The Impact of Green Patent Signals from Start-Up Enterprises on Venture Capital Acquisition

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Abstract. Significant information asymmetry often exists between start-ups and venture capital institutions, making it difficult for enterprises to achieve ideal valuations. To improve financing success rates, enterprises need to release signals reflecting their value to enhance competitiveness in the capital market. This study uses data on green granted patents and financing of start-ups from 2014 to 2024 to analyze the impact of green patent signals on venture capital, as well as the moderating roles of venture capital institution reputation, entrepreneurs' backgrounds, and prior financing rounds. The results show a significant positive correlation between the quantity and quality of start-ups' green granted patents and venture capital scale, with endogeneity analysis confirming the robustness of this conclusion. High reputation of venture capital institutions and more prior financing rounds weaken the financing effect of green patent quantity signals on venture capital, while their moderating effects on the relationship between green patent quality and venture capital are insignificant. Entrepreneurs with rich backgrounds strengthen the financing effect of both green patent quantity and quality signals. The nature of start-ups' equity and whether they are located in Beijing, Shanghai, Guangzhou, or Shenzhen affect the financing effect of green patent signals, but the differences are not significant. These findings enrich research on venture capital and provide insights for venture capital institutions to optimize capital allocation and for start-ups to improve financing efficiency.

Keywords: Start-up Enterprises; Green Granted Patents; Venture Capital

1 Introduction

Start-ups face financing constraints due to short operating histories, insufficient financial data, and limited performance records, failing to meet traditional financial institutions' risk control requirements and being excluded from mainstream financing channels. This severely hinders their expansion or traps them in fund shortages. As an innovative equity financing tool, venture capital plays a prominent role in driving start-up development. Venture capital institutions adopt rigorous evaluation criteria, focusing on technological innovation capabilities, market prospects, and entrepreneurial backgrounds, with patents serving as a core indicator of high growth potential.

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Among them, green patents—key carriers of technological innovation covering R&D, production, and process improvement—aim to reduce environmental damage and promote sustainable development[1]. They exhibit dual characteristics in attracting venture capital: enterprises can gain favor from socially responsible investors through environmental innovation, but green patent R&D requires substantial investment and has long payback periods, making many institutions cautious[4].

This study explores the impact of green patent signals on venture capital acquisition, innovatively introducing informal institutions (venture capital reputation, entrepreneurs' backgrounds, and prior financing rounds) as moderating variables to clarify the underlying mechanism. The findings provide scientific strategies for start-ups to improve financing efficiency and achieve sustainable development.

2 Theoretical Analysis and Research Hypotheses

2.1 The Signaling Role of Patent Quantity on Venture Capital

Signaling Theory, first proposed by Michael Spence in 1973[10], focuses on how information-advantaged parties transmit reliable signals to influence the judgments of information-disadvantaged parties in asymmetric information environments. Zhang et al. (2019)[17] point out that enterprise patents reflect not only technological innovation capabilities but also legal compliance, market competitive position, and other multi-dimensional business information, providing comprehensive decision-making basis for venture capital institutions. Sun Defeng (2020)[11] found that patent signals significantly improve enterprises' initial financing efficiency by addressing information asymmetry in the capital market. LI Jieyu (2025)[6] confirmed through empirical analysis that patent signals effectively improve venture capital institutions' judgments of target enterprises' intrinsic value and enhance financing efficiency. Thus, this study proposes the following hypothesis:

H1: The greater the number of green granted patents of a start-up enterprise, the larger the scale of venture capital it obtains.

2.2 The Signaling Role of Patent Quality on Venture Capital

With the in-depth exploration of Signaling Theory, scholars have found that not all information transmission possesses effective signal characteristics. Zhang Guoqing and Chen Qiusheng (2021)[16] found that high-quality patents not only reflect the degree of technological innovation but also significantly promote enterprises' innovation efficiency and economic benefits. Zhao Zhongtao and Li Changying (2020)[18] also confirmed that high-quality patents create more value for companies by optimizing financial performance and boosting stock prices. Wei Wenjiang and Zhong Chunping (2023)[13] argue that high-level patents effectively improve enterprises' total factor productivity, thereby enhancing profitability and market competitiveness. Thus, this study proposes the following hypothesis:

H2: The higher the quality of green granted patents of a start-up enterprise, the larger the scale of venture capital it obtains.

2.3 The Moderating Role of Venture Capital Institution Reputation

Signaling Theory suggests that the effectiveness and efficiency of signal transmission depend not only on the quality of information itself but also on the recipient's ability to decode it. Zhang Guangting et al. (2019)[15], Yang Yanping et al. (2024)[14] and Colombo et al. (2023)[3] found that venture capital institutions with high reputation, rich experience, and strong knowledge integration capabilities have stronger information absorption and screening capabilities, enabling them to better understand complex technical details and select high-quality projects. Chen Jin et al. (2016)[2] found that high-reputation venture capital institutions can more efficiently address information asymmetry and no longer rely solely on patent signals to judge investment target value, weakening the financing effect of patent signals for enterprises. Based on this, this study proposes the following hypothesis:

H3: The higher the reputation of venture capital institutions, the weaker the financing effect of green patent signals from start-up enterprises on venture capital institution.

2.4 The Moderating Role of Entrepreneurs' Backgrounds

Compared with entrepreneurs lacking practical experience, those with rich industry experience can form advantages enhancing recognition in the capital market. Kleinert (2024)[5] argues that in terms of technological innovation, the transfer of knowledge, capabilities, and experience from "parent companies" to "spin-offs" exerts a profound impact on start-up growth. Qi Su et al.,(2020)[9] put forward similar views: compared with first-time entrepreneurs or those with failure experience, individuals with IPO success experience are more likely to establish new enterprises and develop market-competitive products or business models. Van (2022)[12] found that entrepreneurs' social networks significantly affect entrepreneurial performance; experienced founders often attract high-level managers through social networks, directly influencing venture capital institutions' valuation of start-ups. Based on this theoretical foundation, this study proposes the following hypothesis:

H4: The better the background and richer the experience of start-up entrepreneurs, the weaker the financing effect of green patent signals from start-up enterprises on venture capital institutions.

2.5 The Moderating Role of Prior Financing Rounds

Patents, as core assets, play an important role in the initial stage of enterprises' external resource acquisition. However, the promotional effect of patent signals on venture capital acquisition is not constant and weakens as the risk of intellectual property leakage increases. Ma Zhongfa and Xie Diyang (2020)[7] argue that as enterprise scale expands, the risk of illegal acquisition of innovative achievements by competi-

tors—i.e., intellectual property leakage—increases significantly. Zhao Zhongtao and Li Changying (2020)[18] note that in large-scale social network environments, while "plagiarists" suffer reputational losses, which inhibits malicious competition among peers to a certain extent, it also creates the possibility of "plagiarized" enterprises losing their innovative achievements. Meng and Li (2019)[8] argue that enterprises' patents play an important role in attracting venture capital institutions, with significant financing signaling functions. However, this effectiveness is not constant but gradually weakens with increasing investment rounds. Thus, this study proposes the following hypothesis:

H5: The more prior financing rounds of a start-up enterprise, the weaker the financing effect of green patent signals on venture capital institutions.

3 Research Design

3.1 Data Sources

Data in this study are sourced from multiple authoritative platforms, including PEdata, PatSnap Global Patent Database, CVSource Database, and CSMAR Database. A dataset of 581 financing sample enterprises spanning 2000–2024 is obtained for subsequent detailed analysis.

3.2 Variable Definitions

To clarify the measurement standards of research variables, the definitions of core variables, moderating variables, and control variables are shown in Table 1.

Table 1. Variable Definitions

Variable Type	Variable Name	Variable Symbol	Variable Definition
Dependent Variable	Venture Capital Amount	VC_Scale	Investment amount in this round
Independent Variables	Quantity of Green Patents	NU_Pat	Total number of granted invention patents and utility model patents
	Quality of Green Patents	QU_Pat	Patent width = $1-\Sigma\alpha^2$, where α represents the proportion of each Main Group classification in the patent classification number
Moderating Variables	Venture Capital Reputation	Rep	Ln(1 + number of successful exits)
	Entrepreneurs' Backgrounds	Xp	1 if with experience in founding enterprises or financing; 0 otherwise
	Prior Financing Rounds	Rnd	1 if this financing round is among the first 3 rounds; 0 otherwise
Control Variables	Enterprise Age	Age	Number of years since the start-up was established

Enterprise Scale	Size	Registered capital of the enterprise
Nature of Enterprise Property Rights	PR	1 for state-owned enterprises; 0 for private enterprises
Equity Concentration	Crn	Degree of concentration or dispersion of shareholders' shareholding ratios before financing
Location in Bei-jing/Shanghai/Guangzhou/Shenzhen	Area	1 if located in the above cities; 0 otherwise
Equity Ratio of Participating Institutions	Pct	Equity ratio of venture capital institutions after financing

3.2.1 Analysis Models.

This study uses multiple regression analysis and designs models to examine the impact of green patent signals from start-ups on venture capital, as well as the moderating roles of venture capital institution reputation, entrepreneurs' backgrounds, and prior financing rounds, based on the five hypotheses above. The specific formulas are as follows:

$$VC\_Scale=a0+a1NU\_Pat+\beta k\sum Control+\varepsilon \quad (1)$$

$$VC\_Scale=a0+a1QU\_Pat+\beta k\sum Control+\varepsilon \quad (2)$$

$$VC\_Scale=a0+a1NU\_Pat+a2Rep+a3NU\_Pat*Rep+\beta k\sum Control+\varepsilon \quad (3)$$

$$VC\_Scale=a0+a1QU\_Pat+a2Rep+a3QU\_Pat*Rep+\beta k\sum Control+\varepsilon \quad (4)$$

$$VC\_Scale=a0+a1NU\_Pat+a2Xp+a3NU\_Pat*Xp+\beta k\sum Control+\varepsilon \quad (5)$$

$$VC\_Scale=a0+a1QU\_Pat+a2Xp+a3QU\_Pat*Xp+\beta k\sum Control+\varepsilon \quad (6)$$

$$VC\_Scale=a0+a1NU\_Pat+a2Rnd+a3NU\_Pat*Rnd+\beta k\sum Control+\varepsilon \quad (7)$$

$$VC\_Scale=a0+a1QU\_Pat+a2Rnd+a3QU\_Pat*Rnd+\beta k\sum Control+\varepsilon \quad (8)$$

4 Empirical Results and Analysis

4.1 Descriptive Statistical Analysis

Table 2 shows significant differences in green patent quantity/quality among samples, meeting research needs.

Table 2. Descriptive Statistical Results

Variable	Sample Size	Mean	Standard Deviation	Minimum	Maximum
VC_Scale	581	7.711	0.597	5.075	9.024
NU_Pat	581	11.148	12.321	1	58
QU_Pat	581	17.485	12.651	3.257	89
Rep	581	3.032	0.765	0.693	3.912
Xp	581	0.589	0.493	0	1
Rnd	581	0.468	0.499	0	1

Age	581	18.632	5.010	3	25
Size	581	6.526	0.813	3.912	8.036
PR	581	0.081	0.273	0	1
Crn	581	52.896	22.120	6.308	100
Area	581	0.246	0.431	0	1
Pct	581	17.567	7.294	10.370	65.560

4.2 Regression Analysis

Columns (1) and (2) in Table 3 verify H1. This indicates that more green granted patents reflect stronger innovation capabilities and market competitiveness of start-ups. Columns (3) and (4) verify H2. This shows that high-quality green patents are important carriers of technical information, playing a key role in start-ups' acquisition of financial capital.

Table 3. Regression Results of the Impact of Green Patent Signals on Venture Capital

	(1)	(2)	(3)	(4)
	VC_Scale			
NU_Pat	0.042***(0.001)	0.035***(0.001)		
QU_Pat			0.013***(0.002)	0.008***(0.001)
Age		0.006***(0.002)		0.007**(0.004)
Size		0.220***(0.015)		0.471***(0.022)
PR		-0.014(0.037)		-0.066(0.065)
Crn		0.002***(0.001)		0.001(0.001)
Area		0.004(0.023)		-0.028(0.041)
Pct		-0.002(0.001)		-0.003(0.002)
_Cons	7.239***(0.016)	5.723***(0.104)	7.484***(0.041)	4.424***(0.171)
Year	Yes	Yes	Yes	Yes
N	581	581	581	581
R2	0.764	0.838	0.760	0.798

*Note: 1)*p<0.1, **p<0.05, **p<0.01;

Table 4 further examines the moderating effects. Column (1) shows that venture capital reputation exerts a negative moderating effect on the relationship between green patent quantity signals and venture capital scale, which is significant at the 1% confidence level. Column (4) indicates that the moderating role of venture capital reputation in the relationship between green granted patent quality signals and venture capital scale is insignificant. Column (2) reveals that entrepreneurs' backgrounds have a negative moderating effect on the relationship between green patent quantity signals and venture capital scale, which is significant at the 1% confidence level. Column (5) shows that the moderating effect of entrepreneurs' backgrounds on the relationship between green patent quality signals and venture capital scale is insignificant. Columns (3) and (6) demonstrate that prior financing rounds exert a negative moderating effect on the relationships between green patent quantity signals, green patent quality

signals, and venture capital scale, which are significant at the 1% and 10% confidence levels, respectively.

Table 4. Regression Results of the Moderating Effect

Variable	(1) VC_Scale	(2) VC_Scale	(3) VC_Scale	(4) VC_Scale	(5) VC_Scale	(6) VC_Scale
NU_Pat	0.040***(0.004)	0.049***(0.003)	0.030***(0.001)			
QU_Pat				0.010*(0.006)	0.005**(0.002)	0.009***(0.002)
NU_Pat*Rep	-0.002*(0.001)					
NU_Pat*Xp		0.017***(0.003)				
NU_Pat*Rnd			-0.023***(0.003)			
QU_Pat*Rep				-0.001(0.002)		
QU_Pat*Xp					0.004(0.003)	
QU_Pat*Rnd						-0.004*(0.003)
Rep	0.020(0.018)			0.015(0.040)		
Xp		0.204***(0.029)			0.287***(0.059)	
Rnd			-0.326***(0.029)			-0.393***(0.056)
Age	0.006***(0.002)	0.006***(0.002)	0.004**(0.002)	0.007**(0.004)	0.006*(0.003)	0.004(0.003)
Size	0.220***(0.015)	0.191***(0.015)	0.162***(0.014)	0.471***(0.022)	0.384***(0.023)	0.332***(0.022)
PR	-0.017(0.037)	0.002(0.035)	0.012(0.033)	-0.067(0.065)	-0.031(0.061)	-0.019(0.057)
Crn	0.002***(0.001)	0.002***(0.001)	0.002***(0.001)	0.001(0.001)	0.001(0.001)	0.001(0.001)
Area	0.004(0.024)	0.005(0.023)	0.010(0.021)	-0.029(0.042)	-0.042(0.038)	-0.032(0.036)
Pct	-0.002(0.001)	-0.002*(0.001)	-0.002*(0.001)	-0.003(0.002)	-0.003(0.002)	-0.003(0.002)
_Cons	5.664***(0.117)	5.815***(0.101)	6.296***(0.108)	4.383***(0.206)	4.868***(0.167)	5.585***(0.178)
Year	Yes	Yes	Yes	Yes	Yes	Yes
N	581	581	581	581	581	581
R^2	0.839	0.851	0.868	0.698	0.668	0.613

5 Robustness Tests

5.1 Endogeneity Test

To address sample selection bias, this study divides the quantity and quality of green granted patents into two groups: the experimental group (above the mean) and the control group (below the mean). Univariate analysis is conducted on different groups to judge the impact of patent signal intensity on enterprise financing. Table 5 shows the results of grouped univariate tests. Significant differences exist between mean tests and median tests, confirming that green granted patent intensity has a genuine signaling effect on venture capital.

Table 5. Results of Grouped Univariate Tests

Variable	Low Group (Sample)	Low Group (Mean)	Low Group (Median)	High Group (Sample)	High Group (Mean)	High Group (Median)	Mean Test	Median Test
NU_Pat	395	4.339241	3	186	25.60753	21	-32.7699***	307.6665***
QU_Pat	417	12.05465	12.121	164	31.29124	23.6625	-22.6253***	229.6635***

Subsequently, Propensity Score Matching (PSM) is used. Based on the division of the experimental group and the control group, the nearest neighbor matching method is adopted to measure the difference in the impact of green patent signal intensity on start-up financing. The results show significant differences in venture capital performance between the experimental group and the control group, confirming that green patent granted signals have a significant promotional effect on start-up financing.

5.2 Replacement of Independent Variables

The number of patent applications reflects enterprises' innovation investment intensity and technical reserve capabilities. Here, the quantity and quality of applied green invention patents and utility model patents are used to replace the quantity and quality of granted green patents in the independent variables, and the replacement indicators are incorporated into the model for regression analysis. The conclusion remains valid.

6 Heterogeneity Analysis

6.1 Considering Differences in Equity Concentration

Samples are divided into state-owned and private enterprises based on the nature of start-ups' equity. The results show a significant positive correlation between green granted patent signals and venture capital. This may be because start-ups can avoid information asymmetry through patent signal transmission, helping venture capital institutions accurately evaluate enterprise quality and increase investment in high-quality enterprises.

6.2 Considering Differences in Enterprise Location

Samples are divided into two regional groups: Beijing/Shanghai/Guangzhou/Shenzhen and other regions based on start-ups' locations. The results indicate a significant positive correlation between green patent signals and venture capital. This means that both start-ups in regard green patent quality as a core consideration when evaluating a start-up's technological innovation capabilities, recognizing its importance.

7 Research Conclusions and Recommendations

Based on Signaling Theory, this study empirically examines the impact of green patent signals from start-ups on venture capital, with informal institutions as moderators. Key findings are summarized as follows: Green patent quantity and quality both exert a significant positive effect on venture capital scale, which is robustly validated by endogeneity tests. High venture capital institution reputation and more prior financing rounds weaken the financing effect of green patent quantity signals (insignificant for quality), while entrepreneurs with rich backgrounds strengthen the positive impact of both patent quantity and quality. Heterogeneity analysis reveals no significant differential effects of equity nature or regional location on the relationship between green patent signals and venture capital. The findings enrich the application of Signaling Theory in venture capital research, especially by clarifying the heterogeneous moderating roles of informal institutions. Practically, they provide actionable insights for start-ups to optimize financing strategies, venture capital institutions to improve capital allocation efficiency, and governments to guide sustainable investment.

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