Productive Government Debt and Urban Innovation: An Empirical Study Based on Chinese City Panel Data

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Abstract: *Urban innovation is essential to strengthening national innovation capacity and technological capabilities, placing its sustained development at the heart of scholarly debate. This study explores the impact of productive-oriented local government debt expansion on urban innovation, leveraging China's "Four Trillion Yuan" stimulus plan in 2008 as a natural experiment and drawing on urban panel data. Through the lens of productive government debt, we find that such expansion significantly boosts urban innovation, driven by three key mechanisms: infrastructure support, government innovation subsidies, and talent agglomeration. However, heterogeneity analysis reveals that this positive effect weakens in China's central and western regions, cities with higher administrative status, and those with lower marketization levels, where the impact becomes negligible. Further scrutiny shows that local government financing vehicle (LGFV) bonds and special local government bonds earmarked for infrastructure effectively spur urban innovation, whereas general bonds and LGFV bonds used for "borrowing new to repay old" yield little to no benefit. These findings underscore that local government debt, when channeled toward productive ends, can fuel urban innovation. As the central government works to mitigate implicit debt risks, it must weigh the distinct roles of debt funds—considering regional economic conditions and institutional contexts—and tailor policies to time and place. This study offers theoretical insights and practical guidance for decoding the intricate link between government debt and innovation, enriching both scholarship and policy discourse.*

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1. Introduction

In the pursuit of technological capabilities and national competitiveness, urban innovation capacity stands as a cornerstone of high-quality development. How to systematically enhance and optimize this capacity has become a significant area of academic research. Economic theory and development

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practice demonstrate that fostering urban innovation demands a dual approach: the "invisible hand" of the market to nurture innovation entities and factors, and the "visible hand" of a proactive government to allocate public resources effectively, continually optimize the urban institutional and factor environment, and strengthen governance for innovation. This dual role requires sustained government investment in innovation, necessitating expanded fiscal resources. Indeed, since the rise of Keynesianism, major market economies have increasingly relied on government debt to boost public goods provision, infrastructure investment, and economic stability, compensating for weak social demand. Yet, this growing debt reliance has sparked crises, and prompted scholars to debate its impact on economic growth—particularly long-term growth, which hinges on innovation. As China transitions to high-quality development, research increasingly probes the nexus between government debt and innovation, tackling key questions: Does local government debt influence urban innovation? Does it foster or hinder it? What mechanisms are at play? Addressing these issues not only clarifies the role of local governments in elevating China's urban innovation but also offers theoretical grounding for the innovation-driven development strategy.

Empirical studies on government debt, which spanning various levels, periods, and statistical measures in China, have produced conflicting findings. Some research contends that government debt hampers corporate innovation and high-quality economic growth (Bai et al., 2016; Xiong & Shen, 2019; Liu et al., 2020), while other studies assert it fosters corporate innovation (Zhang et al., 2021). These divergent conclusions likely stem from a critical oversight: while the aggregate level of government debt matters, its expenditure structure plays an equally pivotal role, as different uses yield distinct socioeconomic outcomes. Broadly, debt channeled into operational costs, social welfare, or debt repayment proves ineffective in spurring corporate innovation and markedly crowds out private investment. Conversely, when directed toward productive ends—such as infrastructure, talent development, and R&D—government debt tends to catalyze social innovation, with a muted crowding-out effect on private investment, particularly when total debt remains moderate.

To test this hypothesis, this study assesses the impact of local government debt expansion, chiefly for productive purposes, on urban innovation through the lens of productive government debt. It leverages China's "Four Trillion Yuan" stimulus plan in 2008 as a natural experiment to differentiate debt types, using urban panel data and a difference-in-differences (DID) model. The findings confirm that both the extraordinary debt surge during this stimulus period (e.g., financing platform debt, bank loans, or LGFV bonds for infrastructure) and productive debt represented by special local government bonds consistently boost urban innovation. Mechanism analysis reveals that this expansion drives innovation by enhancing infrastructure investment, boosting fiscal spending on science and education, and fostering talent agglomeration, without inflating housing prices or crowding out corporate investment and financing. Heterogeneity analysis indicates that this positive effect diminishes—and often becomes negligible—in central and western cities, high-administrative-level cities, and those with low marketization.

This paper's potential marginal contributions reside in: (1) Broadening the analysis of China's "Four Trillion Yuan" fiscal stimulus in 2008. While extensive research has explored the plan and financing platform debt expansion (Bai et al., 2016; Chen et al., 2020; Wu et al., 2021), few studies address the role of interest-bearing platform debt in urban innovation. This study deepens understanding of how proactive fiscal policies—both at central and local levels—enhance urban innovation in China, offering theoretical and empirical backing for innovation-driven urban strategies and shedding light on leveraging debt for economic growth and corporate innovation in the economic new normal.

(2) Reframing the link between local government debt and innovation through productive debt. This paper, unlike prior research, delivers a more precise assessment of productive debt's impact on urban innovation by putting it into the context of the "Four Trillion Yuan" stimulus plan, using a difference-

in-differences (DID) approach with exogenous geographical distance as an instrumental variable, and employing multiple measures of productive debt.

(3) This study identifies three pathways: infrastructure support, government innovation subsidies, and talent agglomeration, through which productive local government debt boosts urban innovation, while showing this effect hinges on reduced administrative interference in resource allocation and a robust institutional environment. It highlights that mitigating implicit debt risks requires tailoring policies to debt purposes, regional economic conditions, and institutional contexts.

2. Literature Review and Theoretical Hypotheses

2.1 The Impact of Local Government Debt on Innovation

Existing literature offers initial insights into the link between local government debt and innovation. Zhu et al. (2018), using matched provincial panel and listed company data, measured local debt as the ratio of debt for which local governments bear the repayment responsibility to provincial GDP and found a negetive association with corporate innovation. Xiong & Shen (2019) reached broadly similar conclusions with comparable data. In contrast, Liu et al. (2020) and Chen et al. (2021), adapting Lv's (2015) method, estimated provincial debt via municipal fixed asset investment and paired it with listed company data, concluding that debt expansion hampers corporate innovation. Liu et al. (2022), measuring debt as the ratio of general and special bond balances to provincial fiscal revenue and linking it to manufacturing firm data, identified an inverted "U" relationship between local debt and corporate innovation. However, since general bonds fund only non-profit public welfare projects and are issued primarily by provincial governments[1], these studies struggle to isolate the effects of city-level debt—particularly productive debt—on urban innovation.

The study most pertinent to this paper, Zhang et al. (2021), analyzed city-level panel data from 2011 to 2017, gauging debt via the ratio of LGFV bond issuance to GDP and corporate innovation through total year-end patent authorizations per city. It identified an inverted "U"-shaped link between LGFV bond scale and corporate innovation. Yet, it overlooked the distinction between productive and non-productive bonds and focused solely on LGFV bonds—a minor fraction of financing platform debt, where bank loans dominate (e.g., the 2011 National Audit Office report notes 79.01% of local debt was bank loans, versus 7.06% from bonds). This narrow scope undermines the findings' reliability and economic insight. In fact, it is the neglect of the use of government debt funds that has led to controversy over the relationship between government debt and economic growth.[2]

In summary, prior studies largely suggest a negative or inverted "U"-shaped relationship between the scale of local government debt and corporate innovation. However, they fail to differentiate the uses of debt funds, leading to inconsistent conclusions. Furthermore, these studies primarily utilize OLS regression, but the endogeneity issue undermines the credibility of their conclusions. Additionally, existing research primarily uses listed companies as samples, neglecting the positive effects of local government debt expansion on small and medium-sized enterprises (SMEs), particularly on the overall urban innovation capacity. Addressing these gaps, this paper investigates how productive local government debt impacts urban innovation and its underlying mechanisms.

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[1] For the definition and issuance requirements of local government general bonds, please refer to the "Interim Measures for the Administration of the Issuance of Local Government General Bonds" (Cai Ku [2015] No. 64).

[2] For instance, Panizza and Presbitero (2013), surveying literature on government debt and economic growth in developed nations, found that while some studies detect threshold effects or an inverted "U"-shaped link, these findings lack robustness. Others suggest a negative correlation, yet evidence of causality remains elusive. Likewise, empirical research on Chinese government debt and economic growth abounds, but conclusions diverge widely (Mao & Cao, 2019).

2.2 Theoretical Mechanisms of Productive Local Government Debt Affecting Urban Innovation

Innovation investment typically entails long cycles, high risks, slow returns, and significant uncertainty. Additionally, innovation outcomes, resembling public goods, prevent individual investors from reaping full benefits. Left solely to market allocation, urban innovation would likely fall below optimal levels (Arrow, 1962). Thus, government support is essential, with productive local government debt emerging as a potential key instrument to boost urban innovation.

First, productive local government debt contributes to urban infrastructure development, which in turn influences urban innovation. Research indicates that debt obtained through financing platforms provides substantial funding for regional infrastructure and public goods (Zheng et al., 2014). Ample financial resources enable local governments to invest in high-tech parks and economic development zones, as well as improve the supply of public goods such as roads, postal services, and electricity. These infrastructure enhancements create a more favorable environment for urban innovation by lowering transaction costs, attracting high-tech enterprises to industrial parks, fostering industrial clustering, and ultimately promoting higher levels of urban innovation (Dai & Wang, 2020). However, some studies question the extent to which infrastructure development directly promotes innovation. They argue that local governments tend to prioritize large-scale investment as a means of driving economic growth (Zheng et al., 2014). Since government debt is primarily allocated to public infrastructure, excessive or inefficient investment in this sector may crowd out corporate R&D spending, thereby hindering innovation (Xiong & Shen, 2019).

Second, productive local government debt facilitates increased fiscal investment in science and technology, thereby influencing innovation levels. Off-budget debt obtained through financing platforms helps alleviate fiscal pressure on on-budget expenditures. This allows local governments, particularly during economic downturns, to allocate more funds toward science and technology spending (including subsidies), incentivizing regional industrial enterprises to engage in innovation activities. Fiscal support plays a crucial role in fostering innovation. For example, government subsidies can help correct market failures associated with technological R&D, indirectly shaping corporate investment behavior. However, the direction of this influence remains uncertain. Some studies find that government subsidies have a significantly positive impact on corporate R&D investment (Xie et al., 2009), while others argue that subsidies often crowd out private R&D spending, reducing their intended stimulative effect (Marino et al., 2016). Additionally, research by Yang et al. (2015) suggests that in regions where private enterprises face fewer distortions and factor markets function efficiently, government subsidies have a stronger positive effect on corporate innovation.

Third, productive local government debt contributes to increased investment in education and the attraction of high-level talent, thereby enhancing urban innovation. Skilled labors, particularly high-skilled workers, are a crucial driver of innovation. Research indicates that relaxed immigration policies lead to an influx of highly educated, skilled professionals, generating technological spillover effects that strengthen national innovation capacity (Chellaraj et al., 2008). Off-budget debt obtained through financing platforms not only alleviates fiscal pressure on on-budget expenditures, allowing local governments to expand education investment and cultivate innovative talent, but also facilitates the development of transportation infrastructure, creating favorable conditions for high-level talent mobility (Michaels, 2008).

Finally, productive local government debt may drive up housing prices, thereby impacting urban innovation. Since a significant portion of this debt is allocated to municipal infrastructure, its investment ultimately capitalizes into higher land prices, which in turn pushes up housing costs (Zheng et al., 2014; Xiong & Shen, 2019). Rising land and housing prices increase the market value of collateral, enabling firms to access more credit and easing financing constraints on R&D, thereby fostering corporate innovation and enhancing urban innovation levels (Yan & Sun, 2020; Liu et al., 2022). However,

excessive housing price increases not only raise living costs, hindering the concentration of innovative talent and suppressing urban innovation activities (Yan & Sun, 2020), but also incentivize firms to reallocate substantial resources toward the real estate sector, crowding out R&D investment and business financing, ultimately impeding urban innovation growth (Yu & Zhang, 2017; Chen et al., 2021).

In summary, as shown in Figure 1, the expansion of productive local government debt contributes to increased investment in infrastructure, science and technology subsidies, and education, while also enhancing the attraction of high-level talent, thereby strengthening urban innovation. However, it also drives up housing prices, crowds out corporate investment and financing, and ultimately inhibits urban innovation. Accordingly, this paper proposes:

Hypothesis 1a: The expansion of productive local government debt fosters urban innovation.

Hypothesis 1b: The expansion of productive local government debt hinders urban innovation.

This paper contends that in the early phases of industrialization and urbanization, the innovative capacity of cities is relatively limited with firms being modest in scale, and innovation hinges on government funding. Here, productive local government debt fosters a supportive environment via infrastructure, cuts transaction costs, boosts corporate profits, and drives industrial and talent clustering. Moreover, fiscal subsidies signal credibility, optimizing resource allocation and drawing external capital to subsidized firms, thus spurring R&D enthusiasm and elevating urban innovation. Crucially, this study focuses on productive local government debt's role in urban innovation. Unlike debt for loan repayment or real estate, these funds exert minimal pressure on corporate financing, limit housing price spikes, and excel at advancing infrastructure, innovation subsidies, and talent agglomeration. Thus, this paper proposes:

Hypothesis 2: The expansion of productive local government debt enhances urban innovation by facilitating infrastructure development, increasing government innovation subsidies, and fostering the agglomeration of innovative talent.

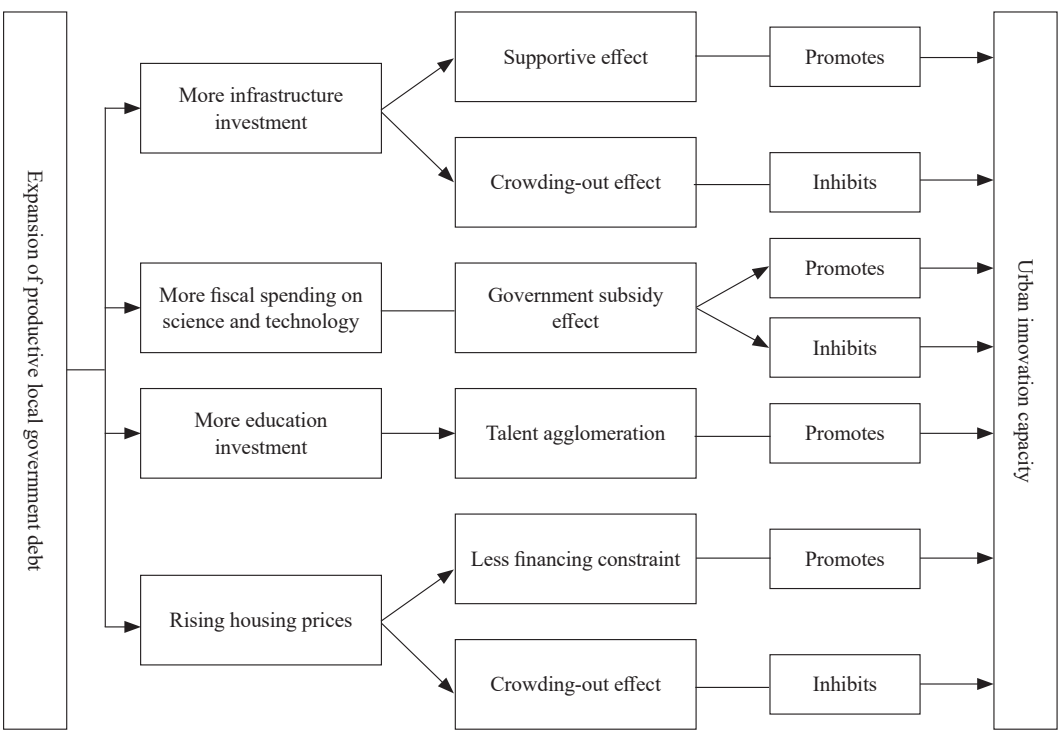


Figure 1: Theoretical Mechanisms through which Local Government Debt Drives Urban Innovation

3. Research Design and Data Sources

3.1 Research Design

In response to the 2008 global financial crisis, the Chinese government introduced the "Four Trillion Yuan" stimulus plan in November 2008, aiming to drive economic growth through large-scale infrastructure development and social welfare investments. The plan remained in effect until its conclusion in 2010 (Bai et al., 2016). To finance this initiative, the central government relaxed restrictions on local government financing platforms, allowing them to issue substantial amounts of interest-bearing debt. As a result, the outstanding interest-bearing debt of local financing platforms surged by 77.09% in 2009 and by 31.50% in 2010. However, after this rapid debt expansion, the government recognized the potential risks of policy-driven debt accumulation, which could spiral out of control and negatively impact the economy (Chen et al., 2020). In response, it swiftly adjusted its policies, imposing stricter regulations on financing platform debt (Wu et al., 2021), leading to a slowdown in debt growth to 19.41% in 2011[3].

The 2008 global financial crisis and China's "Four Trillion Yuan" stimulus plan, launched in response, provides a natural experiment for testing Hypotheses 1a and 1b. This setting is suitable for three key reasons: (1) The central government actively encouraged local governments to expand financing channels to support the stimulus plan, with funding primarily allocated to large-scale infrastructure projects and social welfare investments[4], characteristic of productive government debt. (2) Before this stimulus, local government borrowing was highly restricted by legal frameworks such as the *Budget Law*, *Guarantee Law*, and *General Rules on Loans* of the People's Republic of China. Consequently, local governments had limited debt levels before 2008 and primarily relied on financing platforms to raise funds during the stimulus period. According to Xu et al. (2020), by the end of 2010, the balance of interest-bearing debt on these platforms had surged by 132.88% compared to pre-stimulus 2008 levels. This sudden and substantial expansion provides a strong basis for assessing the causal impact of productive local government debt on urban innovation. (3) Significant inter-city variations: in development models, marketization levels, and administrative tiers, allow for an in-depth examination of the heterogeneous effects of productive local government debt on innovation.

The 2008 global financial crisis had an exogenous impact on all cities, making traditional difference-in-differences (DID) models unsuitable for analysis. However, because the crisis affected cities to varying degrees and local governments faced different levels of pressure to sustain growth, there were significant disparities in policy implementation (Yang & Yang, 2016; Wu et al., 2021). These differences are reflected in the varying scale of productive government debt issued through financing platforms. Building on this variation, this paper constructs an intensity-based difference-in-differences model.

$$ln_innov_{it}=\alpha+\beta(debt_i\times after_t)+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (1)$$

Here, ln_innov_{it} denotes the innovation level of city i in year t. $debt_i$ serves as a proxy for the intensity of productive local government debt issuance in the city, calculated as shown in Equation (2). It is derived by taking the average proportion of the financing platforms' interest-bearing debt balance to city GDP over 2009-2010, minus the average proportion for 2006-2008, prior to the "Four Trillion Yuan" stimulus plan.

$$debt_i=\frac{1}{2}\sum_{\tau=2009}^{2010}\frac{debt_{i,\tau}}{GDP_{i,\tau}}-\frac{1}{3}\sum_{l=2006}^{2008}\frac{debt_{i,l}}{GDP_{i,l}} \quad (2)$$

[3] Calculated based on data from Xu et al. (2020).

[4] According to data from the National Audit Office's Audit Report on Local Government Debt, by the end of 2010, 90.96% of local government debt expenditures had been directed toward municipal construction, transportation, land reserve development, science, education, culture, healthcare, and affordable housing, as well as agricultural and water conservancy projects. In contrast, only 1.15% had been allocated to mitigating local financial risks, while 7.89% remained unclassified.

Since the financing platform debt issued unconventionally during the "Four Trillion Yuan" stimulus plan period was primarily directed toward infrastructure investment with productive aims, a higher $debt_i$ value indicates greater unconventional productive debt issuance by local governments via these platforms during the plan's implementation. To ensure result robustness, this paper employs bank loan data for unconventional local government acquisitions, as calculated by Chen et al. (2020), for robustness testing. $after_t$ is a dummy variable indicating "Four Trillion Yuan" plan implementation, set to 1 for 2009-2014 (post-implementation) and 0 for 2006-2008 (pre-implementation)[5]. X_{it} represents a set of Control variables influencing city innovation levels, drawn from Lu et al. (2018) and Xie (2020). These include the logarithm of per capita GDP (*ln_pgdp*), GDP growth rate (*g_gdp*), the logarithm of population density (*ln_density*), the secondary industry's share of GDP (*sec_r*), and the logarithm of actual foreign direct investment utilized annually (*ln_fdi*)[6]. μ_i and λ_t denote city and Year fixed effects, respectively, while ε_{it} is the error term.

The coefficient β estimated using the interaction term $debt_i \times after_t$ captures a treatment effect similar to difference-in-differences, reflecting how variations in the scale of productive local government debt influence urban innovation. The primary advantage of this model specification is its ability to effectively address endogeneity, provided that two conditions hold: (1) the implementation of the "Four Trillion Yuan" stimulus plan is exogenous, and (2) cities exhibited parallel trends before the plan's introduction. If the estimated coefficient β is significantly positive, Hypothesis 1a is supported; if β is significantly negative, Hypothesis 1b is supported.

To test Hypothesis 2, this paper adopts the mediation effect test method and constructs Equation (3) based on Equation (1) to examine the impact of productive local government debt expansion on the mediating variables, specifically, whether such expansion promotes urban infrastructure development, government innovation subsidies, and the agglomeration of innovative talent. The specific empirical equation is as follows:

$$MV_{it}=\alpha_1+\alpha_2(debt_i\times after_t)+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (3)$$

In Equation (3), MV_{it} represents the mediating variable, constructed from the following three perspectives: (1) Infrastructure Support Effect: Following Dai & Wang (2020), urban infrastructure development is measured by the ratio of road area to administrative land area (*road_r*). (2) Government Innovation Subsidy Effect: The issuance of interest-bearing debt by financing platforms helps alleviate fiscal pressure, allowing local governments to allocate more funds to science and technology expenditures. Drawing on Yang & Wu (2016), fiscal pressure is measured as the ratio of the fiscal gap (expenditure minus revenue) to GDP (*deficit*) to examine whether the expansion of off-budget productive local government debt helps alleviate on-budget fiscal pressure. Additionally, based on Lu et al. (2018) and Xie (2020), government innovation subsidy intensity is measured by the proportion of science and technology expenditure in the total budget (*tech_r*), assessing whether off-budget productive debt expansion alleviates on-budget fiscal pressure and enhances funding for urban innovation. (3) Talent Agglomeration Effect: Off-budget productive debt expansion enables greater investment in education, which in turn attracts high-level talent. Following Xie & Hu (2020) and Dai & Wang (2020), education investment intensity is measured by the share of education expenditure in the total budget (*edu_r*), while human capital is proxied by the number of higher education students per 100,000 people (*capital*). This allows an assessment of whether debt expansion fosters the agglomeration of innovative talent.

[5] The data span 2006-2014, guided by three key considerations: First, prior to 2006, LGFV bonds issued by local financing platforms were limited, and calculating city-level interest-bearing debt from available data would yield substantial missing samples. Second, the impact of productive local government debt on urban innovation is long-term, necessitating an extended post-"Four Trillion Yuan" stimulus plan period. Third, after 2014, the revised *Budget Law of the People's Republic of China* redefined newly issued financing platform debt as distinct from local government debt, prohibiting guarantees for such platforms and curbing excessive borrowing (Xu et al., 2020).

[6] Descriptive statistics for all variables will be provided upon request.

Other variables remain consistent with Equation (1). A significant estimated coefficient α_2 indicates that productive local government debt expansion has a substantial impact on the mediating variables.

Finally, this paper incorporates the mediating variables into Equation (1) and re-estimates the impact of productive local government debt expansion on urban innovation levels, resulting in Equation (4).

$$\ln_innov_{it}=\eta_1+\eta_2(debt_i\times after_t)+\eta_3 MV_{it}+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (4)$$

Under the condition that β and α_2 are both significant, a complete mediating effect exists if η_3 is significant while η_2 is not; a partial mediating effect occurs if both η_2 and η_3 are significant. These results indicate that the mediating variable serves as a crucial transmission mechanism through which productive local government debt expansion affects urban innovation levels.

3.2 Data Sources

(1) Urban innovation level data. Urban innovation data are sourced from the *China Urban and Industrial Innovation Report 2017*, published by Fudan University's Industrial Development Research Center. This dataset is derived from over three million micro-level patent records from the State Intellectual Property Office. Compared to previous studies that measure innovation through input indicators such as R&D expenditure or the number of researchers, this dataset constructs an urban innovation index based on patent value as an output indicator, providing a more accurate reflection of a city's innovation level. More importantly, the index incorporates patent data from not only listed companies but also a large number of small and medium-sized enterprises (SMEs). Compared to studies that rely solely on patent data from listed firms, this dataset offers a more comprehensive representation of urban innovation. It has been widely used in academic research, including studies by Xie & Hu (2020), as well as Xie (2020).

(2) Productive local government debt data. Before the enactment of the 2015 Budget Law of the People's Republic of China, local governments were prohibited from issuing self-financing bonds and primarily relied on local financing platforms to raise funds (Xu et al., 2020). According to Bai et al. (2016), by the end of 2010, total expenditures under the "Four Trillion Yuan" stimulus plan had reached 3.86 trillion yuan. Of this, the central government contributed only 0.05 trillion yuan, while local governments covered 1 trillion yuan through on-budget spending. The remaining 2.81 trillion yuan was primarily raised off-budget via local financing platforms. Given that productive local government debt during this period was mainly issued through financing platforms, this paper adopts the unconventional expansion of interest-bearing debt by these platforms during the stimulus period as a proxy for productive local government debt. The debt data are sourced from Xu et al. (2020), which provides higher statistical accuracy than Wind data and includes both standardized debt (LGFV bonds) and non-standardized debt (primarily bank loans). Compared to existing studies, this dataset offers a more comprehensive measure of local government debt, as it accounts for both types of financing (Xu et al., 2020).

Furthermore, considering that local government debt expansion may also stem from government departments, affiliated institutions, and related public service units, and that most local government debt issued during the "Four Trillion Yuan" stimulus plan took the form of bank loans, this paper employs an alternative proxy variable for productive local government debt in the robustness test. Specifically, it uses data on unconventionally issued bank loans acquired by local governments in 2009. This dataset, sourced from Chen et al. (2020), is compiled based on news reports from Wind Information that track local government bank loan acquisitions. Using this data, we calculate the proportion of unconventionally issued bank loans induced by the stimulus plan in 2009 as a share of GDP (*loan*)[7], following Equation

[7] Since the local government loan data published by Chen et al. (2020) is only available up to 2009, we are unable to obtain data for the extraordinary bank loan ratio from 2009 to 2010.

(5). Specifically, this proxy is computed as the ratio of bank loans obtained by a city in 2009 to its GDP, minus the five-year average ratio of bank loans to GDP for the same city prior to 2009.

$$loan_i = \frac{loan_{i,2009}}{GDP_{i,2009}} - \frac{1}{5}\sum_{\tau=2004}^{2008}\frac{loan_{i,\tau}}{GDP_{i,\tau}} \quad (5)$$

(3) Urban economic variable data. This study focuses on prefecture-level and sub-provincial cities. Due to missing economic data for certain cities, we exclude those with incomplete records, such as cities in the Tibet Autonomous Region, Lijiang, Yichun, Jieyang, and others. The final dataset includes 259 cities, with economic data sourced from various editions of the *China City Statistical Yearbook*.

(4) Other variable data. The geographical distance variable is measured as the straight-line distance between each city's municipal government and the five treaty port cities opened in 1842, calculated based on latitude and longitude. The regional institutional environment is assessed using the marketization index compiled by Wang et al. (2021).

4. Empirical Analysis

4.1 Basic Regression

This study employs the logarithm of the urban innovation index (ln_*innov*) as the dependent variable and the interaction term (*debt* × *after*) as the key explanatory variable. The interaction term consists of the ratio of productive debt to GDP (*debt*), expanded via financing platforms during the "Four Trillion Yuan" stimulus plan, and a dummy variable (*after*) indicating whether the plan was implemented. Table 1 presents the regression results. Column (1) includes only city and Year fixed effects, showing a significantly positive coefficient for *debt* × *after*, which supports Hypothesis 1a: cities that expanded productive local government debt more aggressively under the plan experienced greater improvements in urban innovation. To account for potential confounding factors, Columns (2)-(4) progressively introduce Control variables, including the logarithm of per capita GDP (ln_*pgdp*), GDP growth rate (g_*gdp*), logarithm of population density (ln_*density*), secondary industry share of GDP (*sec_r*), and the logarithm of actual foreign direct investment (FDI) (ln_*fdi*). The coefficient for *debt* × *after* remains significantly positive at the 1% level, reinforcing the robustness of the findings.

Additionally, this study uses the estimates from Column (4) as a benchmark to quantify the impact of financing platform debt expansion on urban innovation under the "Four Trillion Yuan" stimulus plan. Based on the median ratio of unconventionally issued interest-bearing debt (*debt*), cities are divided into treatment and control groups. The results show that the average ratio of unconventionally issued interest-bearing debt (*debt*) in the treatment group is 5.75 units higher than that in the control group. Consequently, compared to the control group, the expansion of productive financing platform debt under the stimulus plan increases the urban innovation index in the treatment group by 19.58%[8], demonstrating significant economic implications.

Table 1: Productive Local Government Debt and Urban Innovation

Variable	(1)	(2)	(3)	(4)
	ln_*innov*	ln*innov*	ln_*innov*	ln_*innov*
debt × *after*	0.0403***	0.0370***	0.0338***	0.0311***
	(0.0077)	(0.0071)	(0.0068)	(0.0064)

[8] As the explained variable is logarithmic and the core explanatory variable is a level value, a debt value of 5.75 increases the urban innovation index by 19.58% ($\approx 100\times(e^{5.75\times0.0311}-1)$).

Table 1 Continued

Variable	(1)	(2)	(3)	(4)
	ln_*innov*	ln*innov*	ln_*innov*	ln_*innov*
ln_*pgdp*		-0.6078***	-0.3297***	-0.3274***
		(0.0978)	(0.0972)	(0.0932)
g_gdp		0.0058*	0.0114***	0.0131***
		(0.0032)	(0.0032)	(0.0033)
ln_*density*			0.0921	0.3209
			(0.4929)	(0.5107)
sec_r			-0.0217***	-0.0230***
			(0.0043)	(0.0042)
ln_*fdi*				-0.0702***
				(0.0166)
Constant term	0.7667***	6.9203***	4.5905	4.0047
	(0.0211)	(0.9997)	(3.1299)	(3.2481)
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	2331	2328	2328	2246
R^2	0.9407	0.9450	0.9488	0.9525

Note: Values in parentheses represent robust standard errors, clustered by city. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

4.2 Robustness Tests

To verify the reliability of the baseline results, this study conducts a series of robustness checks.

(1) Replacing the core explanatory variable. Given the "Four Trillion Yuan" stimulus plan's primary implementation in 2009, this study calculates *debt1* as the 2009 ratio of financing platform interest-bearing debt to city GDP, minus the 2006-2008 average ratio, reflecting unconventional debt issuance. Wu et al. (2021) note that growth-pressure cities issued more LGFV bonds from 2009-2011, while Chen et al. (2020) find the 2009 plan had a long-term effect, with local governments issuing additional bonds from 2012-2014 to repay unconventional bank loans. Accordingly, *debt2* and *debt3* are computed as the average ratios of financing platform debt to GDP over 2009-2011 and 2009-2014, respectively, minus the 2006-2008 average. This study substitutes *debt1*, *debt2*, and *debt3* for *debt* in Table 1, replicating the Column (4) regression. Results show the interaction terms (*debt1* × *after*, *debt2* × *after*, *debt3* × *after*) are all positive and significant at the 1% level, further supporting Hypothesis 1a: productive local government debt expansion enhances urban innovation.

This study calculates *debt2* and *debt3* as the ratios of unconventionally issued interest-bearing debt by financing platforms over 2009-2011 and 2009-2014, respectively, by subtracting the 2006-2008 average ratio of financing platform debt to city GDP from the corresponding 3- or 6-year post-policy average. These variables (*debt1*, *debt2*, *debt3*) then replace *debt* in Table 1, and regressions akin to Column (4) are conducted. The results show that the interaction terms (*debt1* × *after*, *debt2* × *after*, *debt3* × *after*) are all positive and significant at the 1% level, further supporting Hypothesis 1a: that productive local government debt expansion enhances urban innovation.

(2) Parallel trend test. This study's core analysis assumes that differences in urban innovation levels stem from the "Four Trillion Yuan" stimulus plan. To test this, 2008 is set as the base year (value = 0), with dummy variables for other years set to 1, and Equation (6) is constructed for a parallel trend test. The results show that in 2006-2007, prior to the plan, the interaction term coefficients of *debt* and the year dummy (*after*) are close to 0 and statistically insignificant, indicating no significant pre-policy

differences between the treatment and control groups, thus satisfying the parallel trend assumption. For 2009-2014, post-plan, the *debt* × *after* interaction coefficients are significantly positive and increase over time, suggesting that greater unconventional issuance of interest-bearing debt by financing platforms fosters urban innovation post-plan, with a continuously strengthening effect.

$$\ln_innov_{it}=\alpha+\sum_{t=2006}^{2014}\beta_t(debt_i\times after_t)+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (6)$$

(3) Placebo test. This paper conducts a placebo test by constructing "hypothetical" treatment and control groups, randomly assigning the intensity of unconventional interest-bearing debt issuance by financing platforms. The specific process is as follows: 1. Randomly assign the proportion of unconventionally issued interest-bearing debt (*debt*) issued by financing platforms to each city. 2. Estimate Column (4) in Table 1 using the intensity DID model to obtain the regression coefficient. 3. Repeatedly draw treatment groups using a computer, conducting 1,000 regressions, and generate a density plot of the intensity DID estimation coefficient. The results show that after randomization, the intensity DID coefficient estimates are symmetrically distributed around 0, whereas the baseline regression coefficient is significantly different from 0. This further confirms the robustness of Hypothesis 1a.

(4) Excluding the impact of national innovative cities. Urban innovation changes may be influenced by concurrent policies, such as the National Innovative City pilot policy launched in 2008, which aimed to enhance innovation. If so, post-2009 innovation differences among cities with varying degrees of unconventional productive local government debt expansion may be driven by this policy rather than the "Four Trillion Yuan" stimulus plan. To eliminate this potential bias, and following Bai et al. (2022), this study introduces a dummy variable (*cxcs*) to indicate cities that implemented the National Innovative City pilot and conducts a regression similar to Equation (1). The results show that: The *cxcs* coefficient is significantly positive at the 1% level, confirming the policy's positive impact on urban innovation. After controlling for *cxcs*, the interaction term coefficients between various measures of productive debt expansion intensity and the stimulus plan dummy (*after*) are reduced but remain significantly positive at the 1% level. This indicates that while the National Innovative City policy significantly boosts innovation, excluding its impact confirms that unconventional productive local government debt expansion still plays a significant role in enhancing urban innovation. Therefore, Hypothesis 1a remains robust.

(5) Replacing data. Local government debt primarily originates from financing platforms, government departments, agencies, and public institutions, with financing platforms contributing the largest share[9]. However, using financing platform debt to approximate local government debt may introduce errors, especially since bank loans are a key component. Thus, this study uses Chen et al. (2020) data to calculate the 2009 ratio of unconventionally issued bank loans to GDP (*loan*) due to the "Four Trillion Yuan" stimulus plan per Equation (5), replacing *debt* in Table 1 for regression. Results show that the interaction term coefficients of *loan* and the policy dummy (*after*) are significantly positive at the 1% level, indicating that expanded productive bank loans under the stimulus plan significantly enhance urban innovation. These findings further support Hypothesis 1a.

4.3 Instrumental Variable Estimation to Address Endogeneity

Although this study employs an intensity DID model, incorporates a broad set of Control variables influencing urban innovation, and conducts extensive robustness tests, the impact of unconventional productive local government debt expansion on urban innovation may still suffer from endogeneity issues, including omitted variable bias and reverse causality. For example, interest-bearing debt issued

[9]According to the "National Government Debt Audit Results" released by the National Audit Office in 2011 and 2013, the proportions of financing platform debt to local government debt were 46.38% at the end of 2010 and 38.96% at the end of June 2013, respectively.

by local financing platforms accounts for only a portion of total local government debt. Governments might also raise funds through other channels, such as public institutions, which are not fully captured in this analysis. After the "Four Trillion Yuan" stimulus, cities that issued substantial interest-bearing debt via financing platforms were mainly located in eastern China, where economies are more vulnerable to export fluctuations[10]. These eastern cities typically exhibit strong innovation capacity. If, after the stimulus, these cities expanded financing platform debt issuance to mitigate economic downturns, the observed positive relationship between debt expansion and innovation may not be solely due to the policy itself.

In such cases, a simple OLS regression may lead to an underestimation of the true effect of unconventional productive local government debt expansion on urban innovation. The interaction term coefficient between debt expansion intensity and the stimulus plan dummy (*after*) may be biased downward, failing to capture the full causal impact. To address these endogeneity concerns and obtain more accurate causal estimates, this study follows Wu et al. (2021) and employs an instrumental variable (IV) approach, using exogenous geographical distance as an instrument in the regression analysis. This enhances the robustness of the findings.

Instrumental Variable Approach: Treaty Ports and Debt Expansion. In 1842, the Treaty of Nanjing between China and the United Kingdom opened five treaty ports: Guangzhou, Xiamen, Fuzhou, Ningbo, and Shanghai, to foreign trade. This study employs the shortest straight-line distance from each city to these historic ports as an instrumental variable (IV) for the intensity of unconventional financing platform debt expansion. The rationale for selecting this IV is based on the following considerations: Relevance: Cities closer to major ports historically had higher international trade dependence and larger export shares. As a result, these cities were more vulnerable to the 2008 global financial crisis, experiencing steeper economic downturns. To counteract these economic shocks, they were more likely to adopt the "Four Trillion Yuan" stimulus plan and expand debt issuance through financing platforms (Fujita and Mori, 1996; Wu et al., 2021). This satisfies the instrument's relevance requirement.

Exogeneity: The treaty ports were established in 1842, far removed from the study's sample period (2006-2014). Their fixed geographical locations and straight-line distances to other cities remain constant over time, making them unlikely to directly influence urban innovation in the study period. Moreover, these distances are exogenous and unaffected by modern changes in innovation, fulfilling the independence assumption. Given these justifications, this study adopts the two-stage least squares (2SLS) method to estimate the causal effect of unconventional productive local government debt expansion on urban innovation. The following model is constructed to implement this approach:

$$debt_aft_{it}=\alpha+\beta_1(\ln_distance_i\times after_t)+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (7)$$

$$\ln_innov_{it}=\alpha+\beta_2(\widehat{debt_aft}_{it})+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (8)$$

In Equation (8), $\ln distance_i$ is defined as the logarithm of the shortest straight-line distance to the five treaty ports (major trading hubs) plus 1. All other variables remain consistent with those in Equation (1). The first-stage regression, presented in Equation (7), examines the interaction term $debt_aft_{it}$, which represents the ratio of interest-bearing debt issued unconventionally by financing platforms under the "Four Trillion Yuan" stimulus plan, by regressing it on the interaction between the instrumental variable ($\ln_distance_i$) and the stimulus policy. This yields the predicted value of $\widehat{debt_aft}_{it}$. In the second stage, outlined in Equation (8), the logarithm of the urban innovation index ($\ln_innov_{it}$) is regressed on the predicted $\widehat{debt_aft}_{it}$ from the first stage. The regression coefficient β_2 is the focal point of this study. A significantly positive β_2 supports Hypothesis 1a, suggesting that the expansion of productive local

[10] According to our data, the average ratio of extraordinary interest-bearing debt (*debt*) in the eastern region is 4.96%, compared to 3.77% in other regions.

government debt promotes urban innovation.

The regression results examining the relationship between productive local government debt and urban innovation are presented in columns (1) and (2) of Table 2. The first-stage regression in column (1) indicates that the interaction term between the instrumental variable and the policy (ln_*distance* × *after*) exhibits a significant negative correlation with the interaction term between the proportion of unconventionally issued interest-bearing debt by financing platforms and the policy (*debt_aft*). In column (2), the regression coefficient for the interaction term (*debt* × *after*), which captures the relationship between the share of unconventionally issued interest-bearing debt and the stimulus policy, is significantly positive at the 1% level. Moreover, the absolute value of this estimated coefficient is substantially larger than that reported in column (4) of Table 1. This suggests that endogeneity considerably underestimates the positive impact of productive local government debt expansion on urban innovation, likely due to omitted variable bias and issues of reverse causality. Additionally, the F-statistic from the first-stage regression in column (1) of Table 2 is 11.32, confirming that there is no weak instrumental variable problem.

This study also considers that cities closer to treaty ports may have been exposed to foreign cultural influences earlier, which could have accelerated the breakdown of the smallholder economy. As a result, these cities may have developed a foundation for modernization sooner, potentially influencing their current levels of innovation. To control for this factor, we follow Fang and Zhao (2011) and introduce two measures: (1) the number of registered students in Christian primary schools per thousand people in Chinese cities in 1919 (*student_r*), which serves as a proxy for Western cultural influence, and (2) the total agricultural output value of cities in 1984 (*agrivalue*), which reflects early agricultural economic development. These variables are interacted with the policy dummy variable (*after*) and included as controls in the regression, producing the results shown in columns (3)-(5) of Table 2. The findings indicate that, regardless of how these Control variables are incorporated, the coefficient of the interaction term (*debt* × *after*) remains significantly positive. This confirms that even after ruling out alternative pathways through which the instrumental variable could influence present-day innovation, the conclusion remains robust: productive local government debt significantly enhances urban innovation. Thus, Hypothesis 1a is strongly supported.

Table 2: Productive Local Government Debt and Urban Innovation (IV)

	First-stage regression	IV			
Variable	(1)	(2)	(3)	(4)	(5)
	debt_aft	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*
ln_*distance*×*after*	-0.8462***				
	(0.2515)				
debt × *after*		0.1604***	0.1289**	0.1277***	0.0933**
		(0.0467)	(0.0512)	(0.0405)	(0.0368)
student_r × *after*			0.1493		0.1575*
			(0.1186)		(0.0868)
agrivalue × *after*				0.0183	0.0371
				(0.0390)	(0.0328)
Control variables	Yes	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	2246	2246	2246	1820	1820
R^2	0.0858				
First-stage F value	11.3210				

Note: Values in parentheses represent robust standard errors, clustered by city. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

5. Mechanism Analysis

The previous section validated Hypothesis 1a, confirming that the expansion of productive local government debt significantly enhances urban innovation. This section further explores the underlying mechanisms using Equations (3) and (4), demonstrating that this effect primarily operates through three key channels: promoting infrastructure development, increasing government innovation subsidies, and facilitating the agglomeration of innovative talent.

5.1 Infrastructure Support Effect

Theoretical analysis suggests that expanding productive local government debt helps cities secure additional off-budget resources, which, when allocated to infrastructure projects, create a favorable external environment for urban innovation. To test this mechanism, we estimate Equation (3), with the results presented in column (1) of Table 3. The dependent variable is the ratio of urban road area to administrative land area (*road_r*), while the key explanatory variable is the interaction term (*debt* × *after*), which captures the interaction between the proportion of unconventionally issued interest-bearing debt by financing platforms (*debt*) and a dummy variable (*after*) indicating the implementation of the "Four Trillion Yuan" stimulus plan. The results show that the coefficient of *debt* × *after* is significantly positive at the 1% level, indicating that following the "Four Trillion Yuan" stimulus plan, the expansion of productive local government debt significantly accelerated urban infrastructure development.

Table 3: Mechanism Test Results

Variable	(1)	(2)	(3)	(4)	(5)
	road_r	*deficit*	*tech_r*	*edu_r*	*capital*
debt × *after*	0.0045***	-0.1180**	0.0614***	0.0518**	0.0203**
	(0.0017)	(0.0479)	(0.0140)	(0.0214)	(0.0092)
Control variables	Yes	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	2217	2246	2246	2246	2218
R^2	0.9695	0.5369	0.7206	0.7978	0.9762

Note: Values in parentheses represent robust standard errors, clustered by city. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

To further investigate the underlying mechanisms, this study estimates Equation (4), with results presented in column (1) of Table 4. Building on the baseline regression in column (4) of Table 1, this specification incorporates *road_r*, the ratio of urban road area to administrative land area, as an additional explanatory variable. The findings reveal two key insights. First, the coefficient of *road_r* is significantly positive at the 1% level, indicating that urban infrastructure development plays a crucial role in enhancing innovation. Second, after controlling for *road_r*, the coefficient of the interaction term (*debt* × *after*), capturing the effect of unconventionally issued interest-bearing debt under the "Four Trillion Yuan" policy, decreases in magnitude relative to the baseline (column (4) of Table 1) but remains significant at the 1% level. These results suggest that the expansion of productive local government debt promotes urban innovation in part by facilitating infrastructure development, providing empirical support for a key aspect of Hypothesis 2.

Table 4: Further Analysis of Mechanism Testing

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*
debt × *after*	0.0249***	0.0308***	0.0269***	0.0301***	0.0287***	0.0198***
	(0.0059)	(0.0063)	(0.0063)	(0.0063)	(0.0067)	(0.0057)
road_r	0.6522***					0.5471***
	(0.2275)					(0.1825)
deficit		-0.0026***				-0.0009
		(0.0010)				(0.0009)
tech_r			0.0673**			0.0556**
			(0.0333)			(0.0258)
edu_r				0.0196***		0.0155***
				(0.0039)		(0.0042)
capital					0.0983***	0.0749***
					(0.0356)	(0.0266)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2217	2246	2246	2246	2218	2189
R^2	0.9575	0.9528	0.9547	0.9542	0.9540	0.9611

Note: Values in parentheses represent robust standard errors, clustered by city. ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively.

5.2 Government Innovation Subsidy Effect

The previous analysis suggests that local governments' expansion of off-budget productive debt through financing platforms not only alleviates on-budget fiscal pressure but also enhances their capacity to invest in urban innovation, thereby fostering higher levels of innovation. To test this hypothesis, this study replaces *road_r* with two alternative variables: *deficit* (fiscal pressure) and *tech_r* (the proportion of government science and technology expenditure to total budget expenditure). The regression results, presented in columns (2) and (3) of Table 3 and columns (2) and (3) of Table 4, indicate that the expansion of productive local government debt indeed enhances urban innovation by easing fiscal constraints, particularly by enabling local governments to allocate more resources to innovation subsidies. These findings further support Hypothesis 2.

5.3 Talent Agglomeration Effect

Another key channel through which the expansion of productive local government debt influences urban innovation is talent agglomeration. This mechanism operates in two ways. First, by expanding off-budget productive debt, local governments alleviate on-budget fiscal constraints, allowing for increased investment in education. Second, improved transportation infrastructure, facilitated by this debt, creates favorable conditions for attracting and retaining talent. To examine this effect, we replace the previous variables with two alternative measures: *edu_r* (the proportion of education expenditure to total budget expenditure) and *capital* (the number of higher education students per 100,000 people). Regression results, presented in columns (4) and (5) of Table 3 and columns (4) and (5) of Table 4, confirm that the expansion of productive local government debt enhances urban innovation by increasing educational investment and, crucially, by fostering the concentration of innovative talent. These findings provide further support for Hypothesis 2.

Columns (1) through (5) of Table 4 report the regression results obtained by sequentially incorporating

the mechanism variables: *road_r*, *deficit*, *tech_r*, *edu_r*, and *capital*. Given the potential interactions among these mechanism variables and their collective impact on urban innovation, we further include all of them in a unified regression, with results presented in column (6) of Table 4. The findings are notable: even after controlling for all mechanism variables simultaneously, the coefficient of the interaction term *debt* × *after* remains significantly positive. Moreover, with the exception of *deficit*, which is not statistically significant, the coefficients of all other mechanism variables remain significant, with signs consistent with theoretical expectations. These results provide strong empirical support for Hypothesis 2, demonstrating that the expansion of productive local government debt enhances urban innovation through multiple channels, including infrastructure development, increased government innovation subsidies, and talent agglomeration. Additionally, to ensure the robustness of these findings, we conduct a series of robustness checks, all of which further confirm the validity of Hypothesis 2.

6. Heterogeneity Analysis

6.1 The Impact of Productive Local Government Debt on Urban Innovation across Regions

To examine regional disparities, this study divides the sample into four geographic zones, eastern, central, western, and northeastern China, and conducts regressions similar to those in column (4) of Table 1. The results, presented in Table 5, reveal a clear pattern: the expansion of productive local government debt significantly enhances urban innovation in the eastern and northeastern regions, whereas its effect is statistically insignificant in the central and western regions. Several factors may account for this variation: (1) Dependence on Central Transfers: The central and western regions rely more heavily on fiscal transfers from the central government to cover budget shortfalls, reducing their reliance on financing platforms to issue debt for off-budget funding. As a result, the relatively small scale of interest-bearing debt in these regions fails to meaningfully stimulate urban innovation.

(2)Structural Disadvantages: Compared to the eastern region, the central and western regions face challenges in economic development, industrial sophistication, industrial foundations, and the overall urban innovation ecosystem. Local governments in these regions face difficulties in attracting investment and fostering the clustering of innovative talent (Yang et al., 2021; Yang and Wu, 2021). As a result, even when financing platform debt is used to fund new infrastructure or increase government innovation subsidies, it often fails to attract high-tech enterprises or top-tier talent, limiting its ability to enhance urban innovation.

(3)Short-Term Growth Focus: The economic development model in the central and western regions remains relatively rudimentary, heavily dependent on investment-driven growth. Under the pressure of GDP-based performance evaluations, local officials tend to prioritize productive investments that offer short cycles, rapid returns, and minimal risks, while neglecting innovation-driven initiatives that could strengthen long-term economic competitiveness. This results in insufficient support for urban innovation activities (Wu, 2017).

In summary, the central and western regions exhibit a clear pattern: the expansion of productive local government debt has limited effectiveness in fostering urban innovation.

6.2 Impact of Productive Local Government Debt on Innovation Capacity across City Administrative Levels

Cities with higher administrative status typically have access to more resources than those with lower status. As a result, firms often establish themselves in these higher-tier cities to leverage these resources, aligning their operations with various government priorities. However, this dynamic can lead to significant resource misallocation (Jiang et al., 2018). This study suggests that in higher-administrative-level cities, firms are more likely to align with local governments' emphasis on short-

Table 5: The Impact of Productive Local Government Debt on Urban Innovation across Regions

Variable	(1)	(2)	(3)	(4)
	Eastern Region	Central Region	Western Region	Northwestern Region
	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*
debt × *after*	0.0441***	0.0215	0.0142	0.0479**
	(0.0070)	(0.0143)	(0.0096)	(0.0194)
Control variables	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	693	701	567	285
R^2	0.9669	0.9415	0.9542	0.9752

Notes: Values in parentheses represent robust standard errors, clustered by city. ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively.

term economic growth, often at the expense of long-term innovation investments. Consequently, the expansion of productive local government debt in these cities may have limited effectiveness in enhancing urban innovation capacity.

To further investigate this issue, this study divides the city sample into high-administrative-level and low-administrative-level cities[11] and conducts separate regression analyses. The results, shown in columns (1) and (2) of Table 6, reveal a clear distinction. In high-administrative-level cities, the expansion of productive local government debt does not have a significant positive impact on urban innovation capacity. However, in low-administrative-level cities, this expansion significantly boosts urban innovation capacity. These findings suggest that in higher-tier cities, excessive administrative intervention may, to some extent, constrain firms' investments in research, development, and innovation.

6.3 Impact of Productive Local Government Debt on Urban Innovation across Different Institutional Environments

Enterprises are the primary drivers of innovation. When government intervention distorts resource allocation and weakens the institutional environment, firms are more likely to engage in non-productive rent-seeking activities. These behaviors, which tend to reinforce themselves over time, divert resources away from technological innovation, ultimately dampening overall corporate innovation momentum (Xie, 2020). In contrast, a well-functioning market competition mechanism fosters a survival-of-the-fittest dynamic, compelling firms to explore new markets, develop innovative products, and invest in advanced technologies to sustain growth (Lu et al., 2018). Based on this, this study hypothesizes that the expansion of productive local government debt effectively enhances urban innovation capacity only when the institutional environment is favorable.

To test this hypothesis, this study employs the provincial marketization index corresponding to each city as a measure of regional marketization, grouping cities by marketization level for regression analysis[12]. The findings, reported in columns (3) and (4) of Table 6, reveal distinct outcomes. For cities in the higher marketization group, the regression coefficient of the interaction term (*debt*×*after*), representing the interplay between the proportion of unconventional interest-bearing debt issued by

[11] Drawing on Jiang et al. (2018), this study designates sub-provincial cities and provincial capitals as high-administrative-level cities, while classifying other prefecture-level cities as low-administrative-level cities.

[12] Cities are classified into the high marketization group if their corresponding provincial marketization index averaged above the median value of 7.38 during the pre-"Four Trillion Yuan" stimulus plan period (2006-2008). Conversely, those with an average marketization index at or below this median during the same period are categorized as the low marketization group.

financing platforms and the stimulus policy, is positive and statistically significant at the 1% level. In contrast, for cities in the lower marketization group, the coefficient of *debt×after* is positive but lacks statistical significance. These results suggest that the expansion of productive local government debt significantly boosts urban innovation capacity primarily in regions with higher marketization levels, whereas its effect remains muted in less marketized regions. This aligns with the theoretical framework, which links the effectiveness of productive debt expansion in fostering innovation to the presence of a supportive market environment.

Table 6: Heterogeneous Effects of Productive Local Government Debt on Urban Innovation Capacity

Variables	(1)	(2)	(3)	(4)
	High-administrative-level cities	Low-administrative-level cities	High-marketization cities	Low-marketization cities
	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*
debt × *after*	0.0117	0.0260***	0.0358***	0.0138
	(0.0080)	(0.0075)	(0.0071)	(0.0094)
Control variables	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	270	1976	1178	1068
R^2	0.9780	0.9126	0.9637	0.9529

Notes: Values in parentheses are city-clustered robust standard errors. ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively.

7. Expansive Analysis

7.1 LGFV Bonds and Urban Innovation Capacity

While non-standard debts issued by financing platforms, chiefly bank loans, do not detail the specific use of funds, LGFV bonds provide such transparency through their prospectuses. This allows us to assess the varied impacts of LGFV bond expansion under the "Four Trillion Yuan" stimulus plan on urban innovation capacity, based on the intended purpose of the funds. This study categorizes LGFV bond proceeds into four types: infrastructure investment (*bond_jj*), repayment of interest-bearing debt (*bond_hz*), shantytown renovation or affordable housing projects (*bond_pg*), and supplementing working capital (*bond_by*). It then calculates the proportion of unconventional LGFV bond expansion for each category during the "Four Trillion Yuan" plan period[13] and conducts a regression analysis, mirroring the approach in column (4) of Table 1, with results presented in Table 7.

The findings reveal that only the interaction term between the unconventional expansion of LGFV bonds for infrastructure investment (*bond_jj*) and the "Four Trillion Yuan" stimulus plan dummy variable (*after*) yields a significantly positive coefficient. The interaction terms for the other categories show no significant effects. This suggests that, during the "Four Trillion Yuan" stimulus plan, only LGFV bonds directed toward infrastructure construction meaningfully enhanced urban innovation capacity. In contrast, refinancing, housing, and operational funds showed limited impact on innovation. These results reinforce Hypothesis 1a, confirming that the expansion of productive local government debt supports urban innovation capacity.

[13] Using *bond_jj* as an example, this paper measures the unconventional expansion of LGFV bonds for infrastructure (*bond_jj*) by calculating the difference between the average share of such bonds relative to a city's GDP in 2009-2010 (during the "Four Trillion Yuan" stimulus plan) and the pre-plan average from 2006-2008.

Table 7: LGFV Bonds and Urban Innovation Capacity

Variable	(1)	(2)	(3)	(4)
	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*
bond_jj × *after*	0.1787***			
	(0.0551)			
bond_hz × *after*		0.1654		
		(0.1521)		
bond_pg × *after*			-0.0018	
			(0.1344)	
bond_by × *after*				0.4054
				(0.2581)
Control variables	Controlled	Controlled	Controlled	Controlled
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	2246	2246	2246	2246
R^2	0.9547	0.9538	0.9538	0.9540

Notes: Values in parentheses are city-clustered robust standard errors. ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively.

7.2 Local Government Bonds and Urban Innovation Capacity

Local government bonds are categorized into general bonds, which primarily refinance existing debts such as bank loans, trust financing, and LGFV bonds, and special bonds, which fund specific projects like land reserves and infrastructure development. Compared to general bonds that primarily serve as a means of "rolling over debt," special bonds function more as productive debt, potentially fostering urban innovation. To test this hypothesis, we conduct a regression analysis using the log of the urban innovation index (ln_*innov*) as the dependent variable and the share of general or special bonds in provincial public budget revenue as the key independent variables[14]. The results, presented in Table 8, show that the coefficient of general bonds (*debtyb_r*) is significantly negative at the 1% level, while the coefficient of special bond s (*debtzx_r*) is significantly positive at the 5% level. This indicates that general bonds not only fail to enhance urban innovation but may even hinder it, whereas special bonds, characterized by their productive nature, significantly promote innovation. For robustness, we replace *debtyb_r* and *debtzx_r* with the share of general and special bonds in GDP (*debtyb_GDP* and *debtzx_GDP*), respectively, and conduct similar regressions. The results remain consistent, further confirming our findings.

Table 8: Local Government Bonds and Urban Innovation Capacity

Variable	(1)	(2)	(3)	(4)
	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*
debtyb_r	-0.0015***			
	(0.0004)			
debtzx_r		0.0011**		
		(0.0005)		

[14] Local government bond issuance data come from the China Local Government Bond Information Disclosure Platform (http://www.celma.org.cn/), while provincial economic figures are drawn from the *China Statistical Yearbook*. With no public data on bond allocations to specific cities, core explanatory variables are built at the provincial level.

Table 8 Continued

Variable	(1)	(2)	(3)	(4)
	ln_*innov*	ln_*innov*	ln_*innov*	ln_*innov*
debtyb_GDP			-0.0052*	
			(0.0031)	
debtzx_GDP				0.0137***
				(0.0052)
Control variables	Controlled	Controlled	Controlled	Controlled
City fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	974	974	974	974
R^2	0.9962	0.9961	0.9961	0.9962

Note: The values in parentheses are cluster-robust standard errors clustered at the city level. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

8. Conclusions and Policy Recommendations

This study examines the impact of local government debt expansion for productive purposes on urban innovation, leveraging city-level panel data from 2006 to 2014 and the global financial crisis as an exogenous shock. The key findings are as follows. (1) Productive Local Government Debt and Urban Innovation: Amid the global financial crisis, China's central government relaxed restrictions on local financing platforms, leading to a significant expansion of local government debt. This surge in productive debt contributed to a notable increase in urban innovation. These findings remain robust across multiple sensitivity tests. Using an intensity DID model and instrumental variable methods to address endogeneity concerns, we identify a causal relationship between productive debt expansion and urban innovation growth. (2) Mechanism Analysis: The expansion of productive local government debt alleviates fiscal pressures, allowing local governments to increase infrastructure investment and allocate more resources to science, technology, and education. These improvements create favorable conditions for attracting high-level talent and fostering urban innovation. Furthermore, productive debt expansion does not lead to rising housing prices or crowd out corporate investment, thereby avoiding any negative impact on innovation. (3) Heterogeneity Analysis: The positive impact of productive local government debt expansion on urban innovation is less significant in central and western regions, high-administrative-level cities, and cities with lower marketization levels. (4) Extended Analysis: Further examination shows that LGFV bonds and special local government bonds intended for infrastructure investment strongly support urban innovation. In contrast, general bonds and refinancing-oriented LGFV bonds, primarily issued for debt rollover ("borrowing new to repay old"), fail to drive innovation. These findings further reinforce our core hypothesis.

While some studies indicate that the expansion of local financing platform debt raises corporate financing costs, crowds out SME loans, and displaces private-sector investment, it is also crucial to recognize the positive role of appropriately scaled, productive debt expansion. Beyond its function in stabilizing and revitalizing the economy under the "Four Trillion Yuan" stimulus, this study finds that expanding productive local government debt can significantly enhance urban innovation. However, this effect is not uniform across all cities. In cities where economic growth models remain inefficient, government plays a dominant role in resource allocation, and marketization levels are low, the expansion of productive local government debt may have limited impact on enhancing urban innovation capacity. Hence, this paper puts forth the following policy recommendations:

(1) Further deepen the reform of local government performance evaluation. As China advances toward high-quality development, local government performance assessments should gradually move

away from a development model that relies on aggressively attracting low-quality investment. Instead, the reform should focus on changing incentive mechanisms to prioritize urban innovation capacity and technological capabilities. In particular, enhancing urban innovation capabilities and levels should be placed at a key position in the overall promotion of high-quality development and the process of improving technological competitiveness. Greater emphasis should be placed on public-sector innovation investment in strategic emerging and future industries, and local governments' R&D expenditures should be gradually incorporated into performance assessment frameworks.

(2) Further optimize central-local fiscal relations. Particularly at the level of top-level institutional design, the central government should focus on establishing mechanisms for resolving local fiscal risks. When preventing and mitigating financing platform debt risks, policies should fully consider the purposes of different types of debt as well as the economic conditions of various regions and cities, adjusting strategies flexibly based on time and location. For central and western regions, the government should strengthen supervision and regulation over the use of off-budget funds, encourage local governments to increase spending on science and education, expand innovative investment, and reduce inefficient investments made solely for the sake of GDP growth. For the more developed eastern regions, where local financing platforms can operate on a self-sustaining basis, the government should moderately encourage debt issuance, particularly productive government debt, to expand fiscal maneuverability and steadily enhance urban innovation.

(3) Further deepen market-oriented reforms to optimize the urban business environment. It is essential for local governments to gradually reduce administrative intervention in competitive sectors and allow public finance to play a reasonable role in resource allocation. Strengthening market competition mechanisms will enable the market to play a decisive role in resource distribution. In particular, efforts should focus on enhancing intellectual property rights (IPR) protections by strengthening legal frameworks and expanding safeguards for all types of innovation entities. Additionally, functional industrial and innovation policies should be leveraged to foster a more inclusive innovation environment, steadily improving the innovation capacity and overall competitiveness of urban innovation actors.

It should be noted that this paper currently mainly uses city-level panel data to examine the impact of productive government debt on urban innovation capacity. Whether productive government debt can also promote corporate innovation requires more granular data to answer. Additionally, while productive government debt can foster urban innovation, whether issuing an increasing amount of such debt is necessarily beneficial remains an important avenue for future research.

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