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Research on the Impact of Patient Capital on Corporate Green Innovation

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Abstract. Driven by policies and market demands, enterprise green innovation is hindered by financing constraints. This paper conducts an empirical study using panel data of A-share listed enterprises from 2007 to 2022 based on the theoretical model of patient capital's influence on green innovation. Findings show: (1) Patient capital significantly promotes corporate green innovation; (2) It indirectly boosts green innovation by facilitating the construction of a unified national market and enterprise digital transformation; (3) Its promoting effect presents heterogeneity—more significant in the central region, large enterprises and non-state-owned enterprises. Finally, policy suggestions are put forward from optimizing patient capital investment structure, advancing the unified national market construction, and guiding the integration of digital and green technologies.

Keywords: patient capital, enterprise green innovation, national unified large market, enterprise digital transformation

1. Introduction

Against the background of global climate governance changes and China's "carbon neutrality" strategy, corporate green technological innovation is the core driving force for economic and social green transformation [1]. However, green innovation faces a severe "financing-incentive" dilemma due to long R&D cycles, huge initial investment, high uncertainty and difficulty in converting environmental benefits into short-term financial gains, which conflicts with the short-term profit orientation of traditional capital, leading to financing constraints for enterprises.

Patient capital, featuring long investment cycles, tolerance for temporary failures and focus on long-term returns, has attracted widespread attention as a solution. China's financial regulatory authorities have issued a series of policies (e.g., the 2016 Guiding Opinions on Building a Green Financial System) to guide the development of patient capital, creating institutional conditions for its role in green transformation. Theoretically, patient capital matches green innovation's demands by providing stable funding, recognizing non-financial values and participating in corporate governance to empower green innovation.

Current academic research on patient capital and green innovation is still in its infancy: research perspectives are fragmented, and there is a lack of systematic analysis on their correlation, as well as in-depth exploration of transmission paths and boundary conditions. Based on China's green transformation practice, this paper explores the impact, mechanism and heterogeneity of patient

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capital on corporate green innovation, aiming to enrich cross-disciplinary research and provide evidence-based references for green financial policy design.

2. Theoretical analysis

2.1. Patient capital directly promotes corporate green innovation

Different from traditional financial capital, patient capital is characterized by long-term value orientation, deep governance participation and multi-goal investment, which perfectly matches the characteristics of green innovation and makes up for the insufficient market investment in this field [2]. Based on multiple theories, its direct promotion mechanism is as follows:

Financing constraint theory. Green innovation's characteristics lead to a "green financing gap" and severe information asymmetry [3]. Patient capital tolerates long investment recovery cycles, aligns with green innovation's cycle, and reduces information asymmetry through professional due diligence and post-investment management, allocating capital to enterprises with genuine green potential.

Principal-agent theory. Traditional performance evaluation leads to management short-sightedness. As an active owner, patient capital reshapes corporate governance and incentive structures (e.g., appointing directors, linking executive compensation to long-term ESG performance), internalizes environmental performance into core assessment indicators, and curbs short-sighted behavior to guide resources into green innovation [4].

Resource dependence theory. Green innovation relies on a comprehensive innovation ecosystem. Patient capital investment sends "certification signals" to the market, attracting complementary resources such as green technology partners and government subsidies [5]. Its investors leverage network resources to help enterprises integrate into green innovation networks, reducing innovation risks and costs.

Hypothesis 1: Patient capital can effectively drive enterprises to engage in green innovation activities.

2.2. Patient capital indirectly promotes enterprise innovation

The enabling effect of patient capital on green innovation is constrained by external institutional environment and internal enterprise capabilities. The construction of a unified national market (external) and enterprise digital transformation (internal) are the key paths for patient capital to indirectly promote green innovation.

2.2.1. Construction of a unified national market

The unified national market eliminates regional barriers, unifies rules and expands market scale, which amplifies the role of patient capital in promoting green innovation: it increases the expected returns of green innovation investments, reduces institutional transaction costs of cross-regional innovation cooperation, and unifies environmental regulations to curb "greenwashing" and improve capital allocation accuracy [6].

Hypothesis 2: Patient capital facilitates the construction of a unified national market, thereby promoting corporate green innovation.

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2.2.2. The digital transformation of enterprises

Enterprise digital transformation restructures operational models through data-driven methods, providing technical support for green innovation [7]. Patient capital accelerates digital transformation: on the one hand, digital transformation alleviates information asymmetry in patient capital's post-investment management, improving governance and supervision efficiency; on the other hand, patient capital provides long-term funds for enterprises to invest in digital technologies, enhancing their ability to convert green innovation intentions into actual results.

Hypothesis 3: Patient capital promotes enterprise digital transformation, thereby boosting corporate green innovation.

3. Research design and variable selection

3.1. Data sources and sample selection

This paper selects A-share listed companies from 2007 to 2022 as research subjects (data from CSMAR, CNRDS, National Intellectual Property Administration). Sample processing: (1) Exclude ST, ST*, PT companies, enterprises listed for less than three years and those with severely incomplete data; (2) Winsorize continuous variables at the 1% and 99% quantiles; (3) Conduct natural logarithmic processing. Missing data are supplemented by linear interpolation, and the final sample includes 26,829 observations, covering large, medium and small enterprises.

3.2. Variable description and descriptive statistics

3.2.1. Dependent variable: green innovation efficiency (GI)

Green innovation is divided into R&D and achievement application stages. This paper identifies green patents based on WIPO's 2010 environmentally friendly international patent classification indexes, and measures energy consumption and pollution emission indices through standardization and entropy method. The DEA-SBM model is used to calculate green technological achievement application efficiency, and the logarithm of the result is the dependent variable [8].

3.2.2. Core explanatory variable: stable equity (epatient)

The ratio of the overall holding ratio of institutional investors to the standard deviation of their holding ratios in the past three years is used to measure the stability of institutional investors' holdings, representing patient capital [9].

3.2.3. Control variable

The control variables include enterprise size (Size, total assets), enterprise age (Age, years since establishment), R&D investment (R&D, total R&D expenditure), revenue growth (Growth, year-on-year growth of total revenue), property right nature (State, 1 for state-owned enterprises, 0 otherwise), and integration of the two positions (Dual, 1 for the same person as chairman and general manager, 0 otherwise).

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Table 1. Descriptive statistics of the main variables

Variable name	Sample size	Maximum value	Minimum value	Mean value	Standard deviation
GI	26829	-0.001	-2.015	-0.750	0.479
Epatient	26829	0.057	1.12×10^{-24}	2.16×10^{-6}	3.02×10^{-4}
Size	26829	0.068	2.03×10^{-5}	0.002	0.008
Age	26829	35	7	18.952	5.950
R&D	26829	3.853	4.57×10^{-4}	0.209	0.514
Growth	26829	4.091	-0.704	0.183	0.576
State	26829	1	0	—	—
Dual	26829	1	0	—	—

3.3. Model construction

To test Hypothesis 1, the benchmark regression model is constructed:

$$GI_{it} = \beta_0 + \beta_1 Epatient_{it} + \beta_2 Controls + \varphi_i + \lambda_i + \varepsilon_{it} \quad (1)$$

Among them, φ_i represents the individual fixed effect, λ_t represents the time fixed effect, and ε_{it} is the random disturbance term. Furthermore, ' i ' and ' t ' respectively represent individual enterprises and the years.

To test Hypothesis 2 and 3, the mechanism test models are constructed:

$$UniMarket_{it} = \beta_0 + \beta_1 Epatient_{it} + \beta_2 Controls + \varphi_i + \lambda_i + \varepsilon_{it} \quad (2)$$

$$\text{Digital}_{it} = \beta_0 + \beta_1 Epaint_{it} + \beta_2 Controls + \varphi_i + \lambda_i + \varepsilon_{it} \quad (3)$$

Among them, $UniMarket_{it}$ and $Digital_{it}$ are explanatory variables, representing the construction of a unified national market and the digital transformation of enterprises respectively. $UniMarket_{it}$ measures it based on the degree of reliance on corporate income tax. $Digital_{it}$ measures the utilization level of enterprise data elements.

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4. Empirical testing and analysis

4.1. Baseline regression analysis

Benchmark regression results (Table 2) show that the regression coefficient of Epatient is significantly positive at the 1% level, verifying Hypothesis 1: patient capital significantly promotes corporate green innovation. Economically, a one standard deviation increase in equity stability raises green innovation level by 0.12%.For control variables: Size, Age, Growth, State and Dual coefficients are positive (State significant at 5% level), indicating larger scale, longer establishment time, good operation, state-owned nature and dual positions are conducive to green innovation; R&D coefficient is significantly negative at the 10% level, possibly because enterprises with poor green innovation outcomes increase R&D input. The results are generally in line with expectations.

Table 2. Baseline regression results

Variable	*GI*	*GI*
	(1)	(2)
Epatient	4.127*** (0.687)	3.815*** (0.672)
Size		0.017 (0.982)
Age		0.007 (0.005)
R&D		-0.014* (0.007)
Growth		0.0005 (0.003)
State		0.023** (0.012)
Dual		0.006 (0.006)
Constant	-1.485*** (0.007)	-1.526*** (0.050)
Year fixed effect	Yes	Yes
Individual fixed effect	Yes	Yes
Sample size	37310	26829
R^2	0.682	0.573

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Note: The numbers in parentheses represent the robust standard errors. *, **, *** respectively indicate that the regression results have passed the significance tests at the 10%, 5%, and 1% levels (the same below). For the fixed effect model, the reported value is the within-group R-squared (Within R-squared). The values are rounded to the thousandth place.

4.2. Robustness test

Three methods are used for robustness test: variable substitution, sub-sample regression and elimination of special years, with results shown in Table 3.

Variable substitution: Replace Epatient with the natural logarithm of the ratio of long-term liabilities to total liabilities (Epatient'). The coefficient is significantly positive at the 5% level, consistent with baseline regression.

Subsample regression (panel quantile regression): Epatient coefficient is significantly positive at 0.3 and 0.5 quantiles (at least 5% level), but insignificant at 0.7 quantile, and the coefficient shows a monotonically decreasing trend. This means patient capital's promoting effect is concentrated in enterprises with low green innovation efficiency.

Elimination of special years: Excluding 2020 (COVID-19 pandemic) data, Epatient coefficient is significantly positive at 1% level, indicating the effect is not driven by pandemic shocks. Staged regression shows: 2007-2016 (immature green finance system), Epatient coefficient is significantly negative at 1% level; 2017-2022 (mature green finance system), the coefficient is significantly positive at 1% level, proving the institutional environment is a key regulatory factor.To measure the robustness level of the above model, three methods were employed for robustness assessment: variable substitution, sub-sample regression, and elimination of special years.

Table 3. Robustness test

Variable	Baseline regression	Replace the explanatory variable	τ=0.3	τ=0.5	τ=0.7	Excluding 2020	2007-2016	2017-2022
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Epatient	3.815*** (0.672)		5.380*** (1.867)	3.557** (1.383)	2.026(1.687)	3.126*** (0.389)	-28.260*** (2.277)	4.864** (0.861)
Epatient’		0.004** (0.002)						
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	26829	23076	26829	26829	26829	23884	10752	16077
Within R^2	0.573	0.573				0.584	0.537	0.254

4.3. Mechanism analysis

This paper verifies the two indirect transmission paths of patient capital on green innovation from the perspective of unified national market construction and enterprise digital transformation (Table

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4).

4.3.1. Construction of a unified national market

The coefficient of Epatient on UniMarket is significantly negative at the 1% level (inverse measurement). This shows patient capital alleviates local governments' short-term tax dependence, weakens local protectionism, promotes market unification, and indirectly drives green innovation by providing a fair competitive environment and rich knowledge spillovers.

4.3.2. Digital transformation of enterprises

The coefficient of Epatient on Digital is significantly positive at the 10% level. Patient capital supports enterprises' forward-looking digital investment, and digital transformation enhances enterprises' green R&D and low-carbon management capabilities, becoming an internal bridge for patient capital to boost green innovation.

Table 4. Mechanism effect test

Variable	UniMarket	Digital
	(1)	(2)
Epatient	-0.315*** (0.071)	376.369* (218.666)
Control variables	Yes	Yes
Year fixed effect	Yes	Yes
Individual fixed effect	Yes	Yes
Sample size	26610	26812
Within R^2	0.629	0.091

4.4. Heterogeneity analysis

4.4.1. Regional heterogeneity

This paper conducts group regression from three dimensions: region, enterprise scale and enterprise nature, with results shown in Table 5.

Regional heterogeneity. Epatient coefficient is negative but insignificant in the eastern region (mature financial market, diverse financing channels); significantly positive at 1% level in the central region (tight financing constraints, scarce long-term capital); no reliable coefficient estimated in the western and northeastern regions due to sample and technical limitations.

Enterprise size heterogeneity. For large enterprises (annual revenue ≥ 4 million yuan or employees ≥ 1,000), Epatient coefficient is significantly positive at 1% level, as large enterprises have complete R&D systems and strong resource integration capabilities; for small and medium-sized enterprises, the coefficient is high but insignificant, due to their survival pressure and multiple innovation barriers.

Enterprise nature heterogeneity. For non-state-owned enterprises, Epatient coefficient is significantly positive at 5% level, as patient capital alleviates their financing constraints and

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motivates high-risk green innovation; for state-owned enterprises, the variable is automatically excluded due to complete collinearity, as their institutional advantages absorb the independent effect of patient capital.

Table 5. Heterogeneity analysis

Explanatory variable	Eastern region	Central Region	Western region	Northeast Region	Large enterprises	Small and medium-sized enterprises	State-owned enterprises	Non-state-owned enterprises
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Epatient	-13.994 (46.070)	4.110*** (1.312)	0 (omitted)	0 (omitted)	3.234*** (1.042)	47.778 (38.029)	0 (omitted)	4.197** (1.752)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	17735	3953	3628	1240	24774	1542	10071	16397
Adj. R^2	0.597	0.627	0.642	0.619	0.609	0.619	0.672	0.549

5. Conclusion and recommendations

5.1. Research conclusion

Based on the theoretical model and empirical test of A-share listed enterprises from 2007 to 2022, this paper draws the following conclusions:

Firstly, patient capital, as a stabilizing factor of equity structure, effectively drives corporate green innovation by providing long-term stable financial support and helping enterprises overcome green R&D bottlenecks. Secondly, patient capital indirectly promotes green innovation through two paths: promoting the construction of a unified national market (optimizing external market environment) and accelerating enterprise digital transformation (enhancing internal innovation capabilities), realizing the leap from "funding infusion" to "capacity generation". Thirdly, the promoting effect of patient capital presents obvious heterogeneity: significant in the central region, large enterprises and non-state-owned enterprises; insignificant in the eastern region, small and medium-sized enterprises, and unidentifiable in state-owned enterprises due to institutional advantages.

5.2. Policy recommendations

Firstly, Optimize Patient Capital Supply Structure and Cultivate Market-Oriented Long-Term Capital.Expand long-term capital sources: relax investment proportion restrictions of insurance and pension funds in equity funds, establish green innovation investment assessment coefficients, and encourage commercial banks to participate in green development funds and issue special financial bonds. Innovate investment and exit models: design financial products such as "loan + equity

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option", and build regional green technology property trading platforms in pilot zones to reduce liquidity risks.

Secondly, Stimulate Endogenous Demand for Green Innovation and Enhance Enterprise Capabilities.Improve incentive mechanisms: implement higher proportion of R&D expense additional deductions for green core technologies and link green innovation performance with credit limits and bond interest rates. Adopt differentiated empowerment strategies: encourage large enterprises to form green innovation consortia; build a support system for small and medium-sized enterprises (public R&D services, management training). Improve the assessment system of state-owned enterprises and include green technology reserves in performance assessment.

Thirdly, Deepen Factor Market-Oriented Reform and Accelerate the Construction of a Unified National Market.Promote the reform of resource and environmental factor trading systems (electricity, carbon emissions rights) and build a unified national trading market. Eliminate local protectionism and market segmentation, implement a national unified negative list system, and strengthen anti-monopoly law enforcement. Enhance cross-regional regulatory coordination and intellectual property protection, increase infringement costs, and stabilize patient capital investment confidence.

Forthly, Promote the Integration of Digital and Green Technologies and Lay a Solid Innovation Foundation.Increase public investment in digital infrastructure: set up special funds to subsidize enterprises for deploying industrial internet and carbon footprint monitoring systems, especially for small and medium-sized enterprises. Improve technical integration standards: formulate digital-green technology guidelines and build demonstration projects through industry-university-research collaboration. Cultivate interdisciplinary talents: encourage universities to set up "digital green technology" majors and build joint training bases with enterprises.

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