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Venture Capital, Environmental Regulation and Regional Green Innovation: Evidence from China

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Abstract

Venture capital can promote green innovation by providing financial support for green innovation activities. Based on panel data from 30 provincial-level administrative regions in China, this research analyzes the impact of venture capital on green innovation and its underlying mechanisms. The results show that venture capital significantly promotes regional green innovation. Through the mediation analysis, it is found that venture capital primarily promote green innovation by increasing R&D investment and improving the level of research team level. The increase in R&D investment is the main pathway through which venture capital influences the level of green innovation, as firms receiving venture capital are more willing to allocate these funds towards green innovation activities. The study also finds that the impact of venture capital on green innovation is influenced by environmental regulation, with an upper limit to the intensity of environmental regulation. Environmental regulation below this limit value amplifies the positive effect of venture capital on green innovation, while regulation exceeding this threshold reduces the effect of venture capital on green innovation. The article confirms the important role of venture capital in promoting green innovation, enriches the research on the innovation effects of venture capital, and provides theoretical references for green development.

Keywords: Venture capital, green innovation, environmental regulation, R&D investment, R&D teams

1. Introduction

Since the reform and opening-up, China’s economy has achieved remarkable high-speed growth. However, in its early stages, China's economic growth relied heavily on high-pollution, high-emission industrial sectors. Since the 18th CPC National Congress, President Xi Jinping has repeatedly emphasized the concept of balancing environmental protection with economic development by advocating for “lucid waters and lush mountains as invaluable assets” in both domestic and international forums. This highlights the importance of harmonizing environmental conservation with economic development. The 19th CPC National Congress emphasised the need to prioritise ecological civilisation. Increasing attention has been paid to ecological and environmental protection by the Party and the government. The report from the 20th National Congress set forth the goal of building a modern socialist country in all respects, with the synergy between ecological protection and economic growth being a critical pathway to achieving this objective. Green innovation is a vital engine for the coordinated development of the environment and economy, as well as for achieving high-quality economic growth (Wen et al., 2022).

“Green innovation” can be defined as the process of developing new products and technologies aimed at reducing the adverse consequences of environmental risks (Karimi Takalo et al., 2021). This process often requires significant financial support and is associated with high investment risks and long payback periods, which result in a reluctance investment from traditional financing channels. Venture capital, as an emerging financing mechanism in high-tech industries, can meet the financing needs of technological innovation because it not only provides financial support for innovation activities but also delivers a range of non-capital value-added services (Yang et al., 2022).

Kortum and Lerner (2000) were the first to systematically study the relationship between venture capital and technological innovation. Using data from 20 U.S. industries between 1965 and 1992, they analyzed the relationship between venture capital and patent output, which represents technological innovation. They found that venture capital had a significant effect in encouraging innovation, with an impact 3 to 4 times greater than

that of ordinary R&D. Hirukawa and Ueda (2011) found that venture capital significantly promotes the transformation of innovative outcomes. Gu and Qian (2019) empirically analyzed the innovation effects of venture capital on firms, discovering that companies receiving venture capital obtain more patents and have stronger innovation capabilities compared to firms without venture capital, confirming that venture capital effectively stimulates corporate innovation. However, Qiao et al. (2021) found that firms' innovation inputs and outputs do not show obvious enhancement due to VC entry. Overall, existing research mainly indicates that venture capital positively promotes technological innovation (Arqué-Castells, 2012; Cailou & DeHai, 2022; Guo & Jiang, 2022; Maiti, 2022).

It must be noted that, compared to general innovation activities, green innovation has a stronger public goods attribute and externalities. Therefore, even though existing literature confirms that venture capital promotes innovation, the relationship between venture capital and green innovation remains a topic of significant interest. Dong(2021) found that venture capital effectively improves the efficiency and quality of green innovation in these firms through their study of environmental protection enterprises. Azhgaliyeva (2023) also found that venture capital participation significantly promotes innovation in clean technologies. Existing studies demonstrate the substantial role of venture capital in promoting green innovation in specific industries.

Regarding environmental regulation, Porter and Van der Linde (1995) first proposed the "Porter Hypothesis", which suggests that reasonable environmental regulation can stimulate corporate technological innovation. The savings from energy conservation and improvements in product quality brought about by technological innovation can offset the costs of compliance, thereby enhancing a firm's competitiveness while improving environmental quality. Nesta et al. (2014) and Du et al. (2018) found that environmental regulation promotes corporate green innovation. Liu et al. (2024) using the difference-in-differences (DID) method, found that strengthening environmental constraints can enhance the level of urban green technological innovation. The reason environmental regulation promotes green innovation may lie in the compliance requirements that guide firms to invest in green innovation activities. Wang et al. (2024) discovered that after the implementation of environmental protection tax, the quantity of green patents increased significantly. Conversely, Hu et al. (2020) found that under carbon emission constraints, no form of government subsidy can significantly promote high-quality corporate innovation. In general, existing academic research validates the Porter Hypothesis.

In summary, prior research on venture capital, technological innovation, and environmental regulation has yielded substantial findings, with most studies affirming the importance of venture capital in technological innovation. However, there is a paucity of research on the interaction between venture capital and green innovation from a provincial perspective, as well as on the mechanisms through which venture capital affects green innovation. Additionally, few studies have examined the role of environmental regulation in the context of venture capital's effect on green innovation.

In this context, what impact does venture capital have on green innovation under the current macroeconomic backdrop of tightening environmental regulation? Through which pathways does it exert its influence? What role does environmental regulation play in the relationship between venture capital and green innovation? A deeper investigation into these questions can enrich research on the innovation effects of venture capital and has both theoretical significance and practical value for green development.

Based on this, the paper uses panel data from 30 Chinese provinces from 2009 to 2020 to examine the impact of venture capital on green innovation and the mechanisms through which it operates. The results show that: First, venture capital significantly enhances the level of green innovation across provinces by increasing R&D investment and improving the capabilities of innovation teams. Second, the promotion of green innovation by venture capital in each province is influenced by the intensity of environmental regulation. There is a threshold for the strength of environmental regulation; once this threshold is exceeded, the effect of venture capital on green innovation diminishes.

The contribution of this paper can be summarized as follows. First, unlike previous studies that primarily focused on the impact of venture capital on technological innovation, this paper uses provincial panel data to investigate the effects of venture capital on green innovation at the provincial level. This not only enriches the body of research on the innovation-promoting effects of venture capital but also further explores the driving factors behind green innovation. Second, there is a lack of research in the existing literature on the mechanisms through which venture capital influences green innovation. This paper uses a mediation effect model, along with Sobel and Bootstrap tests, to examine the mechanisms by which venture capital promotes green innovation through enhancing team capabilities and increasing R&D investment. Third, while the impact of venture capital on green innovation is influenced by environmental regulation, there is limited research analyzing this effect

within the context of environmental regulatory policies. This paper fills this gap by employing a panel threshold model to investigate the impact of environmental regulation on regional green innovation.

2. Theoretical Analysis and Research Hypotheses

2.1 The Impact of Venture Capital on Regional Green Innovation

Green innovation is characterized by high risks, long cycles, and significant financing pressures (Xiang et al., 2022). Traditional financing methods are more focused on the safety and profitability of capital use. When companies obtain funds through traditional financing channels, they are often reluctant to invest them in R&D activities that have long return cycles and high failure risks, in order to avoid the substantial financial pressure caused by potential failures. Moreover, given the high externality and risk associated with green innovation, companies face even greater financing challenges in this area.

Compared to traditional financing methods, venture capital has a greater capacity to bear risks and a higher tolerance for failure, which can help alleviate the financing difficulties faced by companies engaged in green innovation.

Based on this, the following hypothesis is proposed:

H1: Venture capital promotes green innovation at the provincial level.

2.2 Mechanisms of Venture Capital's Influence on Regional Green Innovation

Given the high failure risks of green innovation activities, companies are less willing to invest in green innovation after obtaining funds through traditional financing methods. In contrast, venture capital, with its greater risk tolerance and longer investment cycles, encourages companies to allocate such funds to high-risk, high-reward green innovation activities. This will increase R&D investment and, consequently, enhance the level of green innovation.

Based on this, the following hypothesis is proposed:

H1a: Venture capital increases provincial green innovation levels by enhancing R&D investment.

At the same time, from a non-capital perspective, since venture capital tends to favor companies with high growth potential and strong innovation capabilities, Regions with high venture capital activity often attract more innovative professionals. This, in turn, will improve the level of research teams in the region and enhance the green innovation capacity of enterprises.

Based on this, the following hypothesis is proposed:

H1b: Venture capital increases provincial green innovation levels by improving the quality of research teams.

2.3 Moderating Effect

Appropriate environmental regulation policies impose higher requirements on corporate production, increasing costs related to environmental management. When the cost of environmental management exceeds a company's operating income under the existing technological level, the company is forced to increase its investment in the R&D of environmental protection and pollution control technologies to meet regulatory standards. This improves production processes and efficiency, promotes cost reduction through green innovation, and helps the company maintain its market competitiveness.

However, overly stringent environmental regulation may result in environmental management costs exceeding a company's tolerance, leading to the company's withdrawal from the market. Furthermore, excessively high levels of environmental regulation may reduce venture capital investment in green innovation-related enterprises, weaken the geographic advantages of such investments, and suppress the concentration of innovative elements, ultimately having a negative impact on green innovation.

In summary, flexible and appropriate environmental policies can promote green innovation in enterprises within specific regions. However, when the intensity of environmental regulation exceeds a certain threshold, it may have detrimental effects.

Based on this, the following hypothesis is proposed:

H2: Environmental regulation plays a moderating role in the relationship between venture capital and regional green innovation.

3. Research Design

3.1 Variable Definitions

3.1.1 Green Innovation (GI)

Patent output is the most direct indicator of innovation levels. In China, patents are generally divided into three categories: invention patents, utility model patents, and design patents. These three types of patents differ significantly in terms of technological content and innovation difficulty. Generally speaking, invention patents are considered to have the highest level of technological difficulty, the greatest value, and represent substantial innovation (Li G., 2022). Therefore, this paper uses the number of green invention patents in each province to measure green innovation.

3.1.2 Venture Capital (VC)

Venture capital is a form of equity investment that has a strong capacity to bear risks and can provide financial support for corporate green innovation. Existing studies typically use initial investment amounts, the number of venture capital projects, and the total amount of venture capital as measurement standards. In this paper, the total annual venture capital received by each provincial-level administrative region is used as the measurement indicator, and the data is winsorized at the 1st and 99th percentiles.

3.1.3 Research Team (Te)

Considering the characteristics of R&D activities in China and as well as the availability of data, following previous research, this paper selects the number of R&D personnel in each province as the measurement indicator (Lu et al., 2021).

3.1.4 R&D Investment (Rd)

Based on the characteristics of R&D activities and relevant statistical indicators in China, this paper uses the internal expenditure on R&D in each province as the measurement indicator.

3.1.5 Environmental Regulation Intensity (Er)

Environmental regulation refers to the environmental standards established and enforced by the government, which play a supervisory role for market entities (Hou et al., 2023) and can promote enterprises to increase R&D efforts and pursue continuous green innovation. Following previous research, this paper uses the ratio of completed industrial pollution control investment to the added value of the secondary industry in each province to measure the intensity of environmental regulation (Liu et al., 2023).

3.1.6 Control Variables

Based on existing research, the control variables selected in this paper are as follows:

Economic development level (gdp): measured by per capita GDP;

Income level (incom): measured by per capita disposable income of residents;

Education level (edu): measured by the number of students enrolled in regular higher education institutions (undergraduate and junior college students) in each province;

Industrial structure (ind): measured by the ratio of non-agricultural industry output to GDP.

Table 1. Variable definition

Category	Code	Description
Dependent Variable	GI	Number of green invention patents in each provincial administrative region
Independent Variable	VC	Total annual venture capital received by each provincial administrative region
Mediating Variables	Te	Number of R&D personnel in each province
	Rd	Internal expenditure on R&D in each province
Moderating Variable	Er	Ratio of industrial pollution control investment to the added value of the secondary industry in each province
Control Variables	gdp	Per capita GDP in each province
	incom	Per capita disposable income of residents in each province
	edu	Number of students enrolled in regular higher education institutions (undergraduate and junior college students) in each province
	ind	Proportion of non-agricultural industry output to GDP

3.2 Model Construction

To test hypothesis H1, the following model is established:

$$GI_{i,t} = \beta_0 + \beta_1 VC_{i,t} + \beta_2 control_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t} \quad (1)$$

To test hypotheses H1a and H1b, a mediation effect model is further constructed:

$$M_{i,t} = \alpha_0 + \alpha_1 VC_{i,t} + \alpha_2 control_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t} \quad (2)$$

$$GI_{i,t} = \gamma_0 + \gamma_1 VC_{i,t} + \gamma_2 M_{i,t} + \gamma_3 control_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t} \quad (3)$$

Where i refers to the province, and t refers to time. The variable $M_{i,t}$ represents the mediating variable. $G_{i,t}$ denotes the level of green innovation in province i in year t, and $VC_{i,t}$ refers to the venture capital amount in province i in year t. The term $control_{i,t}$ represents a set of control variables. η_i and $\mu_t$account for city and time fixed effects, respectively, while $\varepsilon_{i,t}$ is a random error term.

To test hypothesis H2, a panel threshold model is established:

$$M_{i,t} = \delta_0 + \delta_1 VC_{i,t}(Er_{i,t} < \theta_1) + \delta_2 VC_{i,t} I(\theta_1 < Er_{i,t} < \theta_2) + \ldots$$
$$+\delta_{n+1} VC_{i,t} I(Er_{i,t} > \theta_n) + \delta_{n+2} control_{i,t} + \eta_i + \varepsilon_{i,t} \quad (4)$$

In this model, the threshold variable is the intensity of environmental regulation, represented by Er. I( ) is an indicator function, which takes the value of 1 if the condition inside the parentheses is met and 0 otherwise. θ represents the threshold value of environmental regulation intensity, and δ is the threshold coefficient.

4. Results

4.1 Data Sources and Descriptive Statistics

This paper takes data from 30 regions in China (excluding Tibet, Hong Kong, Macao, and Taiwan) for the years 2009-2020 as the research sample. The data for the explanatory variables are sourced from the Wind database, while the data for the explained variables, mediating variables, moderating variables, and control variables are obtained from the China City Statistical Yearbook, the China Science and Technology Statistical Yearbook, the National Intellectual Property Administration (CNIPA) database, and authoritative data published by each region. Descriptive statistical analysis of the relevant data in the model is presented in Table 2.

The results in Table 2 show that the average level of green innovation is 3.3390, with a standard deviation of 5.0445. The average value of the venture capital indicator is 2.7856, with a standard deviation of 4.5970, indicating significant variation in green innovation levels and venture capital across different provinces.

Table 2. Descriptive statistics

Variable	Sample Size	Mean	Standard Deviation	Minimum Value	Maximum Value
GI	360	3.3390	5.0445	0.0300	32.2690
VC	360	2.7856	4.5970	0.0090	29.5700
Rd	360	47.3904	58.6530	0.5781	347.9883
Te	360	7.9200	9.3976	0.6487	7.5440
Er	360	0.0029	0.0027	0.0000	0.0245
gdp	360	4.9759	2.7056	0.0840	6.4580
incom	360	2.5870	0.2960	0.6099	7.2232
edu	360	86.8742	5.8898	4.3800	249.2200
ind	360	0.8990	0.0539	0.7234	0.9972

4.2 Empirical results and analysis

To test Hypothesis 1, Hypothesis 1a, and Hypothesis 1b, a panel fixed-effects model is constructed based on equations (1), (2), and (3) to analyse and calculate the influencing factors. The regression results are presented in Table 3.

Table 3. Basic estimates

Variable	（1）	（2）	（3）	（4）	（5）
	GI	Rd	GI	Te	GI
VC	0.478***	1.98**	0.311***	0.518*	0.345***
	(0.1148)	(0.6921)	(0.0572)	(0.2097)	(0.0593)
Rd			0.0843***		
			(0.0141)		
Te					0.258***
					(0.0427)
Constant	0.1018	-44.97	6.20	-16.88	6.76
	(9.6747)	(39.7770)	(4.4110)	(12.4981)	(4.4513)
Control Variables	YES	YES	YES	YES	YES
Time Fixed Effects	YES	YES	YES	YES	YES
Province Fixed Effects	YES	YES	YES	YES	YES
Sobel Z			2.584***		2.284**
Mediation Effect Ratio			34.9%		27.9%
R^2	0.7189	0.9539	0.9344	0.9555	0.9344
Observations	360	360	360	360	360

Note. Robust standard errors are reported in parentheses. *** indicates $p < 0.01$, ** indicates $p < 0.05$, and * indicates $p < 0.1$.

Table 3 presents the results of the impact of venture capital on green innovation and the test of the transmission pathways. Column (1) shows the impact of venture capital on green innovation, with a significantly positive coefficient, indicating that venture capital positively influences green innovation, thereby confirming Hypothesis 1. Columns (2) and (3) display the results of the mediation effect model, using R&D investment as the mediating variable. In Column (2), the regression coefficient of venture capital on R&D investment is 1.98, and it is significant at the 5% level, suggesting a positive correlation between the two—venture capital effectively promotes an increase in R&D investment. In Column (3), after adding the mediating variable to the model, the

regression coefficient of venture capital is 0.311, and the regression coefficient of R&D investment is 0.0843, both significant at the 1% level. The Sobel test yields a Sobel Z value of 2.584, significant at the 1% level. This phenomenon may occur because through post-investment management, venture capital can effectively avoid agency problems such as the managerial myopia. This, in turn, leads to increased R&D investment and ultimately enhances innovation capabilities (Zhang et al., 2021). These results indicate that R&D investment is a key factor in enhancing green innovation, and that venture capital promotes R&D investment, thereby improving green innovation, confirming Hypothesis 1a.

Columns (4) and (5) show the results of the mediation effect model using team quality as the mediating variable. In Column (4), the regression coefficient of venture capital on team quality is 0.518, indicating a positive correlation between the two—venture capital effectively enhances team quality. This phenomenon may occur because venture capital will use its own resources and brand, through the unified talent recruitment or targeted headhunting recruitment, to help enterprises to introduce professional and technical talents (Chen et al., 2017). In Column (5), after incorporating the mediating variable into the model, the regression coefficient of venture capital is 0.345, and the regression coefficient of team quality is 0.258, both significant at the 1% level. The Sobel test yields a Sobel Z value of 2.284, significant at the 5% level. These findings demonstrate that team quality is a contributing factor to the improvement of green innovation, and that venture capital enhances team quality, thereby boosting green innovation, confirming Hypothesis 1b.

Thus, it can be seen that the positive effect of venture capital on green innovation is partially mediated by both R&D investment and team quality, with mediation effects accounting for 34.9% and 27.9%, respectively. The proportion of the mediation effect reveals that promoting R&D investment is the primary pathway through which venture capital influences green innovation.

To test Hypothesis 2, a panel threshold model is constructed based on equation (4). We employ the panel threshold regression method proposed by Hansen (1999) and uses the bootstrap method with 300 repetitions of resampling. The results are shown in the table below. And the regression results are shown in Table 4. The empirical results show that under different intensities of environmental regulation, the coefficients of venture capital are all significantly positive, demonstrating that venture capital significantly promotes green innovation. Compared to the regression coefficient of venture capital on green innovation without environmental regulation, when the intensity of environmental regulation is below 0.0021, the coefficient of venture capital rises to 0.603. However, when the intensity of environmental regulation exceeds 0.0021, the coefficient of venture capital drops to 0.400. The empirical results suggest that a moderate level of environmental regulation can enhance the effect of venture capital on green innovation. However, when the intensity of environmental regulation becomes too high and exceeds the threshold value, although venture capital still promotes regional green innovation, the effect is significantly diminished compared to conditions with no or low environmental regulation. This phenomenon may occur because excessive environmental regulation forces enterprises to increase investments aimed at reducing pollution to meet compliance, thereby crowding out investments in green innovation activities (Huang et al., 2018).

Table 4. Threshold effect

Variable	GI
VC_1	0.603***
	(0.0733)
VC_2	0.400***
	(0.0398)
Constant	-0.58
	(9.3033)
Threshold	0.0021
Control	YES
Time Fixed Effects	YES
Province Fixed Effects	YES
R^2	0.7378
Observations	360

Note. The reported values in parentheses indicate robust standard errors. ***, **, and * indicate that the coeffcient is significance at 1%, 5%, and 10%, respectively.

4.3 Robustness Tests

4.3.1 Variable Substitution in the Model

The number of venture capital cases in each province is used as a substitute for the amount of venture capital. The empirical results are shown in Table 5, where the regression coefficient of the number of venture capital cases on green innovation is significantly positive. This demonstrates that venture capital significantly improves green innovation levels, consistent with the previous regression results, confirming the robustness of the results.

4.3.2 Lagging the Venture Capital Amount by One Period to Address Endogeneity

The empirical results, shown in Table 5, indicate that the regression coefficient of the lagged one-period venture capital on green innovation is significantly positive, which is consistent with the previous conclusions and confirms the robustness of the results.

Table 5. Robustness tests

Variable	GI	GI
VC_case	0.276**	
	(0.0810)	
VC_{n-1}		0.561*
		(0.2088)
Constant	0.514	-5.735
	(9.1730)	(10.4213)
Control	YES	YES
Time Fixed Effects	YES	YES
Province Fixed Effects	YES	YES
R^2	0.7482	0.7193
Observations	360	330

Note. The reported values in parentheses indicate robust standard errors. ***, **, and * indicate that the coeffcient is significance at 1%, 5%, and 10%, respectively.

4.3.3 Bootstrap Test

To further confirm the significance of the mediation effect, this paper applies the Bootstrap test to the original model. The Bootstrap test was conducted on the transmission pathways, and the results are presented in Table 6. The results show that the confidence intervals for both the R&D investment and research team quality mediation pathways do not include zero, and the signs of both the direct and indirect effects are the same. This indicates the presence of a partial mediation effect, consistent with the Sobel test results, thus confirming the robustness of the findings.

Table 6 Bootstrap test

	Coefficient	Standard error	95% Confidence Interval	
Indirect Effects				
Rd	0.1672*	0.0758	0.0704	0.3788
Te	0.1333*	0.0673	0.0106	0.3197
Direct Effects				
Rd	0.3111***	0.0640	0.1510	0.4163
Te	0.3450***	0.0650	0.2335	0.4957

Note. ***, **, and * indicate that the coeffcient is significance at 1%, 5%, and 10%, respectively.

5. Conclusion

Based on provincial panel data from China, this paper tests the impact of venture capital on green innovation, its underlying mechanisms, and the threshold effect of environmental regulation. The empirical results indicate the following:

(1) Venture capital significantly promotes green innovation across provinces. Robustness tests, including variable substitution and lagging the venture capital amount by one period, confirm this conclusion.

(2) The mediation effect analysis shows that venture capital promotes the development of green innovation in provincial administrative regions by increasing R&D investment and enhancing team quality, with increased R&D investment being the primary driver of green innovation improvement.

(3) The impact of venture capital on green innovation exhibits a threshold effect based on the intensity of environmental regulation. Under optimal environmental regulation, the positive effect of venture capital on green innovation is amplified. However, once the regulatory intensity exceeds a certain threshold, the effect diminishes.

The conclusions of this paper affirm the important role of venture capital in enhancing green innovation by increasing innovation investment and improving team quality. The contributions of this paper are mainly reflected in the following aspects. First, it enriches the research on the innovation effects of venture capital by exploring the mechanisms through which venture capital promotes green innovation. Second, it fills a gap in the current research by investigating the role of environmental regulation in the relationship between venture capital and green innovation, providing new insights into how external regulatory forces shape the green innovation process.

Our findings have practical implications for fostering green innovation. On one hand, provincial governments should continue to optimise their investment and financing environments, attract venture capital, and expand the scale of venture capital to provide financial support to innovative enterprises, thereby maximising its role in promoting green innovation. Secondly, local governments should implement appropriate innovation incentives and environmental regulation policies to support green economic development, further amplifying the positive effect of venture capital on green innovation. However, care must be taken to avoid excessive regulatory intensity, which could impose overly high “compliance costs” on firms, thereby weakening the positive impact of venture capital on green innovation. Furthermore, local governments should attract talent through policy measures, improve the quality of innovation teams, and lay a solid foundation for the development of green innovation.

Our research has the following limitations. First, due to data availability constraints, we only examined the effect of venture capital on the scale of green innovation, rather than its quality. Additionally, we did not distinguish between the types of venture capital and environmental regulation. In the future, further research should be conducted once data on green innovation quality, as well as categorised data on venture capital and environmental regulation, become available, in order to provide more precise policy recommendations. Second, although we discussed the impact of environmental regulation on the role of venture capital in promoting green innovation, we did not conduct a more detailed analysis of its mechanism from a micro-level perspective. In the future, the mechanism through which environmental regulation influences the effect of venture capital on green innovation should be studied in detail.

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Informed consent

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

References

Arqué-Castells, P. (2012). How venture capitalists spur invention in Spain: Evidence from patent trajectories. *Research Policy*, *41*(5), 897-912. https://doi.org/10.1016/j.respol.2012.01.008

Azhgaliyeva, D., Beirne, J., & Mishra, R. (2023). What matters for private investment in renewable energy? *Climate Policy*, *23*(1), 71-87. https://doi.org/10.1080/14693062.2022.2069664

Cailou, J., & DeHai, L. (2022). Does venture capital stimulate the innovation of China's new energy enterprises? *Energy*, *244*, 122704. https://doi.org/10.1016/j.energy.2021.122704

Chen, S., He, W., & Zhang, R. (2017). Venture capital and corporate innovation: impact and potential mechanisms. *Management World*, *1*, 158-169. https://doi.org/10.19744/j.cnki.11-1235/f.2017.01.014

Dong, W., Li, Y., Lv, X., & Yu, C. (2021). How does venture capital spur the innovation of environmentally friendly firms? Evidence from China. *Energy Economics*, *103*, 105582. https://doi.org/10.1016/j.eneco.2021.105582

Du, L., Zhang, Z., & Feng, T. (2018). Linking green customer and supplier integration with green innovation performance: The role of internal integration. *Business Strategy and the Environment*, *27*(8), 1583-1595. https://doi.org/10.1002/bse.2223

Gu, W., & Qian, X. (2019). Does venture capital foster entrepreneurship in an emerging market? *Journal of Business Research*, *101*, 803-810. https://doi.org/10.1016/j.jbusres.2018.12.011

Guo, D., & Jiang, K. (2022). Venture capital investment, intellectual property rights protection and firm innovation: Evidence from China. *Entrepreneurship & Regional Development*, *34*(5-6), 434-470. https://doi.org/10.1080/08985626.2022.2062618

Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of Econometrics*, *93*(2), 345-368. https://doi.org/10.1016/S0304-4076(99)00025-1

Hirukawa, M., & Ueda, M. (2011). Venture capital and innovation: Which is first? *Pacific Economic Review*, *16*(4), 421-465. https://doi.org/10.1111/j.1468-0106.2011.00557.x

Hu, J., Huang, Q., & Pan, X. (2020). Environmental regulation, government subsidies, and innovation quality: A quasi-natural experiment based on China's carbon emissions trading pilot. *Science of Science and Management of S&T*, *41*(2), 50-65.

Huang, Q., Hu, J., & Chen, X. (2018). Environmental regulation and green total factor productivity: A dilemma or a win-win? *China Population, Resources and Environment, 28*(11), 140-149.

Huo, J., Kang, W., & Bai, W. (2023). Digital economy, environmental regulation, and regional green innovation performance. *Exploration of Economic Issues*, (11), 177-190.

Karimi Takalo, S., Sayyadi Tooranloo, H., & Shahabaldini Parizi, Z. (2021). Green innovation: A systematic literature review. *Journal of Cleaner Production*, *279*, 122474. https://doi.org/10.1016/j.jclepro.2020.122474

Kortum, S., & Lerner, J. (2000). Assessing the contribution of venture capital to innovation. *The RAND Journal of Economics*, *31*(4), 674. https://doi.org/10.2307/2696354

Li, G. (2022). The impact of venture capital on green industry innovation in China (Doctoral dissertation, University of International Business and Economics).

Liu B., Sun Z., Fu K., & Liu J. (2024). Green innovation effect of green fiscal demonstration policy: From the

perspective of multiple pressure constraints. *Journal of Natural Resources*, *39*(9), 2102. https://doi.org/10.31497/zrzyxb.20240906

Liu, C., Zhang, S., & Li, X. (2023). The impact of green credit on regional green total factor productivity: An empirical test based on provincial panel data in China. *Nanjing Social Sciences*, (3), 28-39. https://doi.org/10.15937/j.cnki.issn1001-8263.2023.03.004

Lu, X., Dou, Q., Song, W., & Ge, Z. (2021). Returnee executives and corporate innovation efficiency: A boost or a hindrance? *Science and Technology Management Research*, *41*(1), 143-150.

Maiti, M. (2022). Does development in venture capital investments influence green growth? *Technological Forecasting and Social Change*, *182*, 121878. https://doi.org/10.1016/j.techfore.2022.121878

Nesta, L., Vona, F., & Nicolli, F. (2014). Environmental policies, competition and innovation in renewable energy. *Journal of Environmental Economics and Management*, *67*(3), 396-411. https://doi.org/10.1016/j.jeem.2014.01.001

Porter, M. E., & van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97-118. https://doi.org/10.1257/jep.9.4.97

Qiao, H., Zhang, S., & Xiao, Y. (2021). Modeling the impacts of venture capital investment on firm innovation. *Discrete Dynamics in Nature and Society*, 1-10. https://doi.org/10.1155/2021/8661152

Wang, X., Wang, S., Wu, K., Zhai, C., & Li, Y. (2024). Environmental protection tax and enterprises' green technology innovation: Evidence from China. *International Review of Economics & Finance*, *96*, 103617. https://doi.org/10.1016/j.iref.2024.103617

Wen, S., Liu, H., & Wang, H. (2022). Green finance, green innovation, and high-quality economic development. *Journal of Financial Research*, (8), 1-17.

Xiang, X., Liu, C., & Yang, M. (2022). Who is financing corporate green innovation? *International Review of Economics & Finance*, *78*, 321-337. https://doi.org/10.1016/j.iref.2021.12.011

Yang, S., Feng, D., Lu, J., & Wang, C. (2022). The effect of venture capital on green innovation: Is environmental regulation an institutional guarantee? *Journal of Environmental Management*, *318*, 115641. https://doi.org/10.1016/j.jenvman.2022.115641

Zhang, X., Xu, H. (2021). Venture Capital and Corporate Innovation: Role Mechanisms and Intrinsic Motivations: A Longitudinal Analysis Based on a Single Case of Shenzhen Capital Group's Investment in Jiejie Microelectronics. *Communication of Finance and Accounting*, *14*, 3-7+17. https://doi.org/10.16144/j.cnki.issn1002-8072.2021.14.001