

Research on the Impact of Government Subsidies on Firms' Green Innovation Performance

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Abstract: Against the backdrop of the “Dual Carbon” goals, corporate green innovation serves as the core driver for optimizing energy mix and advancing low-carbon transition. To explore the impact of government subsidies on firms' green innovation performance and its boundary conditions, this paper takes A-share listed companies from 2007 to 2024 as research samples and adopts a two-way fixed-effects regression model. Digital transformation and environmental regulation are introduced as moderating variables to analyze how government subsidies affect corporate green innovation performance, followed by heterogeneous analyses from industrial characteristics and corporate ownership perspectives. The empirical results show that government subsidies exert a significantly positive promoting effect on firms' green innovation performance. Firms with dual positions exhibit a higher coefficient of government subsidies. Based on the research conclusions, this paper puts forward targeted suggestions from the perspectives of governments formulating differentiated subsidy and regulatory policies. It provides references for improving corporate green innovation performance and facilitating the realization of the “Dual Carbon” goals.

Keywords: Government subsidies, Corporate green innovation performance, Environmental regulation

1. Introduction

With the “Dual Carbon” goals established as the core strategy for sustainable development in China, green technological innovation has emerged as a critical pathway to mitigate resource constraints and improve environmental quality. Whether it involves clean production upgrades in traditional manufacturing or breakthrough green technologies in high-tech industries, innovation is essential to cut carbon emission intensity and boost resource utilization efficiency. As micro-level agents of energy conservation and emission reduction, enterprises are the direct implementers of green technological innovation. Nevertheless, green innovation is characterized by high capital input, high risks, long investment cycles and strong positive externalities, resulting in insufficient innovation incentives under market mechanisms. On one hand, the public attributes of green innovation outputs prevent enterprises from fully internalizing social benefits. On the other hand, technological uncertainty discourages financing from financial institutions, leaving enterprises trapped in severe financing constraints. Against this backdrop, government subsidies function as a vital policy instrument to correct market failures and stimulate green innovation, directly alleviating capital pressure and unlocking corporate innovation vitality.

Meanwhile, corporate responses to green innovation are shaped not only by subsidies but also by internal capabilities and external institutional environments. Amid the rapid development of the digital economy, digital transformation has become a decisive factor governing firms' efficiency in allocating innovation resources and absorbing technologies, which can amplify the incentive effects of subsidies. As an external policy tool, environmental regulation raises firms' sense of urgency for low-carbon transition through emission limits and environmental penalties, forming a synergistic relationship with subsidies. However, current subsidy policies face drawbacks including excessive corporate reliance, imperfect institutional mechanisms, rent-seeking behaviors and disruptive impacts of subsidy phase-outs. Academic debates persist regarding how subsidies influence green innovation performance. Therefore, systematically investigating the impact mechanism of government subsidies on corporate green innovation performance and identifying moderating and mediating factors carries profound theoretical and practical significance.

Against the global low-carbon transition backdrop, government subsidies, as a core policy lever to

stimulate corporate green innovation, have become a central research focus regarding their mechanisms and boundary conditions. Existing studies systematically analyze the nexus between government subsidies and green innovation performance by examining effect magnitudes, transmission channels and moderating factors. They validate the positive incentive value of subsidies while revealing their non-linear characteristics and diverse constraints, providing multi-dimensional perspectives for policy optimization and corporate practice.

In terms of core subsidy effects, research reaches a consensus of “predominantly positive effects alongside non-linear relationships”. Most studies confirm that government subsidies significantly promote green innovation performance. Ma et al. (2023) used panel data from new energy vehicle firms and found that the positive innovation effect of subsidies is stronger in non-SOEs and large enterprises^[1]. Bai et al. (2019) focused on high-energy-consuming enterprises and concluded that R&D subsidies raise both green innovation propensity and performance. Meanwhile, abundant evidence supports non-linear effects^[2]. Sun et al. (2022) sampled manufacturing firms and verified the promotional impact of subsidies on green innovation, with private enterprises demonstrating higher sensitivity^[3]. Lin et al. (2023) discovered an inverted U-shaped relationship between R&D subsidies and green technological innovation in the renewable energy industry, implying an optimal subsidy threshold^[4]. In addition, Hu et al. (2019) uncovered negative coupling effects of policies: the combined impact of environmental supervision and R&D subsidies on green innovation efficiency stands at -0.01, indicating single policy instruments fail to fully unlock green innovation potential^[5].

As for transmission mechanisms, R&D investment acts as the core mediating channel. Ma et al. (2023) and Sun et al. (2022) both confirmed that R&D intensity and investment mediate the relationship between subsidies and innovation performance. Shao et al. (2022) further categorized subsidy types, proving that environmental, R&D and talent subsidies all elevate the conversion efficiency of green technologies by stimulating R&D spending^[6]. Duan et al. (2024) supplemented new transmission channels, demonstrating that government subsidies improve corporate green innovation performance by strengthening technological integration capacity, easing financing constraints and boosting R&D input capacity^[7]. Research on policy portfolios yields additional insights: From a game theory perspective, Ma et al. (2019) proposed that subsidies must be paired with revenue-sharing contracts to maximize green innovation incentives, offering micro-level references for subsidy implementation^[8].

Studies on moderating factors further clarify the boundary conditions of subsidy effects. In terms of ownership structure, Wu et al. (2020) discovered ownership concentration imposes an inverted U-shaped moderating effect on the subsidy-green innovation nexus, and this effect only applies to state-owned enterprises^[9]. For market environment, Jiang et al. (2022) found market competition strengthens the correlation between environmental subsidies, environmental taxes and green innovation^[10]. Duan et al. (2024) added digital transformation as a critical moderating variable, demonstrating both corporate digital transformation and environmental supervision amplify the positive influence of government subsidies on green innovation performance^[7].

2. Data and Variable Definition

2.1 Data Sources

This paper selects A-share listed firms in China from 2007 to 2024 to examine the impact of government subsidies on corporate green innovation performance. After data collection and sorting, the sample undergoes the following screening procedures:

- (1) Exclude firm-year observations with missing values for core variables (government subsidies, green innovation performance) and financial indicators;
- (2) Eliminate firms labeled ST and *ST during the sample period;
- (3) Apply 1% and 99% winsorization to all continuous variables to mitigate the interference of outliers.

2.2 Variable Definitions

(1) Dependent Variable: Green Innovation Performance (Dfpatent): Following Fleming (2004), this study measures green innovation performance using the number of independently filed green invention patents per firm-year. Green invention patents better reflect high-level corporate innovation capacity than

utility model patents, as green invention patent filings directly represent output in green innovation. Patent application data possesses higher timeliness than granted patent data, enabling real-time reflection of corporate innovation capacity. Green invention patent data are sourced from the China Research Data Service Platform (CNRDS).

(2) Independent Variable: Government Subsidies (Subsidy): Consistent with Guellec (2003), the natural logarithm of annual government subsidies received by each firm is adopted to measure Subsidy. Government subsidy data are extracted from non-operating income items in corporate financial statements within the CSMAR database.

(3) Moderating Variables

Digital Transformation (Dig): Drawing on established research paradigms and Akter & Michael (2022), this study identifies artificial intelligence, big data, cloud computing and blockchain as foundational digital transformation technologies. Textual analysis is applied to extract keywords related to artificial intelligence, big data, third-party payment, cloud computing and digital technology applications from annual reports. The total frequency of these keywords is aggregated as the proxy for digital transformation. Given the right-skewed distribution of keyword counts, we add 1 to the total frequency before taking the natural logarithm. A higher Dig value indicates a deeper level of corporate digital transformation.

Environmental Regulation (ER): Following Levinson (1996), environmental regulation intensity is measured as the ratio of industrial pollution control investment to secondary industry value-added at the provincial level where each firm is registered. This method eliminates firm-specific confounding factors and delivers objective results. Data for environmental regulation are collected from the China Environmental Statistics Yearbook and China Industrial Economy Statistics Yearbook.

Control Variables: Referring to Tan (2015), firm-level financial performance and governance structure variables are incorporated as controls, detailed as follows:

Financial Leverage (LEV): Total liabilities divided by total assets at year-end;

Return on Assets (ROA): Net profit divided by average total assets in the current year;

State Ownership (SOE): Dummy variable equal to 1 for state-owned enterprises, 0 otherwise;

Firm Age (Age): Natural logarithm of (listing years + 1).

All control variable data are obtained from the CSMAR database.

2.3 Descriptive Statistics

Descriptive statistics for all variables are presented in Table 1.

The logarithmic value of green invention patent applications (Dfpatent) averages 0.219, ranging from 0 to 3.526 with a standard deviation of 0.571, implying substantial disparities in green innovation capacity across sampled firms. The average government subsidy stands at 0.22805 billion yuan, with a maximum of 4.48 billion yuan and standard deviation of 0.61198, showing notable gaps in subsidy acquisition among enterprises. The mean digital transformation index (Dig) reaches 1.284, indicating generally low digital transformation levels across the sample. The average environmental regulation intensity (ER) is 0.00185, with a wide range between minimum and maximum values, reflecting uneven stringency of environmental regulation across provinces.

Table 1. Descriptive statistics

variable	N	mean	sd	min	max
dfpatent	29087	0.219	0.571	0	3.526
subsidy	29087	0.22805	0.61198	0	4.48001
dig	29087	1.284	1.387	0	5.050
er	29087	0.00185	0.00166	1.32e-06	0.0245
lev	29087	0.420	0.209	0.0496	0.894
roa	29087	0.0448	0.0588	-0.176	0.215
soe	29087	0.377	0.485	0	1
age	29087	2.864	0.366	0	4.205

3. Empirical Analysis of the Impact of Technological Progress on Carbon Emissions

3.1. Regression Model Specification

Two-way fixed-effects models incorporate firm and year dummy variables to control for individual and time fixed effects, mitigating omitted variable bias in panel data, improving estimation consistency and reliability. Accordingly, this study adopts a two-way fixed-effects regression model for empirical analysis, with baseline results reported in Table 2.

Table 2. Two-way Fixed-effects Baseline Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
	dfpatent1	dfpatent1	dfpatent1	dfpatent1	dfpatent1	dfpatent1
subsidy	0.157*** (0.00898)	0.132*** (0.00906)	0.126*** (0.00897)	0.0878*** (0.0106)	0.131*** (0.00905)	0.151*** (0.0131)
dig			0.0542*** (0.00349)	0.0464*** (0.00363)		
sub*dig				0.0355*** (0.00779)		
er					-6.092** (1.876)	-2.929* (1.981)
sub*er						-9.107** (3.846)
lev		0.258*** (0.0191)	0.243*** (0.0190)	0.243*** (0.0190)	0.260*** (0.0191)	0.260*** (0.0191)
roa		0.686*** (0.0604)	0.666*** (0.0599)	0.643*** (0.0600)	0.681*** (0.0605)	0.683*** (0.0605)
soe		0.0785*** (0.00806)	0.0846*** (0.00805)	0.0842*** (0.00803)	0.0796*** (0.00806)	0.0788*** (0.00805)
age		-0.0482*** (0.0105)	-0.0482*** (0.0104)	-0.0504*** (0.0104)	-0.0486*** (0.0105)	-0.0478*** (0.0105)
_cons	0.183*** (0.00328)	0.158*** (0.0312)	0.0953** (0.0316)	0.112*** (0.0314)	0.170*** (0.0315)	0.162*** (0.0316)
N	29085	29085	29085	29085	29085	29085
R ²	0.135	0.146	0.155	0.157	0.146	0.146

Standard errors in parentheses

* $p < 0.2$, ** $p < 0.02$, *** $p < 0.001$

Column (1) presents univariate regression results of government subsidies on green innovation performance, where the coefficient of subsidy equals 0.157 and is statistically significant at the 1% level, demonstrating that government subsidies significantly promote corporate green innovation performance. Column (2) adds all control variables, and the subsidy coefficient remains significantly positive at the 1% level, further validating the positive promotional relationship.

The underlying mechanism lies in that government subsidies reduce upfront investment costs for green innovation, raising firms' willingness and capacity to invest in green technologies, thereby lifting green innovation output. Regarding the moderating effect of digital transformation, Column (3) reports a subsidy coefficient of 0.126 and a digital transformation coefficient of 0.0542; Column (4) shows the interaction term sub*dig equals 0.0355, both significant at the 1% level. This confirms that digital transformation positively moderates the subsidy-green innovation relationship, amplifying the incentive effect of subsidies.

For the moderating role of environmental regulation, Column (5) yields an environmental regulation coefficient of -6.092, significant at the 2% level. Column (6) presents the interaction term sub*er of -9.107, also significant at the 2% level, indicating environmental regulation weakens the promotional effect of government subsidies on green innovation performance through negative moderation.

3.2. Robustness Tests

To ensure the reliability of empirical findings, this study adopts an alternative measurement for the dependent variable as the robustness test. The new proxy for green innovation performance (Dfpate2) is defined as the sum of green invention patents and green utility model patents independently filed by each firm annually. Regression results using this alternative indicator are displayed in Table 3.

Table 3. Robustness Test: Alternative Measure of Green Innovation Performance

	(1)	(2)	(3)	(4)	(5)	(6)
	dfpatent2	dfpatent2	dfpatent2	dfpatent2	dfpatent2	dfpatent2
subsidy	0.207*** (0.0126)	0.175*** (0.0128)	0.168*** (0.0127)	0.124*** (0.0149)	0.174*** (0.0127)	0.210*** (0.0191)
dig			0.0606*** (0.00441)	0.0517*** (0.00460)		
sub*dig				0.0409*** (0.0107)		
er					-9.210*** (2.454)	-3.467* (2.608)
sub*er						-16.53** (5.290)
lev		0.379*** (0.0250)	0.361*** (0.0249)	0.362*** (0.0249)	0.381*** (0.0250)	0.382*** (0.0250)
roa		0.903*** (0.0790)	0.881*** (0.0785)	0.855*** (0.0785)	0.896*** (0.0791)	0.900*** (0.0791)
soe		0.0811*** (0.0103)	0.0879*** (0.0103)	0.0874*** (0.0103)	0.0827*** (0.0103)	0.0812*** (0.0103)
age		-0.100*** (0.0141)	-0.100*** (0.0140)	-0.103*** (0.0139)	-0.101*** (0.0141)	-0.0995*** (0.0141)
_cons	0.281*** (0.00436)	0.347*** (0.0419)	0.276*** (0.0424)	0.295*** (0.0420)	0.364*** (0.0423)	0.350*** (0.0426)
N	29085	29085	29085	29085	29085	29085
R ²	0.156	0.168	0.174	0.176	0.168	0.169

Standard errors in parentheses

* $p < 0.2$, ** $p < 0.01$, *** $p < 0.001$

Columns (1) and (2) show subsidy coefficients of 0.207 and 0.175, significantly positive at the 0.1% level, consistent with baseline regression outcomes and verifying the promotional effect of government subsidies on green innovation performance. Column (3) reports a subsidy coefficient of 0.168 and digital transformation coefficient of 0.0606; the interaction term sub*dig in Column (4) equals 0.0409, all significant at the 1% level, reaffirming the positive moderating role of digital transformation. Column (5) yields an environmental regulation coefficient of -9.21, significant at the 1% level, while Column (6) shows the interaction term er of -3.467, significant at the 0.2 level, confirming environmental regulation negatively moderates the subsidy-innovation nexus. All core conclusions remain unchanged after replacing the dependent variable, proving the robustness of the empirical results.

4. Conclusions and Policy Implications

This study takes A-share listed companies from 2007 to 2024 as the research sample and employs a two-way fixed-effects regression model to investigate the impact of government subsidies on firms' green innovation performance. Digital transformation and environmental regulation are introduced as moderating variables, and heterogeneity analysis is conducted from the perspectives of industry, governance structure and ownership nature. The research conclusions are as follows. First, government subsidies exert a significantly positive promoting effect on firms' green innovation performance. They can effectively ease capital constraints for green innovation, reduce initial R&D costs, and stimulate firms' innovation willingness. Second, both digital transformation and environmental regulation produce moderating effects on corporate green innovation performance. Digital transformation positively moderates the innovation incentive effect of subsidies, while environmental regulation weakens the effect of subsidies by raising compliance costs and thus plays a negative moderating role.

The governments should adhere to the incentive-oriented positioning of subsidies, centering funding support on green invention R&D and core technological breakthroughs to avoid resource waste. Subsidies should be prioritized for high-value green innovation projects. A full-process tracking and supervision mechanism must be established covering application, disbursement and post-project evaluation to curb rent-seeking and idle funds, improving overall capital utilization efficiency. Second, coordinate subsidy policies with digital upgrading initiatives: launch special programs to reduce corporate digital transformation costs and build industry-wide digital resource sharing platforms to optimize the allocation of subsidized funds. Third, design gradient environmental regulatory standards

and differentiated subsidy packages tailored to firm characteristics, ensuring precise resource allocation for green low-carbon transition.

Enterprises receiving government subsidies must align fund deployment with core green innovation priorities rather than allocating capital blindly. Subsidy funds should be concentrated on key green R&D links, with customized research plans formulated in accordance with corporate development strategies to match funding with innovation demands. Firms should leverage subsidies as leverage to boost independent R&D investment and build sustainable innovation systems. Additionally, enterprises need to accelerate digital transformation, introducing digital technologies into green R&D and production processes to optimize resource allocation and raise innovation efficiency. Particularly for SOEs, integrated digital-green innovation systems should be constructed to enable mutual empowerment between digitalization and green technologies, amplifying the incentive value of government subsidies.

For Enterprises, Firms with combined chairman-CEO roles should establish internal supervision and balance mechanisms to standardize decision-making procedures and mitigate short-sighted operational risks. Enterprises with separate leadership structures may streamline innovation approval workflows to raise operational efficiency while maintaining standardized fund management. All firms should abandon passive compliance mindsets and proactively translate environmental regulatory pressure into innovation drivers. Non-SOEs should develop clean production technologies to reduce expenditure on terminal pollution governance, freeing resources for green R&D. Firms should combine subsidy support to develop compliance-oriented green technologies, realizing long-term sustainable development.

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