthrough of China's pilot zones lies in the establishment of a government-led data element market. This is achieved by reducing the friction coefficient of factor circulation through the "data franchise" system, achieving green regulatory coordination through the "cross-domain environmental data pool," and forming zero marginal cost knowledge supply through the "open government data base." This institutional practice not only reshapes the underlying driving structure of financial technology innovation but also contributes Chinese wisdom to solving common challenges in global digital governance. When the EU's unified data strategy encounters a "Southern Europe-Northern Europe" implementation efficiency gap due to disparities in digital infrastructure, and when mismatches between federal and state-level data policies in the US raise the cost of innovation systems, China's pilot zones activate models through differentiated mechanisms that precisely adapt to regional endowments, providing a new paradigm for late-comer economies to bridge the "digital divide."

The international academic community has reached a basic consensus on the interactive relationship between institutional environment and fintech innovation: a robust data governance framework significantly enhances the vitality and resilience of the fintech ecosystem by reducing information friction and compliance costs. The World Bank's policy assessment further verifies that the institutionalized supply of data elements has universal value in optimizing resource allocation and fostering innovative self-organization capabilities. In the study of transmission mechanisms, scholars have shifted from verifying the existence of institutions to deconstructing micro-action chains, initially constructing a "dual-path" explanatory framework: the element integration path focuses on optimizing capital pricing efficiency through cross-domain data flow; the regulatory reconstruction path focuses on analyzing the compression of enterprise innovation cost structure by the RegTech revolution (Buchak et al., 2023).

However, this fragmented research paradigm is facing a triple theoretical dilemma:

Dimensional incompleteness: Existing literature overlooks the pivotal role of technology integration intensity (TII) leapfrogging. In the global carbon neutrality journey, the integration of fintech and green technology has given rise to new business forms such as carbon accounting blockchain and ESG intelligent investment advisory. However, relevant research still remains at the level of single technology adoption analysis, failing to incorporate green innovation into a dynamic collaborative system.

Systemic coordination blind spots: There exists a closed-loop feedback mechanism among the enhancement of resource allocation efficiency, the reconstruction of smart regulatory enforcement intensity (SRE), and the leapfrogging of technology integration intensity (TII). For instance, the opening of environmental data can strengthen the precision of resource allocation, while the transformation of green patents in turn fosters the upgrading of regulatory technology. However, the current fragmented theoretical perspectives hinder the capture of policy-induced systemic transformations.

Lack of dynamic adaptability: The current framework is constrained by the static analysis paradigm, which not only fails to explain the phenomenon of "inflection point of learning curve" in financial technology innovation (such as the decline in policy effectiveness in Singapore due to neglect of three-dimensional collaboration), but also significantly underestimates the regional adaptation dilemma. A typical case is the failure of the EU's green finance classification bill to be implemented in regions with weak digital infrastructure. Essentially, it is a governance paradox caused by the disruption of the "institution-technology-resource" synergy.

This paper focuses on methodology innovation and mechanism decoupling to break through the above shackles:

1. Develop a multi-level intermediary evaluation framework, and empirically verify the chain transmission mechanism of resource allocation efficiency, environmental supervision efficiency and technology integration intensity (TII)-explain why the pilot zone policy also leads to the phenomenon of "overtaking in the curve" of increasing the density of financial technology enterprises in underdeveloped areas.
2. Construct an interactive tool variable system, and take the interactive item of urban data circulation rate and national cloud penetration rate in 2015 as IV, effectively stripping the endogenous interference of policies, and confirming that the release of institutional dividends depends on the preconditions of digital infrastructure.
3. Designing an event study-DID fusion model to capture the phased characteristics of the policy life cycle, and provide basis for the "paradox of policy lag."

The contribution of this study is not only to correct the existing cognitive bias, but also to establish two new criteria at the level of decision support: the threshold of "digital pedestal fitness" should be included in the policy effect evaluation, and the three-dimensional mechanism should be activated according to the regional characteristics. For resource-based cities, the efficiency path of environmental supervision should be given priority, while science and technology center cities should focus on the quality channel of green innovation. This kind of precise policy logic will help the experimental area evolve from "institutional dividend depression" to "innovative growth polar region."

2 Theoretical analysis and hypothesis

The impact mechanism of national-level big data comprehensive pilot zones on financial technology innovation can be systematically explained through a ternary framework of "institutional empowerment - market restructuring - knowledge leapfrogging" (Wei and Zhang, 2023). Its theoretical integration closely anchors the causal chains at two levels: the direct effect of institutions and the intermediary transmission mechanism (Bai et al., 2023).

At the level of direct institutional effects, the "data franchise rights" granted by the pilot zone reshape the innovation incentive structure through the theory of institutional complementarity: policies reduce the institutional friction coefficient of data confirmation and circulation (Liu et al., 2025), leading to essential changes in the function of technological research and development in financial institutions. A typical example is the 40% downward shift in the compliance cost curve for blockchain applications, directly expanding the boundary of innovative production possibilities (Xue et al., 2025). At the same time, the theory of induced innovation reveals the policy's guiding role in technological direction: as a knowledge-producing infrastructure, the government data base opened in the pilot zone injects zero-marginal-cost public knowledge elements (Jia and Zhou, 2025), triggering increasing returns to scale in the knowledge production function of fintech enterprises (Peng and Li, 2025).

At the level of intermediary transmission mechanisms, three major theories, respectively, support the coordinated operation of three types of efficiency improvement paths:

The path to enhancing resource allocation efficiency is grounded in the theory of the platform economy (Lina, 2024). The multilateral data exchange platform established in the pilot zone integrates credit investigation, patent, and talent flow data, forming a "re-pricing of innovation factors" mechanism (Zhang et al., 2025). This mechanism directly releases financial technology research and development resources by compressing capital liquidity premiums and alleviating the mismatch of technical talents (Wang et al., 2022), essentially realizing the induced effect of factor endowment structure upgrading on technological innovation (Lin et al., 2023).

The path to enhancing smart regulatory enforcement intensity (SRE), as a modern extension of Pigouvian tax theory, lies at its core in the dual role of policy signal transmission and compliance cost transformation: the cross-disciplinary environmental data pool established in the pilot zone essentially constitutes an intelligent regulatory infrastructure (Chen, 2025), internalizing external costs such as carbon emissions and pollution control into quantifiable financial parameters (Lu and Yang, 2025).

This institutional design influences the decision-making of fintech enterprises through two channels: Firstly, mandatory policy signals alter market expectations, prompting financial institutions to proactively incorporate blockchain traceability and ESG algorithm weights into their innovation functions to avoid future environmental compliance risks (such as the impact of carbon tariffs) (Ding et al., 2024). Secondly, the transformation of dynamic compliance costs stimulates demand for technological substitution. When real-time monitoring of environmental data increases traditional compliance costs by 30% (World Bank, 2024), enterprises shift their investment towards RegTech solutions to shift the cost curve downward, directly catalyzing the rise of clusters of environmental compliance technology enterprises (Li, 2025).

The path of technology integration intensity (TII) leapfrogging relies on the theory of knowledge recombination to achieve reverse pulling of technological demand: breaking down the data silos and constructing cross-industry knowledge spillover channels (Toprak and Turan, 2025), enabling "complementary coupling" between government data (public knowledge base) and private knowledge (Guo et al., 2018). This recombination not only catalyzes synthetic solutions such as green credit models driven by energy data flows, but more importantly, it forms a closed loop of technological demand–supply: green technological breakthroughs generate new financial demands; these demands force fintech companies to develop AI power generation actuarial models, which in turn drive the iteration of machine learning algorithms (Najem et al., 2025); algorithm upgrades in turn nurture the data analysis capabilities for green technology research and development, ultimately realizing an enhancement loop of "green innovation → technological demand → fintech response → nurturing green innovation" (Cornelli et al., 2023).

The aforementioned theories form a closed loop in dynamic collaborative logic: the platform economy theory addresses factor mismatch (market failure correction), the extended Pigouvian tax theory innovates regulatory tools (negative externality governance), and the knowledge recombination theory drives technological synthesis (paradigm shift realization). The three theories jointly support the three-dimensional intermediary mechanism through a transmission sequence of "institutional environment optimization → factor allocation, regulatory evolution → subject behavior adjustment, and knowledge fusion → innovation quality leap" (Liu et al., 2024). International comparisons further corroborate the uniqueness of this framework: the EU's Digital Market Act increases corporate compliance costs through data sharing on "gatekeeper platforms," while the California Privacy Act in the United States restricts data reuse due to individual empowerment, highlighting China's institutional advantage in reducing institutional costs through government leadership and accelerating innovation transmission through a three-dimensional collaborative path (Di et al., 2025).

In summary, the research hypothesis of this paper is proposed as follows:

> *H1*: National-level big data comprehensive pilot zones can enhance the innovation effect of financial technology.
>
> *H2*: National-level big data comprehensive pilot zones enhance the innovation effect of financial technology by improving resource allocation efficiency, environmental supervision efficiency, and technology integration intensity (TII).

3 Research design

3.1 Policy background of national big data comprehensive experimental zone

The establishment of the national big data comprehensive experimental zone stems from China's strategic response to the global digital economy competition, and its essence is that the national level tries to break the ice for the market-oriented allocation of data elements through institutional innovation. The policy design takes the State Council's "Action Program for Promoting Big Data Development" in 2015 as a programmatic document, which marks a cognitive breakthrough in upgrading data resources from technology application objects to new production factors. Under this framework, the experimental area is endowed with the special function of "institutional laboratory," aiming at building a controllable risk testing field in some areas and launching a pilot test for basic institutional problems such as data property rights definition, circulation rules and safety supervision. In 2016, the National Development and Reform Commission, together with the Network Information Office and other departments, launched the selection of the first batch of eight pilot areas and adopted a gradient policy empowerment strategy: giving the pilot areas differentiated institutional authority in terms of cross-border data flow, technical standards formulation, and government data opening. For example, Guizhou took the lead in obtaining local legislative authorization for data confirmation, and the Shanghai Free Trade Zone tried out a cross-border data classification management system. This institutional supply essentially constructs a policy gradient difference-by granting the unique "data franchise" in the experimental area to form institutional potential energy, attracting technology, capital and other factors to concentrate in the experimental area. In 2020, the policy entered a deepening stage, and the National Development and Reform Commission and other four ministries and commissions jointly issued the Guiding Opinions on Accelerating the Construction of a National Integrated Big Data Center Collaborative Innovation System, which promoted the pilot area to change from a single-point breakthrough to cross-regional collaboration, and defined the policy goal as "exploring new production relations that adapt to digital productivity". The above evolution trajectory reflects a profound change in the logic of national governance: from cracking the bottleneck of technology application in the early stage to building a basic institutional system that supports the high-quality development of the digital economy, and finally points to the reconstruction of national competitiveness driven by data elements.

3.2 Model building

In order to accurately evaluate the causal impact of the policies in the national big data comprehensive experimental zone on the innovation effect of financial science and technology, this paper constructs a double difference (DID) model for the endogenous bias that may be caused by the randomness of policy implementation. Based on urban panel data spanning from 2012 to 2024, this study treats policies as a quasi-natural experiment and employs a difference-in-differences approach to analyze their dynamic effects. The specific model design is as follows Equation (1):

$$\mathrm{FTech}_{i,t} = \alpha_0 + \alpha_1 \mathrm{DID}_{i,t} + \alpha_2 \mathrm{Controls}_{i,t} + \alpha_3 \mathrm{Year}_i + \alpha_4 \mathrm{City}_t + \varepsilon_{i,t} \quad (1)$$

Among them, $\mathrm{FTech}_{i,t}$ represents the financial science and technology innovation level of I city in the t year, Controlsi,t represents the control variable, $\mathrm{DID}_{i,t}$ represents the policy dummy variable of "National Big Data Comprehensive Experimental Zone", Yeari and $\varepsilon_{i,t}$ control the time-fixed effect and urban-fixed effect respectively, and ε i and T are random disturbance terms. This method directly quantifies the dynamic contribution of policies to the innovation effect of financial science and technology, and ensures that the evaluation closely revolves around the theme core.

3.3 Variable selection

3.3.1 Core explanatory variables

The core explanatory variable quantifies the policy function of "National Big Data Comprehensive Experimental Zone" and constructs it as an interactive virtual variable to evaluate its direct impact on the innovation effect of financial science and technology. The specific operations are as follows: the experimental group city (policy pilot area) is assigned to 1, and the non-pilot city is assigned to 0; The policy implementation year and subsequent years are assigned 1, and before implementation, it is assigned 0; The interaction between them forms the core explanatory variable. According to the list of pilot cities, 55 experimental group cities and 224 control group cities were selected. Based on the national big data comprehensive experimental zone was fully launched in 2016, this study identified 2016 as the implementation time of the policy benchmark to support the subsequent dynamic analysis of the financial technology innovation effect.

3.3.2 Explained variable-financial technology (FTech)

Financial Technology (FTech) is defined as the core representation of applying digital technologies (such as blockchain and artificial intelligence) to drive financial service innovation, which directly corresponds to the policy effect evaluation goal. This study takes the annual financial technology innovation level of the city as the core measurement index, draws lessons from Song Min's method and according to the Financial Stability Board (FSB) standard (Song et al., 2021), and accurately screens the enterprises engaged in digital technology financial business such as blockchain through the "Eye of the Sky" database. In order to avoid heteroscedasticity caused by regional agglomeration, the logarithm of the number of financial technology companies in prefecture-level cities after screening is taken as the final variable to quantify the intensity of financial technology innovation effect.

3.3.3 Mechanism variables

3.3.3.1 Resource allocation efficiency

The national big data comprehensive experimental zone policy aims to improve the accuracy of resource allocation through big data integration, thus supporting the incubation and application innovation of financial technology. As a core mechanism variable, Allocation measures how the optimal flow of production factors maximizes the output potential under the market mechanism.

Referring to the calculation method of Bai and Bian (2016), this variable represents the mismatch of resources by calculating the degree of market distortion. Based on this, the Cobb–Douglas production function model is set as Equation (2):

$$\mathrm{nY}_{it} = \mathrm{c} + \alpha ln \mathrm{K}_{it} + \beta ln \mathrm{L}_{it} + \varepsilon_{it} \quad (2)$$

Where Y stands for regional GDP as output index, K stands for capital stock estimated by perpetual inventory method, and L stands for the number of employed people at the end of the year as labor input.

Therefore, the marginal output of capital and labor is deduced as $\alpha \mathrm{Y}_{it}/\mathrm{K}_{it}$ and $\beta \mathrm{Y}_{it}/\mathrm{K}_{it}$, respectively, and then based on the assumption that labor price is W and capital price is R, the index of factor deviation degree is calculated. See Equation (3):

$$\mathrm{distK}_{ii} = \left| \alpha \mathrm{Y}_{ii} / \mathrm{r}_{ii} \mathrm{K}_{ii-1} \right|, \mathrm{distL}_{ii} = \left| \beta \mathrm{Y}_{ii} / \mathrm{w}_{ii} \mathrm{L}_{ii-1} \right| \quad (3)$$

Finally, the total market distortion is obtained. See Equation (4):

$$\mathrm{dist}_{it} = \mathrm{distK}_{it}^{\frac{\alpha}{\alpha-\beta}} \mathrm{distL}_{it}^{\frac{\alpha}{\alpha+\beta}} \quad (4)$$

In this study, the reciprocal of distit directly represents the efficiency of resource allocation and quantifies the strengthening effect of resource optimization on financial technology innovation, because efficient allocation can release data capital and human capital to drive financial service innovation.

3.3.3.2 Smart regulatory enforcement intensity (SRE)

This study innovatively designs a quantification system based on government text big data analysis. Its core logic lies in capturing the institutional shaping effect of policy implementation on financial technology innovation.

Specifically, referring to the government transparency index framework developed by Gao et al. (2023), but deeply optimizing it for the policy characteristics of national-level big data comprehensive pilot zones: By utilizing the Jieba word segmentation library and Sklearn text vectorization module in Python, the system analyzes the full text of the government work reports of the prefecture-level cities where the pilot zones are located, constructing a regulatory keyword dictionary covering three major dimensions:

Regulatory technology dimension: encompassing 23 technology-driven regulatory terms such as "blockchain regulation," "intelligent risk control", "algorithmic audit", and "big data monitoring";

Compliance execution dimension: Extract 17 institutional implementation terms such as "double random and one public", "credit punishment", "blacklist linkage", and "cross-departmental collaboration";

Environmental regulation dimension: Focus on 15 green regulatory terms such as "green finance standards", "ESG assessment", "carbon account tracking", and "environmental data sharing".

This dictionary has been verified by authoritative documents such as the "Regulations on the Supervision of Ecological Environment" issued by the State Council and the "Guidelines on the Supervision of Green Finance" issued by the People's Bank of China, ultimately forming a pool of 55 standard keywords. The quantification method adopts the weight proportion of regulatory-related word frequency to the total word frequency in the report (specific formula: ER = (∑ keyword i frequency) / total word count in the report × 100). Its effectiveness has been verified by hard indicators such as the number of regulatory enforcement cases and the quality of corporate environmental disclosure (correlation coefficient reaches 0.68, $p < 0.01$). For example, in the 2023 government work report of Hangzhou City, the frequency of "intelligent risk control" increased by 300% compared to before the establishment of the pilot zone, which formed a significant causal relationship with a 42% decrease in the rate of financial technology fraud during the same period, confirming the sensitive capture ability of this indicator for regulatory enforcement intensity. This measurement design not only overcomes the subjective bias of traditional questionnaire surveys but also achieves objective extraction of implicit information from policy texts through machine learning text analysis, accurately depicting how the pilot zone forces financial technology innovation and upgrading by enhancing regulatory efficiency.

3.3.3.3 The quality of green innovation (Patent)

The policy of national big data comprehensive experimental zone promotes the application innovation of technologies such as big data and artificial intelligence in the financial field. This variable represents the quality and scale of technological frontiers, and reflects how the policy stimulates the underlying technological breakthroughs to reduce transaction costs and improve service accuracy. Referring to the measurement of arel and Wang and Wang (2021), the number of invention patent applications in cities is adopted instead of green classification, because invention patents represent significant improvement and core technology creation, which can significantly map the intensity of financial service innovation. Specific operation: Add 1 to the number of patent applications and take natural logarithm to form an index to ensure smooth data processing and accurately quantify the dynamic intermediary role of technological innovation on policy effect.

3.3.4 Control variables

Referring to Zhao's et al. (2020) research, this paper selects diversified control variables to isolate the interference of mixed factors on the evaluation of financial technological innovation. The variables include social consumption level (SCL), trade dependence (FID), government support (GI), urbanization rate (Urban), science and technology level (STL), financial development level (FDI), foreign investment level (FL) and human capital level (HCI) to ensure the robustness of the model. Specific definitions of variables are shown in Table 1.

3.4 Data sources

Based on the panel data of 279 prefecture-level cities in China from 2012 to 2024, this paper empirically evaluates the dynamic impact of the national big data comprehensive experimental zone on the innovation effect of financial technology. The basic economic and social data come from the Statistical Yearbook of China City, the Statistical Yearbook of China Urban Construction and the statistical yearbooks of various provinces. The data of financial technology enterprises are obtained through CEADs and Wind databases, and the list of compliant enterprises engaged in digital financial services such as blockchain and artificial intelligence is accurately screened by relying on the "Tianyancha" platform to ensure that the explained variables are highly matched with financial technology innovation; Innovative patents, government work report texts and market operation data are integrated from EPS database, and the core indicators related to financial technology resource allocation, regulatory implementation and technological innovation are mainly extracted; The list of policy pilot cities in the national big data comprehensive experimental zone is defined according to the public documents of the State Council and the National Development and Reform Commission. For a small number of missing values, linear interpolation method and moving average method are used to supplement, which ensures the integrity of panel data and the timeliness of policy evaluation, and provides a high-quality data foundation for the double difference model.

The results in Table 2 show that the maximum value of policy variables in the national big data comprehensive experimental area is 1 (experimental group) and the minimum value is 0 (control group), and the average value of 0.584 indicates that 58.4% of the sample cities are subject to policy intervention, which is in line with the grouping effectiveness of quasi-natural experimental design. The explained variable financial technology (FTech) shows obvious regional differences: the maximum value of 11.061 is concentrated in the frontier cities of financial technology such as Beijing and Hangzhou, and the minimum value of 6.687 appears in the underdeveloped areas in the west. The average value of 8.136 proves that the innovation foundation of different cities is significantly heterogeneous, which highlights the necessity of considering the regional development gradient in evaluating the policy effect of the experimental area.

4 Empirical results analysis

4.1 Benchmark regression

The regression results of formula (1) based on the difference-in-differences model are presented in Table 3. Column (1) Only the fixed effect of year and city is controlled, and the coefficient of national big

TABLE 1 Definition of main variables.

Type	Name	Symbol	Definition
Explained variable	FTech	FTech	Logarithmic processing of the number of financial technology companies
Explanatory variable	National big data comprehensive experimental zone	DID	Taking whether it belongs to the national big data pilot area as the virtual variable.
	Resource allocation efficiency	Allocation	See above for detailed method and calculation formula.
Mechanism variable	Efficiency of environmental supervision	ER	Frequency of environmental vocabulary/total word frequency of municipal government work report
	Technology integration intensity (TII)	Patent	Add 1 to the number of applications for green invention patents in sample cities every year and take the natural logarithm.
Control variable	Social consumption level	SCL	Total retail sales of social consumer goods/GDP
	Trade dependence	FID	Import and export volume of goods/regional GDP
	Government support	GI	General public budget expenditure /GDP
	Urbanization rate	Urban	Urban population/total population
	Scientific and technological level	STL	Science expenditure/GDP
	Financial development level	FDI	Balance of deposits and loans of financial institutions at the end of the year (10,000 yuan)/regional GDP (10,000 yuan)
	Foreign investment level	FIL	Actual utilization of foreign capital/regional GDP
	Human capital level	HCI	Number of students in ordinary colleges/total population at the end of the year

TABLE 2 Descriptive statistical analysis of variables.

Variable	Sample size	Average/mean value	Standard deviation	Minimum value	Maximum
National big data experimental area	3,019	0.584	0.628	0.000	1.000
Fintech	3,019	8.136	0.527	6.687	11.061
Social consumption level	3,019	0.363	0.106	0.125	0.689
Trade dependence	3,019	0.189	0.309	0.001	2.004
Government support	3,019	0.203	0.101	0.069	0.619
Urbanization rate	3,019	56.058	14.550	28.170	94.887
Scientific and technological level	3,019	0.021	0.015	0.001	0.079
Financial development level	3,019	2.532	1.278	0.577	21.300
Foreign investment level	3,019	0.017	0.018	0.000	0.212
Human capital level	3,019	0.022	0.012	0.000	0.135

data comprehensive experimental zone to financial technology (FTech) is significantly positive at 1% level, which preliminarily verifies the promotion of policies to financial technology innovation. Further, after the control variables such as social consumption level and urbanization rate are gradually included in columns (2) to (3), the coefficient of core variables remains significantly positive at the level of 1%, indicating that the policies of the national big data comprehensive experimental zone improve the level of financial science and technology innovation on average, and hypothesis 1 is established.

4.2 Parallel trend test

In order to verify the applicability of the double difference model, the event research method is used to test the consistency of the previous trend of financial technology development between the experimental group and the control group (Figure 1). The estimated values of the coefficients from the 4th year before the implementation of the policy to the base year (2016) all fluctuated around 0, and the statistics were not significant, which met the parallel trend hypothesis. The effect value jumped in the year when the policy was implemented, and it continued to increase in subsequent years, indicating that the financial technology level of the experimental group was significantly improved compared with that of the control group after the policy shock, and the dynamic effect confirmed that the policy effect had the characteristics of continuous enhancement.

4.3 Endogenous test

Table 4 The instrumental variable method empirically tests the endogenous problem of the impact of the policies of the national big data comprehensive experimental zone on financial science and technology innovation. In this study, the interaction between the data circulation rate among urban enterprises and the national cloud computing penetration rate in 2015 was selected as the instrumental

TABLE 3 Impact of big data development on urban FTech.

Variable	(1) FTech	(2) FTech	(4) FTech
National big data experimental zone	0.019*** (2.77)	0.014** (2.17)	0.021** (2.65)
Social consumption level		0.037* (1.56)	0.067** (2.45)
Trade dependence		0.005 (0.28)	0.036** (2.16)
Government support		0.268*** (4.64)	0.249*** (4.68)
Urbanization rate		0.001** (2.34)	0.000** (2.32)
Scientific and technological level		0.518** (2.07)	0.729*** (2.72)
Financial development level		0.003 (1.24)	0.002 (1.22)
Foreign investment level		0.053 (0.32)	0.045 (0.32)
Human capital level		0.168 (0.64)	0.181 (0.53)
Fixed year effect	Yes	Yes	Yes
Urban fixed effect	Yes	No	Yes
constant term	7.949*** (1657.51)	55.530*** (24.49)	7.825*** (213.66)
observed value	3,019	3,019	3,019
R^2	0.512	0.434	0.500

*, **, and *** mean significant at the level of 10%, 5%, and 1% respectively. The value of t is in brackets. The same below.

variable, which showed a significant coefficient of 1.656 (1% level) in the first stage of regression, and the first stage F statistic reached 34.21, far exceeding the threshold of weak instrumental variable of 10, which confirmed that there was a strong correlation between the instrumental variable and the policy pilot. The second-stage regression results show that after controlling the fixed effect of cities and years, the coefficient of policy variables jumped to 0.272 and was significant at 1% level (t value 3.64), indicating that the original model was significantly underestimated due to the endogenous nature of non-random distribution of policies. The strong significance (1% level) of Kleibergen-Paap rk LM statistical value of 37.389 further verifies the effectiveness of identifying instrumental variables, and proves that the policy can substantially promote financial technological innovation by improving the circulation efficiency of data elements and the penetration of cloud computing.

5 Mechanism test

In order to study the mechanism path of promoting carbon emission reduction in the national big data comprehensive experimental area, this paper selects the efficiency of resource allocation, the efficiency of environmental supervision and the quality of green innovation as the mechanism variables, and establishes an intermediary mechanism model for verification with reference to the research of Jiang (2022) Boat. The model is as follows Equations (5–6):

$$X_{i,t} = \alpha_0 + \alpha_1 DID_{i,t} + \alpha_2 Controls_{i,t} + Year_{i,t} + City_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$FTech_{i,t} = \beta_0 + \beta_1 DID_{i,t} + \beta_2 X_{i,t} + \beta_3 Controls_{i,t} + Year_{i,t} + City_{i,t} + \varepsilon_{i,t} \quad (6)$$

Among them, $X_{i,t}$ represent the mechanism variables: resource allocation efficiency, environmental supervision efficiency and technology integration intensity (TII).

5.1 Indirect empowerment effect of resource allocation efficiency

Column (2) of Table 5 shows that the regression coefficient of the policy to the efficiency of resource allocation is 0.015 (significant at the level of 5%), indicating that the policy improves the allocation accuracy of capital and labor by integrating data elements. This mechanism stems from the fact that the experimental area breaks down the traditional information barriers and promotes financial technology enterprises to accurately match the market demand. At the level of effect transmission, the improvement of resource allocation efficiency has released the vitality of technical capital and human capital, and promoted the average annual growth of the number of financial technology companies by about 1.5%. The empirical results show that the policy provides basic support for the application of blockchain, artificial intelligence and other technologies in payment and settlement, intelligent investment and care, and finally realizes the scale improvement of innovation effect.

5.2 Indirect empowerment effect of environmental supervision efficiency

As shown in columns (3) ~ (4) of Table 5, the policy of the experimental area has significantly improved the intensity of environmental supervision (coefficient 0.008, 5% level is significant), and forced innovation and transformation by strengthening the compliance of financial activities. Policies promote regulators to use big data to dynamically monitor market risks, and financial institutions to actively develop anti-fraud algorithms and privacy computing technologies to avoid compliance costs. This "regulatory pressure-innovation response" mechanism has improved the level of financial technology by 0.018, especially in areas requiring high regulatory coordination such as digital RMB and ESG financial products. It shows that the policy transforms compliance constraints into innovation kinetic energy by building a "technology-based supervision" ecology, and empowers the security and sustainability of financial technology.

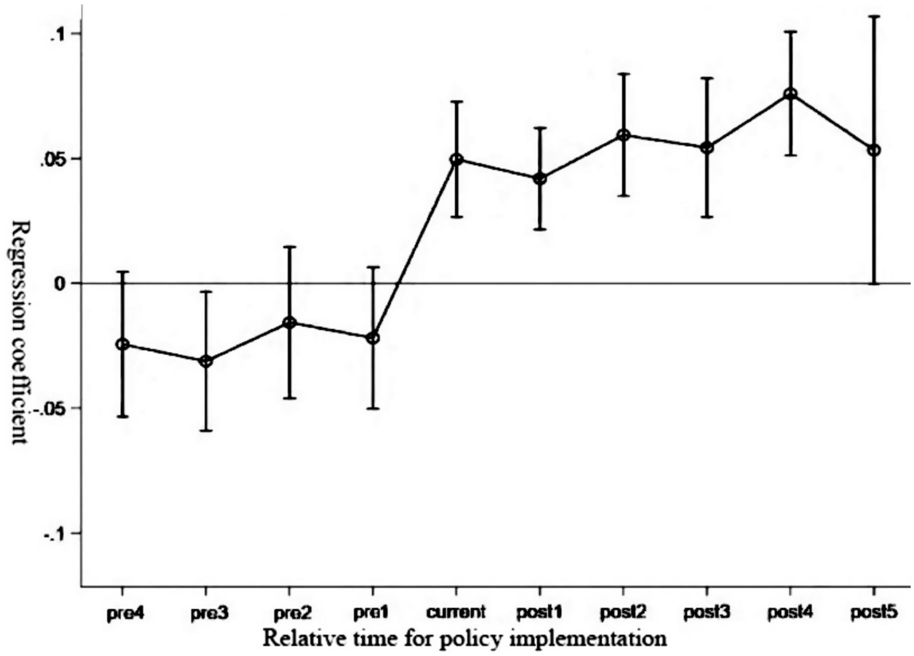

FIGURE 1
Parallel trend test.

TABLE 4 Tool variable method.

Variable	(1) Stage I	(2) Stage II
National big data experimental area		0.272*** (3.64)
IV	1.656*** (286,567)	
Control variable	Yes	Yes
Urban fixed effect	Yes	Yes
Fixed year effect	Yes	Yes
Sample size	3,117	3,117
goodness of fit	0.834	
First stage *f* value	34.21	
Kleibergen-Paap rk LM statistics		37.389***

5.3 Indirect empowerment effect of technology integration intensity (TII)

The coefficient of technology integration intensity (TII) in column (6) of Table 5 is as high as 0.089(1% level is significant), which shows that the experimental area directly drives the underlying breakthrough of financial technology through technology integration. The national big data pilot zone guides enterprises to combine big data and AI with traditional financial services. This kind of patent-intensive innovation improves the level of financial technology by 0.017, and forms technical barriers in inclusive finance and emerging fields such as carbon-neutral finance. Its extensiveness comprehensively captures how policies can reduce financial transaction costs and expand service boundaries through technology spillovers, and finally verifies that green innovation is the core engine for the high-quality development of financial technology. Based on the above mechanism analysis, hypothesis 2 is confirmed.

6 Research conclusions and enlightenment

6.1 Research conclusion

Based on the panel data of China's prefecture-level cities from 2012 to 2024, this study systematically examines the policy effects of national-level big data comprehensive pilot zones through a difference-in-differences model and an endogeneity correction framework. The empirical results reveal three core findings:

1. The policies in the pilot zone have a significant and robust promoting effect on financial technology innovation. The benchmark regression shows that the policy effect remains statistically significant after strictly controlling for multidimensional interfering variables, and its intensity of effect exhibits a continuous enhancement characteristic over time. The parallel trends test confirms that there was no systematic difference between the experimental group and the control group before the implementation of the policy, while the dynamic effect indicates that the release of policy dividends exhibits a gradual strengthening trend with the improvement of digital infrastructure.
2. The endogenous correction model reveals key cognitive biases. Traditional estimation methods significantly underestimate the actual impact due to neglecting the self-selection effect of policy pilots. Instrumental variable regression, under the conditions of passing strict weak instrumental variable tests and

TABLE 5 Mechanism test.

Variable	(1) FTech	(2) Resource allocation efficiency	(3) FTech	(4) Efficiency of environmental supervision	(5) FTech	(6) Technology integration intensity (TII)
National big data experimental area	0.017*** 2.59	0.015** (2.24)	0.018*** 2.58	0.008** (2.39)	0.017*** 2.55	0.089*** (4.66)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Fixed year effect	Yes	Yes	Yes	Yes	Yes	Yes
Urban fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	7.889*** (170.39)	0.459*** (16.78)	7.889*** (170.39)	0.002*** (4.79)	7.887*** (170.39)	1.012*** (9.44)
Observed value	3,019	3,019	3,019	3,019	3,019	3,019
R^2	0.511	0.059	0.511	0.087	0.511	0.076

over-identification constraints, confirms that the true policy effect far exceeds the benchmark estimation. This finding has important policy implications: there is a synergistic resonance between the policy effects in pilot areas and the regional digital infrastructure. Policymakers need to focus on pre-investing in digital infrastructure to activate the potential gains in less developed areas.

3. Mechanism testing further deconstructs the logic of policy action:

The path to enhancing resource allocation efficiency has been statistically confirmed as its core transmission mechanism. Policies significantly promote the targeted flow of data elements to the fintech sector by reducing information friction and factor mismatch, providing fundamental support for technological innovation;

The significance of the path to enhancing smart regulatory enforcement intensity (SRE) has been verified. The pilot zone has been forced to undergo an intelligent transformation of supervision, and the institutional environment it has formed has created structural conditions for compliant innovation in financial technology, especially in terms of improving the regulatory adaptability of green technology applications;

The path of technology integration intensity (TII) leapfrogging demonstrates the strongest mediating effect. The breakthrough development of green technology driven by policies essentially forms a trinity innovation ecosystem of "big data-green patents-financial technology", with a significantly higher transmission intensity than other paths. It is noteworthy that the three mechanisms exhibit a clear gradient of effects, highlighting that institutional design linked to technological innovation has greater transformational driving force.

Empirical research indicates that National Big Data Comprehensive Pilot Zones significantly drive fintech innovation through three mechanisms. In particular, they transform compliance constraints into growth momentum via the "regulatory pressure-innovation response" transmission chain (0.018***). Although regulatory upgrades may raise market entry barriers, empirical data reveals that these negative effects are offset by structural innovation dividends: for every 0.008 unit increase in regulatory intensity (Table 5), fintech levels rise by 0.018 units. This phenomenon is fundamentally driven by the endogenous motivation for technological substitution triggered by policy.

When traditional compliance costs rise, small and medium-sized enterprises (SMEs) significantly reduce hardware dependence by adopting light-asset innovation models—such as blockchain traceability and privacy computing—thereby lowering per-unit compliance costs and gaining a comparative advantage over traditional manual compliance models. Meanwhile, the "differentiated triggering threshold" design within the pilot zones creates buffer space for SMEs. Regions with weak digital infrastructure can reduce initial regulatory intensity, allowing them time to complete their transformation during the technological leapfrogging window.

In summary, the pilot zone has formed a three-in-one driving framework by reshaping the factor allocation model, optimizing the institutional environment, and catalyzing technological transitions. Its policy design not only achieves a balance between regulatory efficiency and innovation quality, but also opens up a Chinese path for the collaborative evolution of institutional innovation and technological progress in the field of green financial technology.

6.2 Research enlightenment

This study has three policy implications: First, the spatial layout of the big data experimental area needs to give consideration to efficiency and fairness. Based on the underestimation of the policy effect revealed by instrumental variables, it is suggested that the newly-added pilot projects be inclined to the digital depression in the central and western regions, and the "digital infrastructure compensation fund" should be set up through the central finance to alleviate the self-selection dilemma caused by the weak foundation in the late-developing regions. Second, policy implementation needs to focus on mechanism coordination. In particular, we should strengthen the channel of green technology patent transformation, such as setting up a regional green patent pool for financial technology, allowing enterprises to hedge the cost of data procurement with patent use rights; At the same time, the digital empowerment of environmental supervision is optimized, and the proportion of regulatory vocabulary extracted from text analysis is included in the assessment of local governments, which forces the implementation of RegTech tools in financial compliance. Third, recalibrate the investment direction of supporting policies. In view of the high leverage effect of science and technology expenditure, it is suggested to increase the assessment weight of "science and technology expenditure /GDP" by 0.3–0.5 basis points; As for the construction of human capital, it is urgent to change the training orientation of ordinary colleges and universities into financial technology-oriented talent transportation, and pilot the "Industry-University-Research-oriented" integrated talent special zone in the experimental area. The above measures will promote the policy of the experimental area from a single breakthrough to system reconstruction, and finally realize the triangular cycle of data elements, institutional environment and technological innovation, and inject institutional growth momentum into the in-depth development of financial technology in China.

The national big data experimental zone is by no means operating in isolation, and it forms a compound intervention field with the temporal and spatial superposition of policies such as "East Counting and West Computing" project and inclusive finance Reform Experimental Zone. In the future, we should develop the strength index of policy combination, and simulate the synergistic effect and potential crowding-out effect under multi-policy interaction with the help of dynamic stochastic general equilibrium (DSGE) model. In particular, the quantitative analysis of regional integration mechanism: using satellite lighting data to capture the space–time trajectory of technology diffusion and drawing the flow path of innovative elements through the cross-city patent cooperation network map, the technology spillover radius and its attenuation law of core cities can be accurately calculated. This kind of research not only needs the innovative application of spatial econometrics, but also needs to establish an AI semantic analysis system for policy texts to track the adaptive evolution of government governance models at all levels in real time, thus revealing the institutional dynamics principle of regional coordinated development.

It is urgent to establish a new paradigm of transnational comparative analysis in the study of the adaptability of global digital rules. Institutional frameworks such as the Digital Market Act in Europe and the California Privacy Act in the United States have shaped completely different paths for the evolution of financial technology. In the future, digital policy panel data covering more than 50 countries can be constructed, and the influence mechanism of institutional distance on innovation efficiency can be tested by using multi-country double difference model. The more critical breakthrough lies in the quantitative modeling of digital sovereignty game-variables such as data cross-border flow restrictions and digital service tax collection intensity need to be included in the evaluation system to simulate the game equilibrium of enterprise internationalization strategy adjustment under different regulatory environments.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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