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Research on the Relationship Between Green Innovation, Carbon Performance, and Financial Performance in Manufacturing

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Abstract

Against the backdrop of the advancement of the "dual-carbon" policy and the green transformation of the manufacturing industry, the impact mechanism of green technological innovation on corporate financial performance has received significant attention. This paper takes A-share listed manufacturing companies from 2010 to 2022 as the sample, constructs a mediating effect model to explore the relationship between green technological innovation, carbon performance, and financial performance, and analyzes property rights and regional heterogeneity. Research hypotheses: Green technological innovation not only has a direct positive impact on financial performance but also indirectly promotes financial performance by improving carbon performance; carbon performance plays a partial mediating role; the transmission effect is more significant for private enterprises and companies in the eastern region. This study enriches the theoretical system of green innovation value transmission and provides a reference for manufacturing companies to optimize green innovation strategies and for policymakers to improve carbon management policies.

Keywords

financial performance; green innovation; carbon performance

1. Introduction

1.1. Research Background

Against the dual backdrop of accelerating global environmental pollution control and the deep advancement of China's "dual carbon" (carbon peaking and carbon neutrality) policies, the manufacturing industry, as a pillar of the national economy and a core source of carbon emissions, has become a key player in the low-carbon transition. The joint guidance issued by seven departments, including the Ministry of Industry and Information Technology, titled "Guiding Opinions on Accelerating the Green Development of the Manufacturing Industry" (MIIT Joint Regulation [2024] No. 26), explicitly proposes leading with carbon peaking and carbon

neutrality, promoting high-end industrial restructuring, low-carbon energy consumption, and clean production processes. This policy direction provides a clear path for the green transformation of manufacturing enterprises and highlights the strategic value of green technological innovation — positioned as a "key breakthrough" to overcome environmental constraints and enhance green competitiveness. Green technological innovation can help enterprises optimize production processes and reduce pollution emissions, but it also faces practical challenges such as "high R&D investment and long conversion cycles," which can easily occupy resources for production and operations. From industry practice, heavily polluting manufacturing sectors such as steel, chemicals, and non-ferrous metals have high carbon emission intensity and face substantial environmental regulation pressure, making their green transformation directly impact the achievement of the "dual carbon" goals. In this context, how to scientifically assess the actual impact of green technological innovation on the financial performance of manufacturing enterprises, and clarify the transmission path of carbon performance between the two, becomes an urgent issue in both theory and practice.

1.2. Significance of the Study

Existing research on the relationship between green technological innovation and financial performance has not reached a consensus, with differing views including positive promotion, negative inhibition, or no significant correlation. The theoretical value of this study lies in constructing an analytical framework of "green technological innovation – carbon performance – financial performance," focusing on the mediating role of carbon performance between the two. This addresses the existing theoretical gap regarding the conversion of green innovation's environmental benefits into economic benefits and further deepens the understanding of the value transmission mechanism of green innovation.

For enterprises, the findings of this study can help manufacturing companies formulate green innovation strategies guided by carbon performance, clarify the value conversion pathways of green investments, and avoid resource misallocation. For policymakers, the study provides a basis for designing differentiated environmental regulations and carbon management policies, supporting the green transformation of the manufacturing industry. At the same time, it can serve as a reference for innovations in green financial instruments and the green transformation of industrial parks, accelerating the low-carbon, high-quality development of the manufacturing sector.

1.3. Research Content

This study selects recently listed A-share manufacturing companies in China as the research sample. After screening and processing, panel data are formed, focusing on the core relationship of "green technological innovation – carbon performance – financial performance." The study conducts the following research: first, it examines

the direct impact of green technological innovation on financial performance; second, it analyzes the effect of green technological innovation on carbon performance; third, it verifies the mediating effect of carbon performance and ensures the reliability of the conclusions through robustness tests and endogeneity treatments; fourth, it conducts heterogeneity analysis from dimensions such as property rights and regional distribution to explore contextual differences in the transmission mechanism.

2. Literature Review and Theoretical Analysis

2.1. Green Technological Innovation and Financial Performance

Research by Chen Zewen et al. (2019) shows that green innovation strategies can enhance corporate performance through the mediating effects of green image and core competencies. Both studies indicate that green technological innovation, as a core resource of manufacturing enterprises, can, on one hand, achieve short-term financial gains through process improvements and reduced pollution control costs, and on the other hand, leverage green intangible assets to build differentiated barriers, forming long-term profit growth points[1].

From the perspective of dynamic capabilities theory, scholars like Teece et al. (1997) proposed that the dynamic adaptability of enterprises to environmental changes is key to sustained performance growth (Liu Yongfeng, 2022)[2][3]. Research by Sun Liwen et al. (2019) demonstrates that strategic flexibility and green innovation have interaction and moderation effects on corporate performance under dynamic environmental regulations. This indicates that the ability for green technological innovation is a core capability of manufacturing enterprises in responding to dynamic environmental changes, helping them quickly respond to policies and market demands, avoid performance losses, and achieve stable financial performance growth[4].

2.2. Green Technological Innovation and Carbon Performance

Sustainable development theory emphasizes the synergy between the economy and the environment. As a core indicator of the environmental performance of heavily polluting manufacturing enterprises, carbon performance is directly related to green technological innovation. Research by Jiang Zi’ang et al. (2011) shows that the use of clean energy contributes significantly to the development of China's low-carbon economy[5]. Zhou Zhifang et al. (2019) suggest that carbon risk awareness can positively moderate the relationship between low-carbon innovation and carbon performance[6]. Scholars such as Zhang Luzheng et al. (2022) indicate that intelligent monitoring of carbon measurement based on enterprise energy metrics can aid in improving carbon performance. Research by Javier Amores-Salvadó et al. (2014) explores the moderating effect of a green corporate image on the relationship between green innovation and performance[7].

Qiu Zhenmin et al. (2025) found that corporate green strategy transformation and green action transformation can impact carbon performance. Specifically, green strategy transformation involves promoting both environmental management and green development strategies according to internal and external environmental conditions, while simultaneously considering green innovation to reduce emissions and achieve green development[8].

2.3. Carbon Performance and Financial Performance

Chen Zewen et al. (2019) argue that for heavily polluting manufacturing enterprises, carbon performance has become an indicator of value creation, and its positive impact on financial performance is realized through two main paths: first, the carbon cost-saving effect—high carbon performance means low carbon intensity and efficient use of carbon quotas, which can reduce costs by selling surplus quotas or avoiding fines; second, the green reputation premium effect—good carbon performance can help enterprises obtain policy subsidies, green credit, and gain market and investor recognition, ultimately transforming into improved financial performance [1]. Zhao Yuzhen et al. (2021) suggest that enterprises with abundant resources and capital reserves are better able to meet stakeholder demands and thus enhance their fulfillment of social responsibilities. Such enterprises pay more attention to shaping a green image and optimizing environmental performance, proactively increase investment in environmental protection technology, and expand the scale of carbon trading with partners, helping them to achieve carbon reduction targets more flexibly and ensuring long-term sustainable operation [9]. He Yu et al. (2017) found that the impact of carbon performance on financial performance varies among enterprises with different ownership types, with improvements in the carbon performance of non-state-owned enterprises having a more significant effect on financial performance [10].

2.4. Literature Review

Existing research has accumulated certain theoretical and empirical results on the pairwise relationships among green technology innovation, carbon performance, and financial performance, but there are still shortcomings. Most existing studies focus on the direct links between variables and fail to systematically analyze the complete mediating path of "green technology innovation → carbon performance → financial performance," leaving the discussion of the intermediate process of converting environmental benefits into economic benefits insufficient. Additionally, the dimensions of heterogeneity analysis are limited; existing studies mainly consider ownership type and resource reserves, while paying insufficient attention to key moderating variables such as industry carbon intensity and regional carbon policy differences. Moreover, theoretical support is relatively single, often relying on only one theory, lacking a systematic integration of multiple theories such as the

resource-based view and dynamic capability theory, and as a result, failing to comprehensively explain the complex relationships among the three variables, making the theoretical framework less multidimensional. This study focuses on the mediating role of carbon performance and constructs a complete transmission framework of "green technology innovation → carbon performance → financial performance," filling the research gap in the conversion of environmental benefits into economic benefits. It also expands the dimensions of heterogeneity analysis by including key variables like region, enhancing the practical relevance of the conclusions, and integrating multiple theories, such as the resource-based view, to form a multidimensional support system, comprehensively explaining the complex relationships among the three variables.

3. Model Setting and Data Description

3.1. Model Setting

Model 1: The direct impact of green technological innovation on financial performance

$$roa_{it} = a_0 + a_1 green\_patent_{it} + a_2 \ln\_assets_{it} + a_3 lev_{it} + a_4 state_{it} + a_5 firmage_{it} + a_6 top1_{it} + a_7 patent_{it} + \sum Year_t + \varepsilon_{it}$$

Where a_1 is the coefficient of the direct effect of green technological innovation on financial performance; if it is significantly positive, it supports the hypothesis that green technological innovation has a positive impact on financial performance.

Model 2: The Impact of Green Technology Innovation on Carbon Performance

$$carbon_{it} = b_0 + b_1 green\_patent_{it} + b_2 \ln\_assets_i + b_3 lev_{it} + b_4 state_{it} + b_5 firmage_{it} + b_6 top1_{it} + b_7 patent_{it} + \sum Year_t + \mu_{it}$$

Where b1 is the coefficient measuring the impact of green technology innovation on carbon performance; if significantly negative, it indicates that green technology innovation can improve carbon performance.

Model 3: Mediation Effect Test of Carbon Performance

$$roa_{it} = c_0 + c_1 green\_patent_{it} + c_2 carbon_{it} + b_3 \ln\_assets_i + b_4 lev_{it} + b_5 state_{it} + b_6 firmage_{it} + b_7 top1_{it} + b_8 patent_{it} + \sum Year_t + v_{it}$$

If c_2 is significantly negative and the coefficient of c_1 decreases or its significance is reduced compared with a_1, it indicates that carbon performance plays a partial mediating role.

3.2. Data Description

(1) Data Source

This study analyzes data from China's manufacturing industry from 2010 to 2022. The relevant data are sourced from the CSMAR database and others.

(2) Variable Selection

Dependent Variable: Financial Performance (ROA): The return on assets indicator

from the CSMAR database is directly used, with the calculation formula as follows: Net Profit / Average Total Assets × 100%

Core Explanatory Variable: Green Technological Innovation (green_patent): The level of corporate green innovation is evaluated based on output. Specifically, the total number of green patents applied for by each sample listed company in a given year is used as the measurement indicator. To enhance the comparability of the data, the number of annual green patent applications plus one is logarithmically transformed and used as the measure. The data is sourced from the CSMAR database.

Table 1. Variable Definition

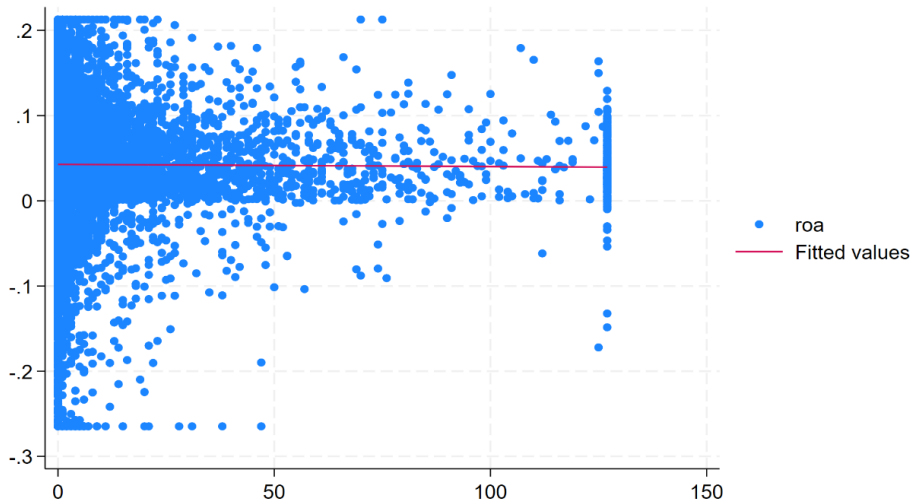
	English Name	Operable Variables
Dependent variable	roa	Return on Net Assets
Explanatory variable	green_patent	Take the logarithm of the number of green patents plus one for the company.
Mediator variable	carbon	Annual corporate carbon emissions (tons of CO_2) / Main business revenue (ten thousand yuan) inversely measures the carbon performance level.
Control variable	ln_assets	Ln Total Assets
	lev	Total liabilities at the end of the period / Total assets at the end of the period × 100%
	state	Dummy variable, equals 1 if the company is state-controlled, otherwise 0
	firmage	Observation Year - Year of Establishment
	top1	Percentage of Shares Held by the Largest Shareholder (%)
	patent	The total number of annual patent applications by the company controlling overall innovation activities
Fixed effects	Yea	Dummy variables, controlling for annual macroeconomic shocks

Table 2. Descriptive Statistical Analysis

Variables	Obs	Mean	Std. Dev.	Min	Max	p1	Median	p99	Skew.	Kurt.
green patent	18001	6.31	17.60	0	127	0	1	127	4.93	30.25
carbon	18001	5775.36	12460.75	69.00	80978.59	118.78	1772.96	80978.59	4.23	22.45
roa	18001	0.04	0.06	-0.27	0.21	-0.19	0.04	0.21	-1.04	8.35
lev	18001	0.42	0.19	0.06	0.97	0.063	0.41	0.87	0.26	2.44
ln assets	18001	22.22	1.19	19.81	25.73	20.01	22.07	25.73	0.65	3.26
firmage	18001	18.64	5.93	6	36	6	18	36	0.34	3.02
top1	18001	34.89	14.50	9.08	74.65	9.09	33	74.65	0.501	2.74
state	18001	0.32	0.47	0	1	0	0	1	0.76	1.58
patent	10253	331.16	2401.29	0	96626	0	45	4438	26.53	844.83

4. Empirical Analysis

4.1. Scatter Plot



4.2. Modeling Results

4.2.1. Descriptive Statistical Analysis

From Table 1, it can be seen that the average number of green patent applications in the sample is 6.309, with a median of only 1 and a standard deviation of 17.599, indicating an uneven distribution of green patents among manufacturing enterprises. Most enterprises have few or no green patents, while only a small number of enterprises concentrate a large number of green patent resources, reflecting the "head concentration" characteristic of green technological innovation. The carbon performance, measured inversely by 'carbon emissions per unit of operating revenue,' has a mean of 5775.364, a median of 1772.961, and a standard deviation of 12460.74, showing a right-skewed distribution. This indicates that most enterprises perform well in terms of carbon performance, but there are some enterprises with extremely high carbon emission intensity, reflecting significant differences in carbon reduction capabilities within the manufacturing sector. The average return on assets is 0.043, with a median of 0.041, a standard deviation of 0.062, a minimum of -0.265, and a maximum of 0.213. This shows that the overall profitability of the sample enterprises is moderate, but there is a differentiation in profitability, as some enterprises face losses or low-profit pressure, while a few enterprises perform exceptionally in terms of profitability.

4.2.2. Robustness Test

To avoid conclusion bias caused by the definition of a single metric and ensure the stability of the "green technological innovation → carbon performance → financial performance" transmission mechanism, this study conducts multidimensional robustness tests from the perspective of alternative measures of core variables. To ensure the reliability of the research findings, carbon performance in the benchmark model is measured by "industry carbon

emissions/enterprise main business revenue." While this reflects the relationship between revenue scale and carbon emissions, it does not fully account for the operational characteristics of heavily polluting manufacturing enterprises, such as the linkage between cost control and emission reduction efficiency. Therefore, this paper constructs a new carbon performance indicator, calculated as (enterprise revenue / (enterprise operating costs/industry operating costs)) × industry CO_2 emissions. If the results show that the b_1 coefficient remains significantly positive at the 1% level, it indicates that green technological innovation indeed improves the restructured carbon performance.

On the other hand, the benchmark model uses return on assets (ROA) to measure financial performance. This indicator primarily reflects short-term profitability efficiency, but since green technological innovation is a long-term strategic investment, its value is more likely to be reflected in the long-term market valuation of the enterprise. Therefore, this paper adopts Tobin's Q as an alternative measure of financial performance, calculated as "(market value of common stock + market value of preferred stock + book value of liabilities) / book value of assets." If the results remain significant, it suggests that the argument that green technological innovation promotes financial performance through carbon performance is robust and does not depend on the definition of specific indicators.

4.2.3. Endogeneity Test

There may be endogeneity issues between green technological innovation and financial performance, mainly arising from two aspects: first, omitted variable bias, such as unobserved factors at the city level like economic development level and the intensity of industrial policies, which may simultaneously affect firms' green innovation decisions and financial performance; second, reverse causality, meaning that firms with better financial performance may have more resources to invest in green technological innovation, forming a reverse causal relationship of "performance → innovation." To address these issues, this study adopts a multidimensional approach to optimize causal identification, as follows:

First, mitigate omitted variable bias by including more precise control variables and fixed effects. Based on the control variables in the baseline model, we add city-level economic characteristic variables, including per capita GDP and the proportion of secondary industry output. These variables can effectively control for the common impact of the regional macro environment on firms' green innovation and financial performance. If regression results show that after adding city-level variables, the positive effect of firms' green technological innovation on financial performance (ROA) remains significant at the 1% level, it indicates that the influence of omitted variables on the core conclusion is limited. Furthermore, we strengthen the fixed effects setting by adding province fixed effects and province × time fixed effects on top of the baseline model's "year × industry" fixed effects. Province fixed

effects can control for characteristics at the provincial level that do not change over time, while province × time fixed effects can capture shocks at the provincial level that vary over time, more comprehensively eliminating omitted factors along the region-time dimension, further verifying the reliability of the conclusions.

Second, the two-stage least squares (2SLS) method is used to address the reverse causality issue. The lagged green technological innovation (green_patent_lag1) is selected as the instrumental variable for current green technological innovation. In the first stage, we regress current green_patent on green_patent_lag1 as the core explanatory variable, controlling for ln_assets, lev, state, firmage, top1, patent, and year fixed effects, obtaining the fitted values of current green patents through this regression. In the second stage, these fitted values are inserted into the original mediation effect model, replacing the original green_patent, and the core transmission relationship is re-examined. If confirmed, this indicates that after controlling for reverse causality, the core conclusion of "green technological innovation → carbon performance → financial performance" remains robust.

4.2.4. Heterogeneity Analysis

To explore the differences in the mechanism through which green technological innovation impacts financial performance via carbon performance under different contexts, this study conducts a heterogeneity analysis from two dimensions: property rights nature and region. From the perspective of property rights, state-owned enterprises, benefiting from policy resources, are estimated to have certain advantages in enhancing carbon performance through green technological innovation. Private enterprises, guided by market efficiency, focus their green technological innovation on practical technologies for cost reduction and emission reduction. Once carbon performance improves, it can more quickly translate into financial performance through market premiums, showing higher market sensitivity.

From a regional perspective, estimates indicate that in the eastern coastal areas, where environmental regulations are strict and the carbon market and green financial systems are mature, the carbon reduction outcomes of corporate green technological innovation can be directly monetized through market-based channels such as carbon trading and green credit, making the positive impact of carbon performance on financial performance more significant. In other regions, constrained by the intensity of environmental enforcement and awareness of green markets, the improvement in carbon performance from green technological innovation is relatively small, and without effective market conversion channels, the promotional effect on financial performance is relatively weak.

5. Conclusion

This study uses A-share manufacturing listed companies from 2010 to 2022 as the

sample and explores hypothetical assumptions surrounding the core logic of "green technological innovation → carbon performance → financial performance." The results are expected to show that green technological innovation has a significant positive impact on financial performance. It contributes directly through cost reduction and efficiency improvement via process optimization and the establishment of barriers based on green intangible assets, and indirectly promotes financial performance through production upgrading and carbon management that enhances carbon performance, with carbon performance playing a partial mediating role in this process. At the same time, this transmission mechanism exhibits heterogeneity: the effect is more pronounced for private enterprises due to higher market sensitivity and for eastern regions due to more developed carbon markets and green financial systems. This study enriches the theory of green innovation value transmission, providing references for corporate green strategies and policymaking; however, it also has limitations, such as the limited sample period and variable measures not covering patent conversion efficiency.

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