Does Carbon Neutrality Performance Affect Enterprises' Green Dual Innovation?

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Abstract. Under new development concept of low-carbon and green, the carbon neutrality performance of enterprises has become an important issue that attracts widespread attention from both the academic community and the practical sector. How does the performance of carbon neutrality affect enterprises' green dual innovation? Is there a difference between exploratory and exploitative green innovation? Using the sample of A-share listed companies in Shanghai and Shenzhen from 2018 to 2024, the effect of carbon neutrality performance on enterprises' green dual innovation was empirically examined. The results show that good carbon neutrality performance can significantly promote green dual innovation, and has a stronger effect on exploratory green innovation. Financing constraints and institutional shareholding act as mediators in this process. The impact of carbon neutrality performance on enterprises' green dual innovation is more pronounced in central and western regions and manufacturing enterprises.

Keywords: carbon neutrality performance, green dual innovation, financing constraints, institutional shareholding.

1 Introduction

In August 2024, General Office of the State Council released the "Work Plan for Accelerating the Establishment of a Dual-Control System for Carbon Emissions", requiring the establishment of a comprehensive assessment and evaluation system for carbon peak and carbon neutrality. This assessment system can systematically and objectively evaluate the implementation progress and effectiveness of each region, industry, and enterprise in the process of carbon peak and carbon neutrality, and use incentive and restraint mechanisms to guide market entities to actively practice low-carbon behaviors. As the primary entities for achieving emission reduction and carbon reduction, enterprises urgently need to systematically enhance green innovation capabilities to promote green innovation development. However, enterprises currently face many challenges in implementing green innovation, including limited financing channels and insufficient technical capabilities, which hinder the sustainable transformation. Carbon neutrality performance is a standard for evaluating the effectiveness of enterprises' green development, reflecting actual progress in areas such as emission reduction actions, carbon management disclosure, and low-carbon transformation, and has become an important

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reference for investors and partners to identify enterprises' environmental responsibilities and long-term potential. Carbon neutrality performance information can link enterprises with the market, improve the transparency of enterprises, reduce enterprise risks and agency costs, and leverage market incentives and external supervision mechanisms, thereby gathering more innovation resources and facilitating the provision of internal impetus for green innovation. Thus, it's essential to research how carbon neutrality performance affects businesses' green innovation.

Current literature on carbon neutrality primarily focuses on theoretical aspects such as implementation pathways[1] and macroeconomic impacts[2], with limited empirical research directly addressing corporate carbon neutrality performance. Studies examining the drivers of corporate green innovation falls into two levels. Internal factors include managerial characteristics[3] and corporate governance quality[4], while external factors include carbon emission trading policy[5] and media attention[6], etc. In terms of the relationship between the two, there are relatively few existing literatures. The prior study discovered carbon neutrality management can enhance corporate green innovation[7], but there is no research that clearly distinguishes green innovation into exploratory and exploitative and separately examines the differentiated impacts of carbon neutrality performance on each sort of innovation activity. This theoretical gap limits in-depth understanding of how carbon neutrality strategy of enterprises affects heterogeneous green innovation.

In this context, this research seeks to explore the following questions: How does carbon neutrality performance affect enterprises' green dual innovation? Are there significant differences in the impact between exploratory and exploitative? What particular mechanism is it? Clarifying these questions not only helps deepen the theoretical research on carbon neutrality performance and green innovation, but also is of great significance for scientifically guiding industrial green transformation practice.

2 Theoretical Analysis and Research Hypothesis

Good carbon neutrality performance can stimulate green innovation momentum. On the one hand, good carbon neutrality performance means that enterprises have resource advantages in the implementation of carbon neutrality policies. According to the signaling theory, enterprises with better performance can release positive signals, build a positive social image, and enhance the reputation effect in the capital market, so as to obtain more abundant credit resources and the favor of the capital market. This provides more financial support for enterprises' green innovation activities[8] and effectively alleviates the financial tension faced by enterprises. Secondly, stakeholder theory posits that corporate survival and development depend on multi-party support and collaboration. Positive carbon neutrality performance can signal firm's low-carbon attributes, thereby attracting attention and participation of institutional investors. As external supervisors, institutional investors are closely related to company's long-term worth. When shareholding ratio is high, it is more motivated and able to supervise the business behavior of enterprises and intervene in the green business decision-making, so as to actively communicate and force green dual innovation.

The dual innovation theory divides green innovation into exploratory and exploitative. Specifically, exploratory green innovation emphasizes originality and pioneering spirit, mainly utilizing newly acquired knowledge and skills to continuously develop new green products and services, explore new markets, and innovate marketing approaches. It is characterized by fundamental and radical large-scale green innovation activities, aiming for technological breakthroughs and transformative changes. In contrast, exploitative green innovation usually utilizes existing knowledge and skills to improve and refine the original green products and production processes, with relatively low technical content and marginal contribution, and having little significance for future growth. Thus, businesses are more likely to participate in exploratory green innovation to strengthen competitive advantage and ultimately achieve transformational upgrading. Based on this, hypotheses are proposed:

H1: Enterprises with good carbon neutrality performance can promote green dual innovation, and has a greater impact on exploratory green innovation.

H2: Carbon neutrality performance promotes enterprise green dual innovation by alleviating financing constraints.

H3: Carbon neutrality performance promotes green dual innovation in enterprises by attracting institutional shareholding.

3 Research Design

3.1 Sample Selection and Data Sources

This paper takes A-share listed companies in Shanghai and Shenzhen from 2018 to 2024 as the sample. Considering that patent research and development takes time, the sample interval of explained variable is from 2019 to 2024, and other variables are from 2018 to 2023. Carbon neutrality performance data come from Huazheng Carbon Neutrality Rating Database, green dual innovation and media attention data come from CNRDS, and other data are from CSMAR. The data are processed by: (1) excluding ST, *ST and financial companies; (2) excluding missing data; (3) winsorizing continuous variables at the 1% and 99% levels. Finally, 23,439 valid observation samples were obtained.

3.2 Models and Variables

To test hypothesis H1, H2 and H3, the following model is constructed in this paper.

$$GI1/GI2_{i,t+1} = \alpha_0 + \alpha_1 CNP_{i,t} + \alpha_2 Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (1)$$

$$Channel_{i,t} = \alpha_0 + \alpha_1 CNP_{i,t} + \alpha_2 Controls_{i,t} + Year + Industry + \varepsilon_{i,t} \quad (2)$$

Where GI1 and GI2 are exploratory and exploitative green innovation, which are measured by the number of corporate green invention patent applications and green utility model patent applications[5]. CNP refers to carbon neutrality performance of enterprises. It is measured by the HuaZheng Carbon Neutrality Rating[9]. Channel

represents the mechanism variables, namely financing constraints and institutional shareholding. The specific variable definitions are shown in Table 1.

Table 1. Variable definitions.

Variable	Variable measurement
GI1	Ln(the number of green invention patent applications of enterprises+1)
GI2	Ln(the number of green utility model patent applications of enterprises+1)
CNP	Carbon neutrality rating of Huazheng is assigned 1-9 from low to high, and calculate the average of the two carbon neutrality ratings each year
KZ	KZ index
INST	Shareholding ratio of institutional investors
Size	Ln(year-end total assets+1)
Lev	Asset-liability ratio
Growth	Operating income growth rate
Sc	Shareholding ratio of the largest shareholder
Boa	Ln(the number of board members+1)
Indep	Proportion of independent directors
Cp	If the chairman and the general manager are the same person, the value is 1; otherwise, it's 0
Age	Ln(the years of establishment+1)
Soe	1 for state-owned enterprises, 0 for non-state-owned

4 Empirical Analysis

4.1 Regression Results

Benchmark regression. The benchmark regression results are presented in columns (1) and (2) of Table 2. The coefficients for CNP are 0.087 and 0.03, both statistically significant at the 1% level.This indicate carbon neutrality performance advantage can positively promote green dual innovation, and has a greater impact on exploratory. Hypothesis H1 is verified.

Mechanism test. Columns (3) and (4) of Table 2 display the mechanism test results. The previous theoretical analysis shows good carbon neutral performance helps alleviate corporate financing constraints and attract institutional shareholding, thus promoting green innovation. Former studies have verified the impact of financial constraints[10] and institutional shareholding[11] on green innovation, so this analysis reports the results of corporate carbon neutrality performance on financial constraints and institutional shareholding. The results demonstrate carbon neutrality performance advantage encourage green dual innovation by easing financing constraints and attracting institutional shareholding, which verifies hypotheses H2 and H3. Meanwhile, using the

Bootstrap test with a sampling frequency of 1000 times, the results show that the mediating effect is still valid.

Table 2. Regression results.

	(1) GI1	(2) GI2	(3) KZ	(4) INST
CNP	0.087***	0.037***	-0.039**	0.017***
	(10.29)	(5.94)	(-2.03)	(8.37)
Constant	-1.575***	-0.870***	7.135***	-1.143***
	(-10.98)	(-7.73)	(18.94)	(-30.86)
Controls	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES
N	23439	23439	23439	23439
adj. R^2	0.156	0.154	0.518	0.437
Bootstrap test			[-.0008785, -.000023]	[-.0017346, -.0002824]

t statistics in parentheses, * p < 0.1, ** p < 0.05, *** p < 0.01, the same below.

4.2 Robustness Tests

Instrumental variable method. To alleviate the reverse causality issue, this study employs the median of carbon neutrality performance in the same industry and year as the instrumental variable for regression. Table 3's findings demonstrate that better carbon neutrality performance can encourage green dual innovation, with a greater impact on explorator. This shows that the main conclusions are robust.

Table 3. Instrumental variable method.

	First stage	Second stage	
	CNP	GI1	GI2
CNP_IV	0.331***		
	(6.40)		
CNP		0.314***	0.273***
		(2.76)	(3.11)
Controls	YES	YES	YES
Year/Industry FE	YES	YES	YES
N	23,439	23,439	23,439
KP rk LM		35.367[0.0000]	35.367[0.0000]
KP rk Wald F		40.969{16.38}	40.969{16.38}

Replace explained variable. Green dual innovation is measured by the ratio of green patents applied by businesses to all patents applied in the current year. The results are displayed in columns (1) and (2) of Table 4, confirming the research conclusions are valid.

Change the regression model. Considering the right-skewed distribution in the number of enterprises' green patents, Tobit model is adopted for regression. The columns (3) and (4) of Table 4 indicate the conclusions are still robust.

Table 4. Other robustness tests.

	(1) RGI1	(2) RGI2	(3) GI1	(4) GI2
CNP	0.007***	0.001*	0.318***	0.071**
	(5.98)	(1.76)	(10.87)	(2.25)
Constant	0.027	0.054***	-3.550***	-4.279***
	(1.50)	(4.57)	(-6.19)	(-7.28)
Controls	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES
N	23439	23439	23439	23439
adj. R^2/ Pseudo R^2	0.090	0.118	0.022	0.021

4.3 Heterogeneity Tests

Regional heterogeneity. Given the disparities in resource endowment and economic development across China's regions, a geographical heterogeneity analysis is essential. Table 5's findings confirm that carbon neutrality performance exerts a significantly positive influence on green dual innovation in both the eastern and central-western regions, but the Chow test reveals the effect is notably more pronounced in the central-western regions. It may be less developed regions are often faced with multiple tasks such as more urgent industrial structure upgrading, job creation and improvement of residents' living standards, and their desire for economic growth is more significant. Therefore, enterprises will devote more energy to green dual innovation to further enhance core competitiveness.

Table 5. Results of regional heterogeneity test.

	East GI1	Midwest GI1	East GI2	Midwest GI2
CNP	0.079***	0.107***	0.027***	0.061***
	(7.83)	(6.87)	(3.70)	(5.05)
Constant	-1.464***	-1.793***	-0.646***	-1.393***
	(-8.55)	(-6.84)	(-4.88)	(-6.50)
Controls	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES
N	17152	6287	17152	6287
adj. R^2	0.156	0.170	0.155	0.162
P value	0.074*		0.007***	

Industry heterogeneity. Under the dual carbon goals, different industries face varying demands and pressures for green transformation. Companies may exhibit

significant differences due to respective industries, which will affect strategic choices and development models. This paper divides the sample into manufacturing and non-manufacturing industries. The results in Table 6 show the promotion of carbon neutrality performance advantage on green dual innovation is more obvious in the manufacturing industry. Because the manufacturing sector contains a higher concentration of enterprises characterized by the "three highs" (high pollution, high emissions, and high energy consumption). It faces greater pressure to improve energy efficiency and reduce environmental impact. Consequently, this sector demonstrates stronger willingness and greater demand for promoting green transformation of production modes and enhancing production efficiency, thereby possessing stronger motivation for green innovation.

Table 6. Results of industry heterogeneity test.

	Manufacturing	Non-manufacturing	Manufacturing	Non-manufacturing
	GI1	GI1	GI2	GI2
CNP	0.097***	0.059***	0.049***	0.008
	(8.90)	(4.79)	(5.92)	(0.99)
Constant	-2.127***	-0.654***	-1.189***	-0.387**
	(-11.26)	(-3.09)	(-7.81)	(-2.52)
Controls	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES
N	15642	7797	15642	7797
adj. R^2	0.153	0.180	0.135	0.220
P value	0.009***		0.000***	

5 Conclusions and Recommendations

5.1 Research Conclusions

This paper studies the impact of carbon neutrality performance on a firm's green dual innovation. It is found that good carbon neutrality performance can promote corporate green dual innovation, with a greater impact on exploratory. Mechanism analysis shows good carbon neutrality performance encourages corporate green dual innovation by easing financial constraints and attracting institutional shareholding. Heterogeneity analysis finds that the impact of carbon neutrality performance advantage on corporate green dual innovation is more obvious in the central and western regions and manufacturing industries.

5.2 Policy Recommendations

First, the government should actively and orderly advance the process of carbon neutrality management to facilitate corporate green transformation. For example, expedite the establishment of a systematic and standardized carbon neutrality information

disclosure framework, and guide enterprises toward energy conservation and emission reduction by combining compulsory and voluntary disclosure. Second, the government should build multi-dimensional assessment and incentive mechanism to link carbon neutrality performance of enterprises with policy instruments such as financial subsidies and tax incentives. This will create sustained incentive effects and promote the carbon neutrality and green development of enterprises. Third, enterprises should establish a collaborative governance framework of "internal resource release + external governance empowerment." This involves improving the internal financing decision-making mechanisms and promoting deeper engagement of institutional investors and other market information intermediaries in low-carbon practice.

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