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Does Financial Innovation Promote Smart City Development? The Single Threshold of Government Digital Governance Capacity

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Abstract: Cities worldwide are rapidly undergoing intelligent transformation, yet smart city development faces persistent challenges such as funding gaps, inefficient technology transfer, and regional disparities. Against this backdrop, this study investigates whether and how financial innovation can drive smart city development, with a particular focus on the threshold effect of government digital governance. To address the lack of systematic understanding regarding the nonlinear mechanisms linking finance, governance, and urban intelligence, this paper employs provincial panel data from China spanning from 2010 to 2023. The empirical results show that financial innovation significantly promotes smart city development, and this effect is more pronounced in regions with higher levels of marketization. Government digital governance exhibits a clear threshold effect: once governance capacity surpasses a certain level, the marginal contribution of financial innovation to smart city development is considerably enhanced. Mechanism testing indicates that regional innovation vitality plays a partial mediating role, and this mediating pathway becomes stronger in regions with higher degrees of openness. By extending the understanding of the micro-mechanisms through which financial innovation empowers high-quality urban development, this study provides empirical evidence for differentiated smart city advancement and the optimization of "finance–governance–innovation" synergistic policies.

Keywords: Financial innovation; Smart city development; Government digital governance; Regional innovation vitality; Degree of openness

1. Introduction

Today, cities worldwide are rapidly entering a new stage of "intelligent transformation," characterized by data-driven operations and intelligent coordination. According to the United Nations' World Cities Report 2024, 55% of the global population resides in urban areas, a proportion expected to rise to 68% by 2050. In China, the urbanization rate has increased from 47.5% in 2010 to 66.2% in 2023. However, smart city development faces challenges such as large funding gaps, low efficiency in technology transfer, and regional disparities. As a key tool

for resource allocation, financial innovation has become increasingly relevant to smart city construction (Yang et al., 2022). Through mechanisms such as digital payments, green finance, and supply chain finance, financial innovation provides low-cost capital for smart city infrastructure while promoting the market-oriented allocation of data resources. Nonetheless, practice reveals significant regional differences: cities like Hangzhou and Shenzhen have leveraged digital governance advantages to achieve efficient "finance–technology–city" coupling, while in some central and western cities, smart transformation has lagged despite heavy investment in fintech projects (Estevez et al., 2021).

Existing research has yet to reach a systematic consensus on this issue. On the one hand, the relationship between financial innovation and urban development has long been discussed within traditional growth frameworks, emphasizing the role of financial innovation in promoting technological progress by easing financing constraints and optimizing capital allocation (Bühler et al., 2023). Although some recent studies have extended this discussion to the smart city domain, most focus on single aspects—such as infrastructure investment or enterprise digital adoption—lacking rigorous measurement of "smart city development" as a multidimensional concept encompassing digital infrastructure, digital industrialization, and industrial digitalization (Ramly and Zabri, 2024). On the other hand, government digital governance is increasingly viewed as a core driver of smart transformation. Yet, existing literature commonly treats it as a control variable or a linear moderating factor, overlooking its potential nonlinear threshold characteristics (Dai, 2025). More critically, although the logical chain of "financial innovation–regional innovation–urban intelligence" is frequently referenced (Gil et al., 2022), few empirical studies test the mediating role of regional innovation vitality (e.g., technology market activity), nor do they examine how macro-institutional factors such as marketization and openness moderate this pathway.

To address these research gaps, this paper systematically investigates the impact of financial innovation on smart city development, with a particular focus on the threshold effect of government digital governance. The core contributions of this study are threefold: first, it introduces government digital governance capacity as a threshold variable to verify nonlinear effects; second, it uses per capita technology market turnover to characterize regional innovation vitality, identifying the mediating pathway of "financial innovation—innovation vitality—urban intelligence"; and third, it reveals the heterogeneity of the mediating effect across regions with different levels of openness. The findings provide new

evidence for understanding the micro-foundations of finance-enabled high-quality urban development and offer important insights for developing context-sensitive, category-based smart city policy frameworks.

2. Research hypotheses

2.1. Financial innovation and smart city development

As a product jointly driven by technological evolution and institutional adaptation, financial innovation can profoundly empower smart city development by restructuring the allocation efficiency of capital, data, and technology. Based on endogenous growth theory and the framework of the digital economy, financial innovation not only enhances resource allocation efficiency but also serves as a core engine driving urban intelligent transformation by lowering the fixed costs and risk premiums of technology adoption, accelerating the clarification and circulation of data property rights (Tran and Nguyen, 2023). On the one hand, the rise of financial technology (e.g.,, blockchain, and big data-based risk management) has significantly reduced the financing costs of smart infrastructure, alleviating funding constraints for local governments and enterprises (He et al., 2025). For example, green finance instruments such as carbon trading markets and green bonds provide long-term, low-cost capital for smart energy systems, directly promoting the low-carbon transition of cities (Guo and Zhong, 2022). On the other hand, the widespread use of digital payments and supply chain finance has enhanced the precision of urban governance, optimizing the supply of public services such as transportation and healthcare through real-time data collection and analysis (Shu et al., 2023). Therefore, financial innovation can significantly advance smart city development through a "capital supplementation–technological empowerment–service upgrading" pathway.

Hypothesis 1: Financial innovation has a significant positive effect on smart city development.

However, the facilitating role of financial innovation is highly dependent on the adaptability of the regional institutional environment. According to the principle of "institutional complementarity" in institutional finance, the efficiency of resource allocation through financial innovation depends on the maturity of supportive market mechanisms (Jebaraj et al., 2023). In regions with a higher degree of marketization, where price signals are responsive, property rights are well protected, and competition constraints are effective, financial technology can accurately identify and support smart city projects with high total factor productivity. Conversely, in less market-oriented regions, where administrative

intervention is strong and factor mobility is restricted, financial resources may flow into inefficient sectors or form "digital showcase projects," thereby weakening the efficiency of innovation transformation (Guo et al., 2022).

Hypothesis 2: The positive effect of financial innovation on smart city development is more pronounced in regions with a higher degree of marketization.

According to dynamic capability theory, the government's digital governance capacity serves as the "digital hub" of the urban governance system, and its level determines the efficiency with which external resources (such as financial innovation) are transformed (Xu et al., 2025). Specifically, the facilitating effect of financial innovation on smart city development is not linear; rather, it depends on the "threshold condition" of government digital governance capacity. When governance capacity is at a low level, the government may be unable to effectively integrate financial resources with urban needs due to issues such as data silos, technological barriers, or policy fragmentation, resulting in stagnant or inefficient financial innovation (e.g., funds flowing into low-efficiency projects) (Du et al., 2023). At this stage, the marginal contribution of financial innovation is constrained by governance shortcomings, making it difficult to achieve the synergistic effect of "finance–technology–city" (Huang et al., 2021). In contrast, when government digital governance capacity surpasses a certain threshold, it can efficiently align the flows of capital and information generated by financial innovation with urban development priorities (such as traffic congestion and energy waste) through real-time monitoring, precise matching, and dynamic optimization, thereby amplifying the multiplier effect of financial innovation (Gracias et al., 2023).

Hypothesis 3: Government digital governance exhibits a significant single-threshold effect in the process through which financial innovation influences smart city development.

2.2. The mediating role of regional innovation vitality

According to the theory of innovation-driven development, financial innovation can stimulate regional innovation vitality—such as R&D investment, patent output, and technology transformation—by optimizing resource allocation and reducing innovation risks, thereby promoting smart city development (Olanrewaju et al., 2024). Specifically, financial innovation provides low-cost and highly flexible financial support for innovation entities (enterprises, universities, and research institutions), alleviating the "financing constraints" of innovation activities and

facilitating the research and application of frontier technologies such as artificial intelligence and blockchain. These technological achievements, once commercialized, are embedded into smart city scenarios, including transportation, energy, and public services, forming a "finance–innovation–city" transmission chain (Zhang et al., 2023). For example, Shenzhen has fostered technological innovations from enterprises such as DJI and Huawei through the synergy between financial technology and industrial funds, thereby supporting globally leading practices in smart transportation and digital governance (Kutkov et al., 2025).

Hypothesis 4: Regional innovation vitality plays a partial mediating role between financial innovation and smart city development.

The strength of the mediating pathway of regional innovation vitality may be significantly moderated by the degree of external openness (Mishra et al., 2022). According to global value chain theory, the level of openness can enhance the transformation efficiency of regional innovation vitality through international technology spillovers, competition effects, and resource flows (Kaiser, 2024). In highly open regions, enterprises are more likely to access global innovation networks—such as multinational R&D cooperation and international standard alignment—thus accelerating technology absorption and reinvention and enabling regional innovation vitality to convert more efficiently into tangible outcomes for smart city development, such as intelligent infrastructure and digital service platforms (Li et al., 2023). For instance, Suzhou has significantly improved its development level in the industrial internet and smart logistics by attracting foreign investment to establish R&D centers and combining this with local financial innovations such as technology loan interest subsidies (Wolniak et al., 2024). Conversely, in less open regions, regional innovation vitality may be constrained by technological lock-in or market segmentation, leading to a weakened mediating effect.

Hypothesis 5: In regions with higher levels of openness, the mediating role of regional innovation vitality between financial innovation and smart city development is more pronounced.

3. Model specification, data sources, and characteristics

3.1. Model specification

(1) Baseline regression model

To thoroughly examine the impact of financial innovation on smart city

development, this paper constructs the panel regression model (1). In model (1), to accurately control for other factors that may influence smart city development, a set of control variables, denoted as *Controls*, is introduced. These mainly include the level of economic development (lnPGDP), government intervention (Gov), human capital level (HumCap), physical infrastructure (Infra), industrial structure upgrading (IndStr), degree of marketization (Market), level of openness (Open), and population density (Density). Meanwhile, to control for unobservable fixed characteristics across regions, the model fixes the regional effect at Province and includes a random error term ω_{it} to capture stochastic factors not reflected in the model. The specific model is expressed as follows:

$$SmartCity_{it} = \sigma + \sigma_1 FinInnovation_{it} + \sigma_n Controls_{it} + Province_i + \omega_{it} \quad (1)$$

Among them, the dependent variable, SmartCity, is used to characterize the level of smart city development. Drawing on existing literature, this study constructs a Digital Intelligent City Index based on a three-dimensional principal component analysis method encompassing digital infrastructure, digital industrialization, and industrial digitization. A higher SmartCity value indicates a higher level of urban intelligence (Zaman et al., 2024).

The core explanatory variable, FinInnovation, represents financial innovation and is measured using a fintech index. This fintech index is constructed based on three dimensions: the number of fintech enterprises, financing scale, and number of patents.

(2) Threshold effect model

To explore whether the government's digital governance capability exerts a threshold effect in the process through which financial innovation influences smart city development, this study constructs the following threshold effect model:

$$\begin{aligned} SmartCity_{it} = {} & \pi_0 + \pi_1 FinInnovation_{it} * I(GovDigitalGov_{it} \le \tau) + \\ & \pi_2 FinInnovation_{it} * I(GovDigitalGov_{it} > \tau) + \pi_n Controls_{it} + Province_i + \omega_{it} \end{aligned} \quad (2)$$

Among them, the threshold variable is GovDigitalGov, representing the government's digital governance capability. This study employs the Government Digital Governance Capability Index to measure the level of digital governance. The index is constructed by developing an indicator system that includes multiple dimensions, such as the degree of digitization of government services, data governance capability, and the ability to apply digital technologies, and is calculated using factor analysis. A higher value of GovDigitalGov indicates stronger government digital governance capability and a higher degree of digitalization and

intelligence in governance.

(3) Mediating effect model

To examine whether regional innovation vitality plays a mediating role in the relationship between financial innovation and smart city development, the following model is constructed:

$$RIV_{it} = \lambda + \lambda_1 FinInnovation_{it} + \lambda_n Controls_{it} + Province_i + \omega_{it} \quad (3)$$

$$SmartCity_{it} = \mu + \mu_1 FinInnovation_{it} + \mu_2 RIV_{it} + \mu_n Controls_{it} + Province_i + \omega_{it} \quad (4)$$

Among them, RIV serves as a mediating variable, measured by the per capita transaction value in the technology market to represent regional innovation vitality. The transaction value of the technology market directly reflects the level of commercialization of technological achievements and the activeness of knowledge exchange. It is a core indicator for evaluating a region's capacity to transform and apply innovation outcomes. Per capita processing of RIV helps eliminate the influence of population size. A higher RIV value indicates stronger regional innovation vitality.

3.2. Data sources and characteristics

This study takes data from 31 provincial-level administrative regions in China (excluding Hong Kong, Macao, and Taiwan) from 2010 to 2023 as the research sample. The data are drawn from multiple authoritative sources: data related to financial innovation mainly come from the People's Bank of China Statistical Database; data concerning government governance and public services are derived from the Statistical Yearbooks published by the National Bureau of Statistics, government work reports disclosed in provincial government gazettes, and the digital government development evaluation reports issued by the Cyberspace Administration of China; data on smart city development are obtained from the information development reports released by the Ministry of Industry and Information Technology (MIIT) and surveys conducted by specialized urban development research institutions, ensuring the authority and accuracy of the measurement of smart city construction levels; data on regional innovation vitality and communication infrastructure are sourced from the MIIT's Statistical Bulletin on the Telecommunications Industry. Other economic and social indicators are drawn from the China Statistical Yearbook and various provincial statistical yearbooks, standardized and calibrated to ensure consistency. All continuous

variables are winsorized at the 1% level from both ends. Table 1 reports the descriptive statistics of the main variables.

Table 1 Descriptive statistical analysis table

VarName	Obs	Mean	SD	Min	Median	Max
SmartCity	434	2.7746	0.7487	1.0986	2.9174	4.1271
FinInnovation	434	4.3812	2.0117	0.0000	4.3944	8.3229
RIV	434	5.8688	1.8368	0.9316	5.8380	10.1661
GovDigitalGov	434	0.2284	0.1213	0.0715	0.1877	0.6744
TCI	434	0.5538	0.1545	0.2400	0.5600	0.8800
lnPGDP	434	10.8456	0.4942	9.7532	10.8353	12.1037
Gov	434	0.2866	0.2011	0.1171	0.2313	1.2727
HumCap	434	0.0208	0.0061	0.0092	0.0204	0.0389
Infra	434	3.5953	0.6969	1.8263	3.6225	5.6667
IndStr	434	0.4973	0.0902	0.3389	0.4935	0.8309
Market	434	7.9684	2.2874	0.7370	8.1705	12.4760
Open	434	0.2865	0.3036	0.0127	0.1542	1.4344
Density	434	0.9253	0.5232	0.1335	0.8257	2.4463

4. Financial innovation and smart city development

4.1. Correlation analysis

To preliminarily investigate the association between financial innovation and smart city development, this study constructs a scatter plot with financial innovation on the horizontal axis and smart city development on the vertical axis, along with a fitted regression trend line. As illustrated in Figure 1, the data points display a generally positive pattern, and the estimated regression line exhibits a consistent upward slope. This visual evidence suggests a clear positive correlation between the two variables, thereby offering a preliminary empirical foundation for the subsequent baseline regression analysis.

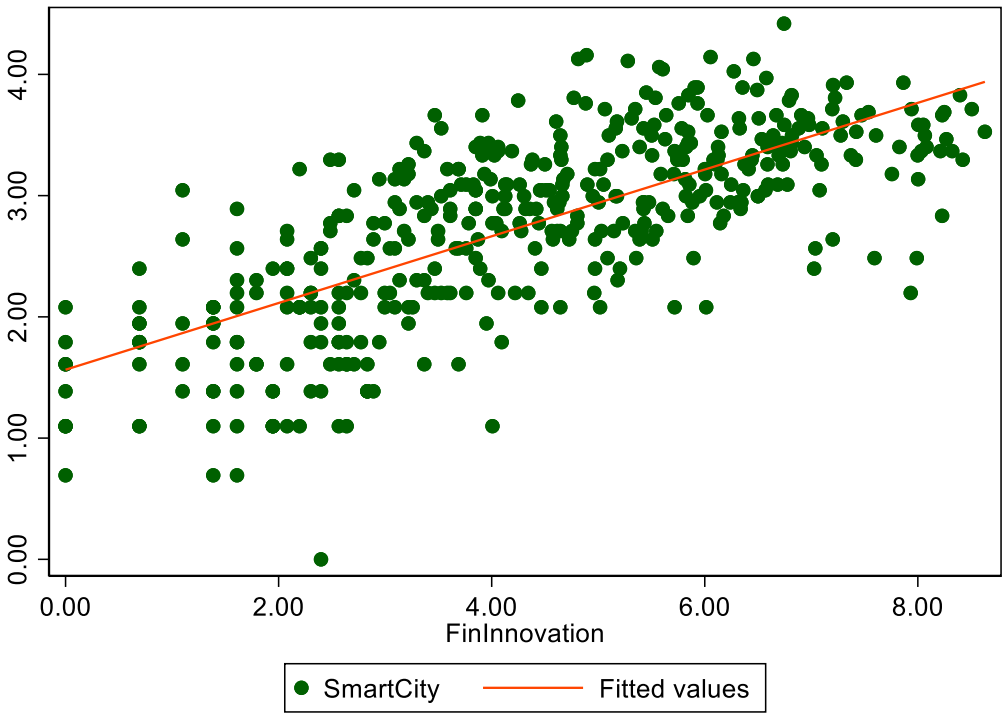


Figure 1: Analysis of the relationship between financial innovation and smart city development

4.2. Benchmark regression analysis

To accurately examine the specific impact of financial innovation on the development of smart cities, this paper conducts a benchmark regression analysis based on Model (1). Specifically, in Column (1) of Table 2, without including any control variables, the regression coefficient of financial innovation is a significant 0.3231, preliminarily indicating a positive correlation between financial innovation and smart city development. After adding control variables in Column (2), the coefficient of financial innovation decreases to 0.2519 while remaining significant at the 1% level. This change suggests that even after considering important factors that may influence smart city development, the promoting effect of financial innovation remains robust. In Column (3), with further control for provincial fixed effects, the R^2 increases to 0.6712, and the coefficient of FinInnovation stands at 0.1764, which remains significantly positive at the 1% level. These results indicate that the positive effect of financial innovation on the advancement of smart city development persists after controlling for other potential influencing factors, thereby confirming Hypothesis 1.

Table 2 Benchmark regression results of the impact of financial innovation on smart city development

VARIABLES	(1)	(2)	(3)

	SmartCity	SmartCity	SmartCity
FinInnovation	0.3231***	0.2519***	0.1764***
	(25.8231)	(6.3757)	(2.6258)
lnPGDP		0.1729	0.6020**
		(1.0816)	(2.1985)
Gov		-0.3408	0.1833
		(-0.8320)	(0.2319)
HumCap		8.3773	-3.6737
		(1.1107)	(-0.2720)
Infra		0.3269**	0.8470**
		(2.5531)	(2.2142)
IndStr		0.6437	1.5739*
		(0.9045)	(1.6958)
Market		0.0105	-0.0506
		(0.3058)	(-1.1763)
Open		-0.2463	0.0626
		(-1.3390)	(0.2213)
Density		-0.0399	-0.2731**
		(-0.4602)	(-2.1376)
Constant	1.3592***	-1.7524	-7.6931***
	(19.8624)	(-1.0385)	(-2.6825)
Province FE	NO	NO	YES
N	434	434	434
R^2	0.6524	0.6588	0.6712

4.3. Endogeneity test and robustness test

To mitigate potential endogeneity biases arising from omitted variables (such as regional innovation culture and entrepreneurship) and reverse causality (such as smart cities attracting fintech clusters), this paper employs the two-stage least squares (2SLS) method for identification. The selected instrumental variable (IV) is the level of regional telecommunication infrastructure (TCI), measured by the Internet penetration rate in each province (i.e., number of Internet users per 100 people). Table 3 reports the estimation results. In the first stage, the coefficient of TCI on FinInnovation is 1.1465 ($p < 0.01$), and the F-statistic is 110.28, well above the 10% bias critical value, indicating that the instrumental variable is strongly correlated. The LM statistic is 89.58 ($p < 0.01$), rejecting the null hypothesis that "all instrumental variables are exogenous," thereby supporting the validity of TCI as an effective instrument. In the second stage, the coefficient of FinInnovation is 0.3355 ($p < 0.01$), which is higher than that in the baseline regression, suggesting that the estimated model evaluating the impact of financial innovation on smart city development is statistically robust, and the conclusion is reliable.

To further verify the robustness of the regression results, Column (3) uses one-period-lagged financial innovation (L. FinInnovation) as the explanatory variable. The coefficient of L. FinInnovation is 0.1786 and remains significantly positive. Column (4) applies a 5% winsorization to all continuous variables, with the coefficient of FinInnovation remaining significantly positive at 0.1764. These results indicate that the promoting effect of financial innovation on smart city development is highly robust, further strengthening the credibility of the empirical conclusions.

Table 3 Results of endogeneity and robustness tests

VARIABLES	Phase I	Phase II	Lag one period	Reduce by 5% at the tail
	FinInnovation	SmartCity	SmartCity	SmartCity
TCI	1.1465***			
	(3.1240)			
FinInnovation		0.3355***		0.1764***
		(5.4561)		(3.1969)
L. FinInnovation			0.1786**	
			(2.1079)	
lnPGDP	2.8755***	-0.0537	1.1194***	0.6499***
	(19.7618)	(-0.3386)	(3.1801)	(2.7238)
Gov	-1.6469***	0.3897	0.5402	1.8140*
	(-2.8245)	(1.1667)	(0.5786)	(1.9332)
HumCap	48.7450***	9.8261*	-11.3990	-10.4208
	(4.8434)	(1.7546)	(-0.7714)	(-0.7748)
Infra	0.4385	0.0656	0.8854**	0.9019**
	(1.4939)	(0.5867)	(2.1813)	(2.4687)
IndStr	6.7905***	-0.7054	2.1542**	0.1600
	(11.2774)	(-0.8397)	(2.2381)	(0.1792)
Market	0.0582*	0.0005	-0.0611	-0.0069
	(1.8202)	(0.0130)	(-1.3475)	(-0.1602)
Open	-1.2586***	-0.3191*	-0.0217	-0.8089**
	(-6.2675)	(-1.7871)	(-0.0712)	(-2.1307)
Density	0.2187**	-0.0481	-0.2727*	-0.3320**
	(2.2805)	(-0.6690)	(-1.9380)	(-2.4299)
Constant	-33.2417***	1.8185	-13.1132***	-8.0509***
	(-23.1051)	(0.9365)	(-3.6840)	(-3.1733)
Province FE	YES	YES	YES	YES
LM value	89.5814			
Cragg-Donald Wald F	110.2836			
N	434	434	403	434
R^2	0.9782	0.5755	0.6330	0.6824

4.4. Heterogeneity analysis

To examine whether the impact of financial innovation on smart city development varies with the degree of regional marketization, this study divides the sample into two groups—high and low levels of marketization—based on the median value of regional marketization, and conducts sub-sample regressions. The results in Table 4 show that in regions with a high degree of marketization, the coefficient of FinInnovation is 0.3388 and is statistically significant at the 1% level, indicating that financial innovation has a significant positive effect on smart city development. This may be because mature market mechanisms—such as responsive price signals, well-established property rights protection, and effective competition constraints—can efficiently guide financial resources toward high-productivity smart city projects. In contrast, in regions with a low degree of marketization, the coefficient of FinInnovation is only 0.1218 and statistically insignificant. The above findings provide strong support for Hypothesis 2.

Table 4 Heterogeneity analysis of the impact of financial innovation on smart city development

VARIABLES	(1) Regions with a high degree of marketization	(2) Regions with a low degree of marketization
FinInnovation	0.3388***	0.1218
	(3.2894)	(1.1911)
lnPGDP	0.1078	0.9298**
	(0.2491)	(2.3150)
Gov	-2.0344	0.0451
	(-1.1871)	(0.0440)
HumCap	-11.4684	6.4032
	(-0.6083)	(0.2864)
Infra	0.2356	-0.1469
	(0.4177)	(-0.1959)
IndStr	-0.2723	2.9592**
	(-0.1569)	(2.1667)
Open	0.3756	-1.1669
	(1.2275)	(-1.1884)
Density	0.1311	-0.2059
	(0.3988)	(-1.0924)
Constant	-0.2728	-8.2153*
	(-0.0575)	(-1.9277)
Province FE	YES	YES
N	217	217
R^2	0.6371	0.6393

4.5. Threshold effect analysis

To gain deeper insight into the dynamic characteristics of the impact of financial innovation on smart city development, this study applies the threshold regression analysis method based on Model (2). First, through a triple-threshold effect test, the model identifies three potential threshold values located at 0.2411, 0.2770, and 0.4832, respectively. Next, a threshold significance test is conducted, and the results are presented in Table 5. The F-statistic for the single-threshold model is 18.1900, indicating the presence of a significant single-threshold effect. In contrast, the P-values for the double- and triple-threshold models do not meet the significance criteria.

Table 5 Results of the triple-threshold effect test

Threshold	RSS	MSE	Fstat	Prob	Crit10	Crit5	Crit1
Single	69.0899	0.1645	18.1900	0.0133	13.2168	15.1685	21.2433
Double	68.6892	0.1635	9.4531	0.2767	10.5265	12.3733	16.6694
Triple	68.3405	0.1627	2.1417	0.8967	11.2535	15.9467	23.9202

Table 6 presents the detailed regression results of the threshold regression model. The results clearly show that the impact of financial innovation on smart city development strengthens progressively as the government's digital governance capacity improves. Specifically, when the level of government digital governance capacity is relatively low, that is, when GovDigitalGov ≤ 0.2411, the regression coefficient of FinInnovation is 0.1090. This indicates that at this stage, the promoting effect of financial innovation on smart city development is relatively limited. However, once the government's digital governance capacity surpasses 0.2411, the regression coefficient of FinInnovation increases to 0.2530. This demonstrates that as the government's digital governance capacity improves, the facilitative effect of financial innovation on smart city development is significantly enhanced, thereby confirming Hypothesis 3.

Table 6 Analysis of the threshold effect of government digital governance capacity

	SmartCity
FinInnovation (GovDigitalGov ⩽ 0.2411)	0.1090
	(1.0650)
FinInnovation (GovDigitalGov > 0.2411)	0.2530***
	(3.5665)
lnPGDP	0.6577*
	(1.7950)
Gov	-0.0201
	(-0.0170)
HumCap	-0.5298

	(-0.0286)
Infra	0.8292
	(1.1451)
IndStr	1.5448
	(1.1205)
Market	-0.0445
	(-0.6948)
Open	-0.0707
	(-0.1601)
Density	-0.2102
	(-1.2658)
_cons	-8.2601**
	(-2.4405)
F	51.4353
N	434
R^2	0.6745

5. The mediating role of regional innovation vitality and its heterogeneity analysis

To further examine the impact of financial innovation on smart city development (SmartCity), this study investigates the mediating role of regional innovation vitality (RIV) in the relationship between the two. Table 7 presents the results of the mediation analysis based on Models (3) and (4). Column (1) shows that the estimated coefficient of FinInnovation on RIV is a significant 0.3638, indicating that financial innovation significantly enhances regional innovation vitality. In Column (2), the coefficient of RIV on SmartCity is 0.0716, while the coefficient of FinInnovation decreases from 0.1764 to 0.1025, remaining significant at the 1% level. These results confirm that regional innovation vitality plays a significant mediating role in the relationship between financial innovation and smart city development, thereby supporting Hypothesis 4.

Table 7 Results of the mediating effect analysis of regional innovation vitality

VARIABLES	(1) RIV	(2) SmartCity
FinInnovation	0.3638***	0.1025***
	(4.0256)	(2.9636)
RIV		0.0716*
		(1.9193)
lnPGDP	0.6028	0.6451**
	(1.6369)	(2.3563)
Gov	-0.2530	0.1651
	(-0.2381)	(0.2097)

HumCap	66.1661***	1.0669
	(3.6422)	(0.0780)
Infra	-1.5705***	0.7345*
	(-3.0525)	(1.9042)
IndStr	2.4788**	1.7515*
	(1.9858)	(1.8842)
Market	0.0312	-0.0483
	(0.5388)	(-1.1278)
Open	0.9231**	0.1288
	(2.4250)	(0.4531)
Density	0.2984*	-0.2517**
	(1.7365)	(-1.9695)
Constant	0.0582	-7.6889***
	(0.0151)	(-2.6902)
Province FE	YES	YES
N	434	434
R^2	0.7408	0.6743

To further examine the specific manifestations of the mediating effect of regional innovation vitality, this paper divides the sample into two groups—regions with high and low levels of openness to the outside world (using the median as the threshold)—and conducts a heterogeneity analysis. The relevant results are presented in Table 8. In regions with a high degree of openness, the coefficient of financial innovation on RIV is 0.4157, and the coefficient of RIV on SmartCity is 0.0923; both are significantly positive, indicating that financial innovation can significantly enhance regional innovation vitality, thereby promoting the development of smart cities. This demonstrates that RIV plays a significant mediating role in the relationship between financial innovation and smart city construction. In contrast, in regions with a low degree of openness, the coefficient of financial innovation on regional innovation vitality is 0.1396, which is not statistically significant, and the coefficient of RIV on SmartCity is 0.0481, which is also insignificant. This implies that the mediating effect of regional innovation vitality is not significant. Combining the analysis results from both high- and low-openness regions, Hypothesis 5 is confirmed.

Table 8 Heterogeneity results of the mediating effect of regional innovation vitality

VARIABLES	High degree of openness to the outside world		Low degree of openness to the outside world	
	RIV	SmartCity	RIV	SmartCity
FinInnovation	0.4157***	0.0850*	0.1396	0.1708**
	(4.1242)	(1.8497)	(0.9147)	(2.5248)
RIV		0.0923***		0.0481
		(2.6097)		(1.0812)

lnPGDP	-0.4447	0.4631	1.7902***	0.7471*
	(-1.0506)	(1.1488)	(2.8426)	(1.7967)
Gov	-0.8566	-1.0498	0.1869	-0.2138
	(-0.5345)	(-0.6893)	(0.1227)	(-0.2171)
HumCap	122.2218***	61.7592***	58.0063*	-18.5083
	(5.6379)	(2.7735)	(1.9389)	(-0.9474)
Infra	-1.5801***	-1.2991**	-2.6811***	2.0725***
	(-2.7118)	(-2.3030)	(-2.6750)	(3.1388)
IndStr	3.0841	6.1804***	3.8670**	1.7616
	(1.5868)	(3.3262)	(2.1058)	(1.4665)
Market	0.0640	-0.0844	-0.0076	-0.0584
	(0.9505)	(-1.3167)	(-0.0818)	(-0.9769)
Density	0.6226**	-0.1269	0.0755	-0.4177**
	(2.3217)	(-0.4913)	(0.3006)	(-2.5734)
Constant	9.1282**	-1.7619	-6.6018	-12.9974***
	(2.0048)	(-0.4032)	(-1.0806)	(-3.2802)
Province FE	YES	YES	YES	YES
N	217	217	217	217
R^2	0.8462	0.6873	0.6518	0.6641

6. Research conclusions and recommendations

This study systematically examines the impact of financial innovation on smart city development, with a focus on the threshold effects of government digital governance and the mediating role of regional innovation vitality. The main findings are as follows: Financial innovation significantly promotes the construction of smart cities, and this effect is more pronounced in regions with a higher degree of marketization. Government digital governance exhibits a significant single-threshold effect in the process through which financial innovation fosters smart city development. Regional innovation vitality serves as a partial mediator in this relationship. Furthermore, the mediating path of regional innovation vitality is more significant in regions with a higher degree of openness to the outside world. Accordingly, the following recommendations are proposed:

First, the government should strengthen its support for financial innovation. It should continue to increase investment in and support for financial technology, encourage the development of financial products that align with smart city construction—such as green finance and supply chain finance—and provide low-cost, sustainable financial support. At the same time, it is necessary to establish and improve the regulatory framework for financial technology to ensure that innovation develops under controllable risk conditions.

Second, governments at all levels should enhance their digital governance

capacity. They should accelerate digital transformation, improve data governance, technological application, and the digitalization of government services. By building data-sharing platforms, optimizing administrative processes, and eliminating data silos, an efficient alignment between financial resources and urban needs can be achieved. Meanwhile, mechanisms for assessing and supervising governance capabilities should be strengthened to ensure continuous improvement.

Third, governments should stimulate regional innovation vitality. Governments and enterprises should jointly foster a favorable innovation ecosystem and increase investment in and support for research and development activities. Measures such as building innovation platforms, attracting and cultivating high-end talent, and strengthening industry–academia–research collaboration should be adopted to enhance regional innovation capacity and the efficiency of technology commercialization.

Fourth, differentiated advancement strategies should be implemented across regions. Given the differences in marketization and openness levels among regions, governments should adopt differentiated approaches to promote smart city development. In regions with high levels of marketization and openness, the roles of market mechanisms and international technology spillovers should be fully leveraged; in regions with lower levels of marketization and openness, governments should strengthen guidance and policy support to cultivate market mechanisms and innovation capacity.

Author contributions

All authors contributed to the conception and design of the study, data collection and processing, empirical analysis, interpretation of the results, manuscript drafting and revision, and approval of the final version.

Competing interests

The authors declare that they have no competing financial or non-financial interests.

Data availability

The data analysed in this study are compiled from publicly available provincial statistical yearbooks, official government reports, and authoritative databases and publications, including sources from the National Bureau of Statistics of China, the

People's Bank of China, the Ministry of Industry and Information Technology, provincial statistical yearbooks, and government digital development reports. Some underlying data may be subject to access, licensing, or redistribution restrictions imposed by the original data providers. The variable definitions, model specifications, and data-processing procedures are described in the manuscript. Processed data and replication materials are available from the corresponding author upon reasonable request, subject to applicable data-use restrictions.

Ethics declaration

This study relies exclusively on secondary, aggregate provincial-level data obtained from public statistical sources, official reports, and databases. It does not involve human participants, human biological materials, animals, clinical information, or personally identifiable private information. Therefore, ethical approval and informed consent were not required.

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