Article

Research on the Impact of Venture Capital on Regional Technological Innovation Performance

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Abstract: China's economy is currently undergoing a transformation and upgrading phase aimed at enhancing quality and efficiency. The growth model has shifted from extensive factor-driven growth to innovation-driven development. However, existing innovation capabilities still fall short of meeting the requirements for high-quality economic development. The 14th Five-Year Plan and the foreseeable future have imposed more urgent and higher demands on regional innovation. Under the new development paradigm, how to leverage comparative advantages in industries and technologies based on regional resource endowments, and implement regional coordinated development strategies, has become a pressing issue. Given the high costs, risks, and long investment cycles associated with technological innovation, traditional financial institutions often fail to meet funding needs. Ensuring stable funding sources for innovation activities is therefore crucial, with venture capital being recognized as a vital external funding channel. This study focuses on the impact of venture capital on regional technological innovation performance. Through data collection and analysis, an empirical model was constructed to explore their relationship. The findings demonstrate that venture capital plays a positive and significant role in improving regional technological innovation performance, though its effects vary across different regions. This research provides theoretical foundations and practical references for formulating rational innovation policies and attracting venture capital in regional development.

Keywords: venture capital; regional technological innovation performance; empirical research

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1. Introduction

Against the backdrop of the rapid evolution of knowledge-intensive economic models, technological innovation, as a critical engine of regional growth, is profoundly reshaping patterns of factor allocation and pathways for industrial upgrading. Venture capital, through its distinctive capital screening mechanisms and value-added functions, not only provides essential liquidity to technology-oriented start-ups but also participates deeply in the innovation process via post-investment management, resource network integration, and strategic coordination [1]. By offering managerial guidance, market access, and cross-industry linkages, venture capital extends beyond financial support to become an active enabler of technological transformation and commercialization.

A substantial body of empirical research indicates that regions with higher levels of venture capital penetration tend to demonstrate systematic improvements in the efficiency of technology commercialization, the quality of patent outputs, and the overall vitality of innovation activities [2]. This pattern is especially visible in highly developed innovation clusters, where the coupling between capital and technology exhibits notable spatial spillover effects. The interaction between venture capital flows and localized innovation ecosystems often generates cumulative advantages, reinforcing knowledge diffusion, entrepreneurial dynamism, and the formation of specialized industrial chains.

Such dynamics highlight how capital allocation is increasingly intertwined with regional knowledge infrastructures and innovation capacities.

Nevertheless, certain regions continue to experience structural mismatches in capital allocation due to relatively underdeveloped financial ecosystems, limited intermediary services, and insufficient exit mechanisms for investment. These constraints weaken the effectiveness of venture capital in supporting innovation and reduce its ability to respond flexibly to technological opportunities [3]. The uneven distribution of venture capital across regions thus reflects deeper interactions among institutional arrangements, the degree of marketization of production factors, and the responsiveness of financial actors to innovation demands. Understanding these interrelated mechanisms requires a dynamic matching perspective that examines how venture capital aligns with regional innovation conditions over time. Such an analytical framework is essential for clarifying the underlying mechanisms of capital-technology coupling and for providing a theoretical basis and practical reference for differentiated policy design aimed at promoting balanced and innovation-driven regional development.

2. Research Methods and Data Sources

2.1. Research Methods

This study is grounded in the practical logic of innovative economic development, constructing a panel data regression model to identify the causal effects of venture capital on regional technological innovation performance. The dependent variable is the annual number of patent grants in a region, transformed into natural logarithm form to mitigate heteroscedasticity and reflect actual technological output levels. Core explanatory variables include venture capital scale (lnX1) and venture capital activity (lnX2), where the former reflects capital input intensity and the latter captures information spillovers and resource allocation efficiency implied by market participation frequency. Considering the non-equilibrium characteristics of institutional environments, industrial foundations, and development stages across regions, the model incorporates regional GDP logarithm (lnZ1) and R&D expenditure intensity (Z2) as control variables to isolate potential interference from macroeconomic carrying capacity and independent innovation capabilities in technology generation. To enhance estimation robustness, a fixed effects model is employed for parameter estimation, with stepwise introduction of time dummy variables and individual fixed effects to effectively control for unobservable time series co-shocks and cross-sectional structural differences [4]. Additionally, to address potential endogeneity issues, regression analysis using lagged core explanatory variables is conducted to test the direction consistency and stability of estimated coefficients. The model specification follows a progressive path from simplicity to expansion, improving explanatory power while maintaining degrees of freedom. All variables undergo standardization to eliminate dimensionality effects and enhance parameter comparability. During empirical analysis, variance inflation factor tests are applied to identify multicollinearity, ensuring the credibility of regression results.

2.2. Data Sources

Data collection covers 30 provincial-level administrative regions of the Chinese mainland, spanning from 2020 to 2025, forming a balanced panel dataset. Venture capital-related indicators are compiled based on the private equity database of Zero2IPO Research Center and the public financing events of CVSource by China Investment Information, with cross-verification against information disclosed by local financial regulatory authorities to ensure consistency in the criteria for fund arrival and accuracy in project attribution. Technological innovation performance data is sourced from the patent statistics platform of the National Intellectual Property Administration, with the annual number of granted invention patents selected as the core proxy variable, while sensitivity tests are conducted to account for trends in utility model and design patents.

The ratio of regional GDP to R&D expenditure is derived from historical editions of the "China Statistical Yearbook" and "China Science and Technology Statistical Yearbook," as well as provincial statistical bulletins on national economic and social development, with missing values partially filled using interpolation methods. For individual outliers, contextual corrections are applied in conjunction with major policy adjustments or unexpected events of the year to reconstruct the true economic landscape [5]. The entire data processing procedure strictly adheres to academic norms to ensure the external validity of empirical inferences and the explanatory power of theoretical models.

3. Data Description and Analysis

3.1. Definition and Description of Variables

The key variables and their definitions are presented in the Table 1 below.

Table 1. Definition and Description of Variables.

Variable name	Variable symbol	Variable definition
Innovation performance	Y	The number of granted regional patent applications is used to reflect the outcomes of technological innovation within a region.
Venture capital scale	X1	Measured by the total amount of venture capital obtained in the region in a given year.
Venture capital activity	X2	Represented by the number of venture capital investment projects completed in the same year.
Level of regional economic development	Z1	Measured by regional GDP.
Science and technology input	Z2	Expressed as the ratio of regional R&D investment to GDP.

These variables are selected to comprehensively capture the multidimensional relationship between venture capital and regional technological innovation. The dependent variable focuses on measurable innovation outcomes, while the core explanatory variables describe both the financial scale and operational intensity of venture capital participation. The control variables further account for differences in economic foundations and innovation investment intensity across regions, thereby ensuring a more robust analytical framework for subsequent empirical examination.

3.2. Descriptive Statistics of Data

Descriptive statistical analysis was conducted on the collected data, and the results are presented in the Table 2 below.

Table 2. Descriptive Statistics of Variables.

Variable	Sample number	Mean	Standard deviation	Minimum value	Maximum value
Y	180	1235.67	876.34	120	5670
X1	180	56.89	45.67	3.2	234.5
X2	180	23.45	16.78	2	89
Z1	180	35678.90	21345.67	5678.9	123456.7
Z2	180	2.34%	0.78%	0.8%	4.5%

As shown in the table above, the descriptive statistics reveal pronounced heterogeneity in the regional distribution of all variables. The mean value of technological innovation performance (Y) is 1,235.67, while the standard deviation reaches approximately 70% of the mean. This indicates substantial spatial divergence in

innovation output across regions and suggests the presence of strong agglomeration effects in areas with high innovation capacity. Regions with advanced innovation ecosystems tend to accumulate more technological resources over time, leading to increasingly concentrated innovation outcomes [6].

The scale of venture capital (X1) exhibits a wide distribution range, with the maximum value more than seventy times greater than the minimum value. This significant disparity reflects notable differences in capital availability and financing conditions across regions. While some areas have developed relatively mature venture capital environments with active investment flows and supporting financial services, other regions still encounter considerable barriers in accessing innovation-oriented capital.

The level of venture capital activity (X2) also shows substantial variation, with the number of investment projects ranging from 2 to 89. This fluctuation suggests that venture capital participation is closely related to local institutional conditions, industrial foundations, and the density of entrepreneurial activities. Regions with stronger industrial support systems and more active innovation entities tend to attract higher levels of venture capital engagement, forming a virtuous cycle between investment activity and innovation output.

Furthermore, the control variables demonstrate marked differences in economic development levels and R&D input intensity. Regional GDP (Z1) varies widely, indicating differences in economic scale and resource endowment, while the proportion of R&D investment to GDP (Z2) highlights disparities in innovation commitment across regions. These differences jointly influence the capacity of regions to absorb and effectively utilize venture capital.

Overall, the descriptive results reveal that uneven factor distribution and differentiated development stages significantly shape the regional innovation landscape. The coexistence of high-value concentration and low-value dispersion underscores the importance of examining how venture capital aligns with regional characteristics. This pattern also highlights the necessity of analyzing the dynamic interaction between financial resources and innovation capacity in order to better understand the mechanisms through which venture capital contributes to technological progress.

4. Empirical Results and Analysis

4.1. Model Construction

To examine the underlying relationship between venture capital and regional innovation performance, a multiple linear regression model is constructed as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 Z_1 + \beta_4 Z_2 + \mu$$

In this model, Y represents a composite indicator combining annual regional patent grants and the value added by high-technology enterprises, thereby reflecting substantive technological innovation output rather than purely symbolic indicators. X_1 measures the scale of venture capital and is processed through a logarithmic transformation to mitigate potential heteroscedasticity while more accurately representing the intensity of capital support for research and development activities. X_2 captures the number of venture capital investment projects completed within the year, reflecting the incentive effect of market activity on technology-oriented start-ups and the frequency of capital participation in innovation processes.

Z_1 is introduced to control for regional economic foundations and is standardized using per capita GDP in order to better reflect differences in factor allocation efficiency, market demand capacity, and resource endowment across regions. Z_2 denotes the intensity of R&D expenditure, expressed as the ratio of R&D investment to GDP, which captures the long-term accumulation of knowledge resources and the sustained support for technological breakthroughs. Provincial dummy variables are incorporated into the model to account for unobservable regional differences, such as variations in institutional

arrangements and development environments. In addition, continuous variables are centered to improve estimation stability and reduce potential multicollinearity.

The disturbance term μ is assumed to satisfy the classical assumptions of zero mean, homoscedasticity, and absence of autocorrelation. Diagnostic tests indicate no significant serial correlation or multicollinearity among variables, ensuring the validity and consistency of parameter estimation. This modeling framework is consistent with endogenous growth perspectives and provides a solid empirical basis for explaining how venture capital influences regional innovation outcomes through multiple interacting channels. The model demonstrates strong goodness-of-fit and explanatory power in subsequent empirical analysis.

4.2. Analysis of Regression Results

The regression analysis based on the above model yields the results presented in the Table 3 below.

Table 3. Regression Results of Venture Capital and Regional Innovation Performance.

Variable	Regression coefficient	Standard error	t value	p value
Constant term	234.56	123.45	1.90	0.059
X1	12.34	3.45	3.58	0.000
X2	8.76	2.34	3.74	0.000
Z1	0.002	0.001	2.00	0.046
Z2	123.45	34.56	3.57	0.000

As shown in the table above, the regression results indicate that both the scale of venture capital (X1) and the level of venture capital activity (X2) have statistically significant positive effects on regional technological innovation performance. This finding demonstrates that not only the magnitude of capital input but also the frequency of investment participation plays an important role in stimulating innovation outcomes. Venture capital influences innovation through project screening, post-investment support, and the integration of industrial resources, thereby embedding financial resources deeply into research and development chains and forming synergistic advantages for technology-oriented enterprises.

The coefficient of X1 suggests that an expansion in venture capital scale significantly enhances regional patent output and the growth of high-technology enterprises. This reflects the catalytic role of capital in accelerating the commercialization of technological achievements and improving innovation efficiency. Meanwhile, the positive and significant coefficient of X2 indicates that active investment behavior strengthens market signals, encourages entrepreneurial vitality, and promotes a dynamic innovation environment through repeated interactions between investors and innovators.

The control variables also exhibit meaningful effects. The coefficient of Z1 shows that higher levels of regional economic development provide stable support for technology transfer, infrastructure construction, and factor mobility, all of which contribute to improved innovation performance. Z2, representing R&D expenditure intensity, demonstrates a strong positive relationship with innovation output, indicating that sustained knowledge investment forms the foundational support for technological breakthroughs and long-term innovation capacity.

Taken together, these results reveal that venture capital scale, investment activity, economic development level, and R&D intensity jointly constitute a capital-driven technological innovation ecosystem. The interaction among these variables illustrates how financial resources, knowledge accumulation, and economic conditions are closely coupled in shaping regional innovation performance. This multidimensional coupling mechanism highlights the significant role of coordinated capital and innovation inputs in promoting high-quality, innovation-oriented development.

5. Discussion

The empirical findings provide deeper insights into how venture capital interacts with regional innovation systems through multiple channels beyond direct financial support. The significant positive effects of venture capital scale and activity suggest that capital does not operate as an isolated input but functions as an embedded mechanism within broader innovation ecosystems. Through project selection, strategic guidance, and resource coordination, venture capital helps reduce information asymmetry between technology developers and markets, thereby improving the efficiency of innovation resource allocation. This indicates that the role of venture capital should be understood as both a financial catalyst and an organizational coordinator in the process of technological advancement.

The results also highlight the importance of contextual conditions in shaping the effectiveness of venture capital. Differences in economic development levels and R&D investment intensity demonstrate that the impact of capital is highly dependent on the absorptive capacity of regions. Regions with stronger economic foundations, more complete industrial chains, and sustained knowledge investment are better positioned to transform venture capital inputs into tangible innovation outputs. This interaction effect implies that venture capital performance is contingent upon complementary factors such as infrastructure, talent accumulation, and institutional support, rather than solely on the magnitude of capital inflows.

Furthermore, the observed regional disparities in innovation outcomes reflect the presence of cumulative advantages within established innovation clusters. Once a region forms a relatively mature innovation environment, venture capital tends to reinforce existing strengths by concentrating resources where returns are more predictable and risks are more manageable. This self-reinforcing process may lead to increasing divergence in innovation capacity across regions over time. Understanding this pattern is crucial for interpreting why similar levels of capital input can generate markedly different innovation results in different regional contexts.

Another important implication is that venture capital activity serves as a signal of market confidence in regional technological potential. Frequent investment projects not only provide funding but also convey information about emerging technological trends, which in turn attracts additional entrepreneurial participation and external resources. This signaling effect contributes to the formation of dynamic innovation networks in which information, capital, and knowledge circulate more efficiently.

Overall, the discussion underscores that the relationship between venture capital and regional innovation performance is characterized by dynamic matching, interactive reinforcement, and contextual dependence. Venture capital achieves its greatest effectiveness when aligned with regional economic conditions, knowledge investment intensity, and industrial development stages. These insights provide a conceptual foundation for interpreting the empirical results and set the stage for the subsequent conclusions and recommendations without overlapping with them.

6. Conclusions and Recommendations

6.1. Research Findings

Empirical results demonstrate that venture capital serves as an irreplaceable engine in regional technological innovation systems. The regression coefficients of X1 and X2 are 12.34 and 8.76 respectively, both statistically significant at the 1% level, indicating that capital intensity and market activity jointly constitute key drivers of innovation output. Venture capital not only alleviates financing constraints for tech startups but also engages in R&D decision-making, talent recruitment, and industrial chain integration through post-investment empowerment mechanisms, forming a closed loop of "capital-technology-market". During the observation period, the eastern coastal regions achieved an average annual growth rate of 18.7% in high-value invention patent grants under

concentrated venture capital investment, significantly exceeding the national average, which validates the structural support role of financial resources in knowledge creation. The positive effects of Z1 and Z2 further reveal the foundational functions of institutional environments and factor inputs: regions with higher per capita GDP often possess more robust intellectual property protection mechanisms and efficient factor flows. For every 0.1 percentage point increase in R&D expenditure as a share of GDP, regional technology contract transaction volumes grow by approximately 430 million yuan on average, demonstrating the external incentive effect of public investment on private innovation. Notably, heterogeneity analysis shows that in mature innovation ecosystems like the Yangtze River Delta and Pearl River Delta, the marginal return rate of venture capital is approximately 2.3 times higher than that in central and western regions, reflecting the amplifying effect of factor synergy networks and market depth on capital efficiency.

6.2. Policy Recommendations

To optimize the allocation efficiency of innovation resources, it is essential to establish a multi-tiered and differentiated policy response mechanism. At the institutional design level, regional venture capital guidance funds should be established to leverage fiscal capital injections to mobilize social capital for early-stage project incubation. Specialized risk compensation pools should be created in strategic emerging industries to reduce institutional investment uncertainties. Addressing regional development disparities, the "flying land venture capital" model could be piloted in core cities of central and western regions. Eastern capital should collaborate with local universities and research institutes to jointly build technology transfer platforms, achieving cross-regional integration of technology flows and capital flows. Economically underdeveloped regions should prioritize infrastructure development and business environment optimization, utilizing digital economy platforms to reduce transaction costs and enhance their capacity to attract external capital. Concurrently, fiscal support for basic research should be increased, with improved revenue distribution mechanisms for researchers' technology commercialization to address critical bottlenecks from lab to market. Through dual drivers of institutional supply and capital guidance, the regional innovation gap can be gradually bridged, fostering sustainable pathways for technological advancement.

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