The Impact of Green Technology Innovation on Capital Cost of Heavy Polluting Enterprises: The Mediating Effect of Carbon Performance

Liming Zhang\textsuperscript{1}, Jingyi Li\textsuperscript{1}, Kuankuan Luo\textsuperscript{1}, and Thi My An Trieu\textsuperscript{2,*}

\textsuperscript{1}Business School, Sichuan University, Chengdu 610065, People’s Republic of China
\textsuperscript{2}Department of Chinese Language, Thanh Dong University, Hai Duong Province 34000, Socialist Republic of Vietnam

Abstract. Under the background of the carbon peaking and carbon neutrality goals proposed in 2020, making heavy polluting enterprises realize that low-carbon measures can bring enough economic benefits is conducive to enhancing their enthusiasm to adopt green behaviors. Using data from 320 listed companies in heavily polluting industries from 2006 to 2019 as samples, our study used multiple linear regression to explore the relationship between green technology innovation, carbon performance, board characteristics and cost of capital. Based on these data, we draw the following conclusions: green technology innovation and carbon performance are significantly negatively correlated with capital cost, carbon performance plays a mediating role in the relationship between green technology innovation and capital cost, and board characteristics play a moderating role in the relationship between green technology innovation and carbon performance. These conclusions bring some implications for enterprises to develop and implement low-carbon measures and reduce capital cost. Keywords: Green manufacturing, Technology and innovation, Carbon performance, Capital cost, Characteristics of board of directors.

1 Introduction

According to the Vision 2035, we will continue to innovate in technology, and promote the interaction between technology, finance and industry. The 19th National Congress stressed that to make ecological progress, we need to establish the economic system with green, low-carbon and circular development, and comprehensively promote sustainable technological innovation. Green technology innovation can effectively help enterprises break through difficulties and achieve long-term development. Heavy polluting enterprises face greater pressure of legitimacy. The active practice of green innovation concepts by enterprises is conducive to the coordinated development of economy and ecology.

In the past, many heavy polluters ignored the environmental costs and made super-high profits. However, faced with the increasingly serious environmental problems, the impact of government environmental policies has become an unavoidable topic in the decision-making of enterprises and investors. The investment and production activities of enterprises will be directly constrained by environmental policies. Investors tend to take green innovation
and carbon performance into account when investing in heavily polluting industries. Under environmental pressure, heavy polluting enterprises which are no matter forced to survive passively or adapt to policy changes actively, need to make changes such as updating outdated equipment or adjusting development strategies. Such changes in investment direction will affect the cost of capital of enterprises to a large extent.

Under the background of carbon peaking and carbon neutrality goals and national economic transformation, how does the green technology innovation of heavy polluting enterprises affect the capital cost? What role does carbon performance play? What effect does the characteristics of the board of directors play in the process of carrying out environmental responsibilities of heavy polluting enterprises? These problems are the core issues of great concern in this study. We constructed panel data of heavy polluting enterprises from 2006 to 2019 to explore the relationship between green technology innovation, carbon performance and capital cost of heavy polluting enterprises.

The main contributions of this work are: (1) In this study, carbon performance is introduced as the mediating variable between green technology innovation and capital cost, which increases the degree of information transparency and exposes the "black box" between green technology innovation and capital cost of heavily polluting enterprises. (2) We explore how two types of green technology innovation affect the decisions of two different types of investors which broadens the research perspective on the relationship between green technology innovation and capital cost. (3) From the three dimensions of board characteristics, we explore the influence of internal governance on low-carbon strategy and behavior of heavy polluting enterprises, which is of enlightening significance for enterprise management practice.

The rest of this paper is organized as follows. Section 2 discusses relevant literature and develops our hypotheses. Section 3 describes the data, measure and models. Section 4 presents the results from our analysis. Section 4.5 summarizes the main conclusions and makes corresponding suggestions for governments and enterprises.

2 Literature Review and Hypothesis Development

2.1 Green Technology Innovation and Capital Cost

Green product innovation labels products as “green”, which satisfies consumers’ requirements for corporate environmental responsibility, increases product premium, enhances customer loyalty, and accumulates social capital for enterprises [1]. The product sales situation is reflected in the financial statements, which conveys to creditors that the enterprise has good profitability, which can effectively reduce creditors’ borrowing risks and enhance their borrowing willingness. Companies are more willing to provide private information to banks than other investors. Therefore, creditors can obtain more information, reduce the degree of information asymmetry, and reduce the financing cost of borrowers [2].

The capital demand of technological innovation is great, the cycle is long and the uncertainty is high, which leads to the increase of enterprise risk and makes investors ask for higher financing costs [3]. Green technology innovation has problems of information asymmetry and moral hazard, which will lead to the increase of financing costs [4]. Enterprises improve production process, increase productivity and reduce cost through green process innovation and also, they achieve differentiated development and expand market share through green product innovation. These ways of green technology innovation are all conducive to establishing a good reputation for the enterprise, enhancing its competitiveness, highlighting the enterprise’s good development prospects and strong ability to create value. At this time, equity investors have a strong investment intention for the enterprises.
Therefore, we predict the following:

*Hypothesis 1.* Green technology innovation will be negative to enterprise capital cost.

### 2.2 Green Technology Innovation and Carbon Performance

Enterprises actively carry out carbon emission reduction activities in response to the national call, which puts forward higher requirements for technological innovation. Meanwhile, through green technological innovation, carbon emissions can be effectively reduced and carbon performance can be promoted. Dong et al. (2022) found that green technology innovation can promote economic development and urbanization process, thus improving carbon emission efficiency [5]. Green technology innovation affects carbon performance from three aspects: green process innovation, green product innovation and end-treatment technology innovation [1]. First of all, through green process innovation, enterprises optimize production process, improve energy efficiency, use clean energy, optimize energy structure, reduce carbon emissions from the source, and improve environmental performance. Secondly, the use of advanced technology to develop and produce green products, improve product design, product quality and packaging design, so that the product can be recycled and recover the residual value of it, and then form a green circular economy, relieve the legal pressure of enterprises. Finally, innovate end treatment technology, update pollution control equipment or change the way of pollutant treatment to realize harmless emissions or reducing emissions of pollutants and then promoting sustainable development.

Therefore, we predict the following:

*Hypothesis 2.* Green technology innovation will be positively to carbon performance.

### 2.3 Carbon Performance and Capital Cost

Environmental performance is an important basis for creditors to evaluate enterprise risk and financial cash flow [6]. Carbon performance reflects the performance of enterprises’ environmental responsibility and the moral level of enterprises. Creditors usually take the moral level into consideration when evaluating enterprise credit risk [7]. Enterprises with good environmental performance can establish long-term relationships with stakeholders [8], gain their trust and support, and reduce litigation costs. The reduction of carbon emissions is conducive to establishing a good image for enterprises, reducing carbon risks and pollution control costs [9], thus reducing credit risks and gaining the trust of creditors, which is conducive to the signing of a loan agreement between both parties. National financial institutions strictly examine the loan qualification of enterprises in heavily polluting industries, which puts forward further requirements on the carbon performance of enterprises [10].

Enterprises with good environmental performance are considered to have less investment risk, more trust from investors [2], and more hope to increase stock price and reduce capital cost. The signal transmission theory points out that information disclosure can convey the signal that enterprises actively fulfill their social responsibilities to the outside world, which is conducive to reducing the information asymmetry between enterprises and stakeholders, so that external stakeholders can grasp the operation and financial condition of enterprises. A good carbon performance level can set up a good image for enterprises, enable enterprises to form unique competitive advantages in the market, obtain more resources from the outside, improve corporate financial performance, increase corporate valuation and improve investor confidence.

Therefore, we predict the following:

*Hypothesis 3.* Carbon performance will be negative to capital cost.
2.4 Mediating Effects of Carbon Performance

Enterprises invest more in green technology innovation, which leads to greater risks, stronger uncontrollability and information asymmetry. Without disclosure of patent output or innovation performance, investors cannot know the situation of innovation investment, which is likely to lead to adverse selection and moral hazard and increase the uncertainty of investment. Carbon performance can reliably reflect an enterprise’s innovation ability and social responsibility performance. The higher the level of green technology innovation is, the higher the enterprise’s carbon performance is. Creating a good social image can attract the attention of investors and government policy support, so as to effectively integrate resources and reduce the cost of capital.

Therefore, we predict the following:

**Hypothesis 4.** Carbon performance plays an intermediary role in the relationship between green technology innovation and capital cost.

2.5 The Moderating Effect of Board Characteristics

One of the purposes of the establishment of the board of directors is to alleviate agency conflicts and reduce agency costs. Independent directors are usually industry experts or successful people with strong professional ability, social responsibility and legal consciousness, so they can better exercise supervision and management functions. Because independent directors do not hold positions in the enterprise, their decisions are more independent and objective, and they are more able to make scientific decisions compared with internal directors [11]. The higher the proportion of independent directors is, the more conducive it is to make decisions to achieve a win-win situation between the enterprise and the environment from the overall perspective of the enterprise, so as to actively support the enterprise’s green technology innovation, avoid the short-sighted behavior of the management to the maximum extent, and ensure the improvement of carbon performance.

According to the high-level echelon theory, the cognitive ability, perception ability and value of management affect the strategic decision and organizational performance of an enterprise. Female directors pay more attention to environmental pollution than male directors. They are willing to participate in environmental protection activities, assume social responsibilities, solve environmental problems from the perspective of stakeholders, improve environmental performance, meet stakeholders’ expectations of corporate environmental responsibility, and strengthen the relationship with stakeholders.

The role of directors is to supervise the decisions and actions of management so as not to harm the long-term interests of company. Board interlocking occurs when board members hold board positions in different enterprises. However, each person’s time and energy are limited. Serving as a director of several enterprises will cause members to be unable to take care of these enterprises at the same time, and may be absent from the board of directors, weakening the supervision of the board of directors, and easily leading to the management violating shareholders’ rights and interests for their own interests, thus aggravating agency conflicts and increasing the principal-agent costs. The strategy of enterprises to improve carbon performance through green technology innovation requires a lot of time and energy to be deployed, and faces uncertain investment risks. Board interlocking will weaken the supervision effectiveness and investment prudence, and reduce the governance role of the board of directors.

Therefore, we predict the following:

**Hypothesis 5.** Board independence and board gender diversity will positively moderate the relationship between green technology innovation and carbon performance. Board link-age will negatively moderate the relationship.
3 Measure and Model

3.1 Data Source

The A-share listed companies in the heavily polluting industries in China from 2006 to 2019 were selected as the research object, and the industry codes of the heavily polluting enterprises were determined according to the Guidelines published by the MEP in 2010 and the industry codes from the National Bureau of Statistics. In order to ensure the quality of data, the following processing was carried out in this study: companies with ST and ST* were excluded, companies without fourteen years of continuous data were excluded, and companies with serious data missing were excluded. After summarizing and collating the data, 4480 observed values of 320 heavy polluting enterprises were obtained. Data sources for our study include the CSMAR database, the official website of the People’s Bank of China, the State Intellectual Property Office of the People’s Republic of China (SIPO), the Carbon Emissions Trading Network and the China Statistical Yearbook. Winsorize each continuous variable by up or down 1% to reduce the impact of outliers.

3.2 Measure

(1) Explained variables

Cost of debt capital ($K_d$): Refer to Gong et al. (2021) and Bacha (2021) to express the cost of debt capital ($K_d$) in terms of the ratio of interest expense to total liabilities.

Cost of Equity Capital ($K_e$): Currently commonly used methods to measure the cost of equity capital include capital asset pricing method (CAPM), multi-factor model method, historical average earnings method, dividend discount method and dividend growth model method, among which CAPM method and multi-factor model method are the most widely used and CAPM method is the most classic. CAPM method was applied to the research of Faysal et al. (2021) and Abu et al. (2022). We use CAPM method to calculate the cost of equity capital of listed companies in heavy pollution industries.

\[
K_e = R_f + \beta * (R_m - R_f).
\]  

Total cost of capital ($K$): Using Kling et al. (2021) and Khanchel (2022) as reference, the simplified formula of weighted average cost of capital is adopted to calculate capital.

\[
K = K_d * (1 - T) * \frac{D}{A} + K_e * \frac{E}{A}.
\]

Where, $T$ is the corporate income tax rate, $D$ is total liabilities, $E$ is ownership equity, and $A$ is total assets.

(2) Explanatory variables

Green technology innovation ($GTI$): Feng et al. (2022) measured corporate green innovation by the number of green patent applications. In order to eliminate the right-biased distribution of green patent application data, this study added 1 to the number of green patent applications and took the natural logarithm. According to Ma et al. (2021), green invention patents are identified as disruptive green technology innovation and green utility patents as progressive green technology innovation.

(3) Mediating variable

Carbon performance ($CP$): Referring to Aslam (2021) and Peng (2021), the operating revenue of an enterprise’s unit carbon emissions is used to measure carbon performance. The
Table 1. Variable definition.

<table>
<thead>
<tr>
<th>Variable Type</th>
<th>Variable Name</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explained Variable</td>
<td>Total Cost of Capital</td>
<td>K</td>
<td>The cost of raising and using funds</td>
</tr>
<tr>
<td></td>
<td>Cost of Debt Capital</td>
<td>Kd</td>
<td>The cost of bearing liabilities</td>
</tr>
<tr>
<td></td>
<td>Cost of Equity Capital</td>
<td>Ke</td>
<td>The price of issuing common stock</td>
</tr>
<tr>
<td>Explanatory Variable</td>
<td>Green Technology Innovation</td>
<td>GTI</td>
<td>It is aimed at reducing environmental pollution and realizing sustainable development of ecological environment and social economy</td>
</tr>
<tr>
<td></td>
<td>Disruptive Green Technology Innovation</td>
<td>Inb</td>
<td>The number of green invention patents</td>
</tr>
<tr>
<td></td>
<td>Progressive Green Technology Innovation</td>
<td>Inr</td>
<td>The number of green utility patents</td>
</tr>
<tr>
<td>Mediating Variable</td>
<td>Carbon Performance</td>
<td>CP</td>
<td>The operating revenue of an enterprise’s unit carbon emissions</td>
</tr>
<tr>
<td>Regulating Variable</td>
<td>Independence of the Board of Directors</td>
<td>BI</td>
<td>Proportion of the number of independent directors in the scale of the board of directors</td>
</tr>
<tr>
<td></td>
<td>Board Gender Diversity</td>
<td>BGD</td>
<td>The number of female directors as a percentage of board size</td>
</tr>
<tr>
<td></td>
<td>Board Interlocking</td>
<td>IB</td>
<td>The logarithm of the number of listed companies in which the average interlocking board member concurrently serves</td>
</tr>
<tr>
<td>Control Variable</td>
<td>Enterprise Size</td>
<td>Size</td>
<td>The logarithm of the total assets of the business</td>
</tr>
<tr>
<td></td>
<td>Growth</td>
<td>Grow</td>
<td>Current main business revenue growth rate</td>
</tr>
<tr>
<td></td>
<td>Asset-liability Ratio</td>
<td>Lev</td>
<td>Ratio of total liabilities to total assets</td>
</tr>
<tr>
<td></td>
<td>Return on Total Assets</td>
<td>ROA</td>
<td>Ratio of net profit to average annual total assets</td>
</tr>
<tr>
<td></td>
<td>Profitability</td>
<td>Profit</td>
<td>The company’s gross profit margin on sales for the year</td>
</tr>
<tr>
<td></td>
<td>Book Ratio</td>
<td>B/M</td>
<td>The ratio of book value of owners' equity to market value</td>
</tr>
<tr>
<td></td>
<td>Listing Years</td>
<td>Age</td>
<td>The logarithm of the distance between the reporting year and the listing year</td>
</tr>
</tbody>
</table>

higher the value is, the better the carbon performance will be. Enterprise carbon emissions cannot be obtained directly, so we use operating costs and industrial carbon emissions to obtain. The formula for calculating carbon performance is shown below.

Carbon performance \((CP) = \text{enterprise revenue}/(\text{Enterprise operating cost} \times \text{Industry carbon emission/industry operating cost})\)

4) Regulating variables

This study selects board independence, board gender diversity and board interlocking as three dimensions of board characteristics. The independence of the board of directors \((BI)\) is expressed by the proportion of the number of independent directors in the scale of the board of directors. Board gender diversity \((BGD)\) is expressed as the number of female directors as a percentage of board size; Board interlocking \((IB)\) is expressed as the logarithm of the number of listed companies in which the average interlocking board member concurrently serves.

5) Control variables

The control variables selected in this study include enterprise size \((S\text{ize})\), growth \((Grow)\), asset-liability ratio \((Lev)\), return on total assets \((ROA)\), profitability \((Profit)\), book ratio \((\frac{B}{M})\) and listing years \((Age)\).

The definition of all the above variables are shown in table 1.
3.3 Model Setup

In order to test our hypotheses, we employ the following econometric models:

\[
K_{it} = \alpha_0 + \beta_1 GTI_{it} + \beta_2 Size_{it} + \beta_3 Grow_{it} + \beta_4 Lev_{it} + \beta_5 ROA_{it} + \beta_6 Profit_{it} + \beta_7 \frac{BM_{it}}{M_{it}} + \beta_8 Age_{it} + \epsilon_{it}. 
\] (3)

\[
CP_{it} = \alpha_0 + \beta_1 GTI_{it} + \beta_2 Size_{it} + \beta_3 Grow_{it} + \beta_4 Lev_{it} + \beta_5 ROA_{it} + \beta_6 Profit_{it} + \beta_7 \frac{BM_{it}}{M_{it}} + \beta_8 Age_{it} + \epsilon_{it}. 
\] (4)

\[
K_{it} = \alpha_0 + \beta_1 CP_{it} + \beta_2 Size_{it} + \beta_3 Grow_{it} + \beta_4 Lev_{it} + \beta_5 ROA_{it} + \beta_6 Profit_{it} + \beta_7 Profit_{it} + \beta_8 \frac{BM_{it}}{M_{it}} + \beta_9 Age_{it} + \epsilon_{it}. 
\] (5)

\[
K_{it} = \alpha_0 + \beta_1 CP_{it} + \beta_2 GTI_{it} + \beta_3 Size_{it} + \beta_4 Grow_{it} + \beta_5 Lev_{it} + \beta_6 ROA_{it} + \beta_7 Profit_{it} + \beta_8 \frac{BM_{it}}{M_{it}} + \beta_9 Age_{it} + \epsilon_{it}. 
\] (6)

\[
CP_{it} = \alpha_0 + \beta_1 GTI_{it} + \beta_2 BI_{it} + \beta_3 BGD_{it} + \beta_4 IB_{it} + \beta_5 GTI_{it} * BI_{it} + \beta_6 GTI_{it} * BGD_{it} + \beta_7 GTI_{it} * IB_{it} + \beta_8 Size_{it} + \beta_9 Grow_{it} + \beta_{10} Lev_{it} + \beta_{11} ROA_{it} + \beta_{12} Profit_{it} + \beta_{13} \frac{BM_{it}}{M_{it}} + \beta_{14} Age_{it} + \epsilon_{it}. 
\] (7)

4 Results

4.1 Descriptive Statistics

The minimum value of capital cost \((K)\) is 0.0101, the maximum value is 0.132, and the average value is 0.0598, indicating that the financing cost of some companies is high. The mean value of green technology innovation \((GTI)\) is 0.485, the minimum value is 0, and the maximum value is 7.810. It can be seen that the green technology innovation level of listed companies with heavy pollution varies greatly, and some enterprises do not pay enough attention to green technology innovation, and their green technology innovation efforts need to be improved. The mean value of carbon performance \((CP)\) is 6.016, the minimum value is 0.00652, the maximum value is 187.4, and the standard deviation is 12.00, indicating that the gap between the carbon performance of different enterprises is increasing. Many enterprises did not actively carry out carbon emission reduction management from 2006 to 2019, and there is still a large room for improvement of their carbon performance.

4.2 Correlation Analysis

In this study, Stata16.0 was used to test the correlation of sample data. The correlation coefficient between enterprise capital cost and green technology innovation is negative and significant at the level of 1%, which is consistent with hypothesis 1. The correlation coefficient between carbon performance and green technology innovation is significantly positive at the level of 10%, which is consistent with hypothesis 2. The correlation coefficient between carbon performance and cost of equity capital and cost of debt capital is significantly negative at the level of 1%, which is consistent with hypothesis 3. The correlation coefficients of the main variables are all significantly correlated at 1% or 5% level, and the correlation coefficients among all variables are less than 0.5, indicating that there is no serious multicollinearity problem in the model.
Table 2. Regression Analysis for Hypothesis 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model1</th>
<th>Model2</th>
<th>Model3</th>
<th>Model4</th>
<th>Model5</th>
<th>Model6</th>
<th>Model7</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTI</td>
<td>-0.031***</td>
<td>-0.063***</td>
<td>-0.036**</td>
<td>(-2.64)</td>
<td>(-4.58)</td>
<td>(-2.08)</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>-0.144***</td>
<td>-0.080***</td>
<td>-0.079***</td>
<td>-0.090***</td>
<td>-0.214***</td>
<td>-0.207***</td>
<td>-0.220***</td>
</tr>
<tr>
<td>Grow</td>
<td>0.041***</td>
<td>-0.006</td>
<td>-0.006</td>
<td>0.007</td>
<td>0.007</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>Lev</td>
<td>-3.66</td>
<td>(-0.44)</td>
<td>(-0.44)</td>
<td>(-0.36)</td>
<td>(-0.46)</td>
<td>(-0.42)</td>
<td>(-0.48)</td>
</tr>
<tr>
<td>ROA</td>
<td>-0.719***</td>
<td>0.298***</td>
<td>0.297***</td>
<td>0.301***</td>
<td>0.088***</td>
<td>0.086***</td>
<td>0.090***</td>
</tr>
<tr>
<td>Profit</td>
<td>-0.112***</td>
<td>-0.040**</td>
<td>-0.039**</td>
<td>-0.040**</td>
<td>-0.169***</td>
<td>-0.170***</td>
<td>-0.169***</td>
</tr>
<tr>
<td>B/M</td>
<td>0.067***</td>
<td>0.141***</td>
<td>0.138***</td>
<td>0.143***</td>
<td>0.077***</td>
<td>0.075***</td>
<td>0.078***</td>
</tr>
<tr>
<td>Age</td>
<td>-0.055***</td>
<td>-0.081***</td>
<td>-0.080***</td>
<td>-0.083***</td>
<td>-0.016</td>
<td>-0.016</td>
<td>-0.016</td>
</tr>
<tr>
<td>Inb</td>
<td>-0.067***</td>
<td>-0.049**</td>
<td>(-5.14)</td>
<td>(-2.90)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inr</td>
<td>-0.045***</td>
<td>-0.026</td>
<td>(-3.26)</td>
<td>(-1.43)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>0.039***</td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.011</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Observations</td>
<td>4.014</td>
<td>4.054</td>
<td>4.054</td>
<td>4.054</td>
<td>4.439</td>
<td>4.439</td>
<td>4.439</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.048</td>
<td>0.203</td>
<td>0.204</td>
<td>0.202</td>
<td>0.092</td>
<td>0.093</td>
<td>0.091</td>
</tr>
<tr>
<td>F-test</td>
<td>459.6</td>
<td>114.5</td>
<td>115.6</td>
<td>113.4</td>
<td>53.28</td>
<td>54.31</td>
<td>52.77</td>
</tr>
</tbody>
</table>

Note: *, ** and *** are significant at the level of 10%, 5% and 1% respectively

4.3 Hypotheses Testing

(1) Green Technology Innovation and Capital Cost

To verify hypothesis 1, multiple linear regression analysis was carried out on models (1) - (7), and the results were shown in table 2. Green technology innovation has a negative impact on both the cost of capital and the cost of debt capital, and the result is significant at the 1% level, and the negative impact of green technology innovation on the cost of equity capital is significant at the 5% level, indicating that improving the level of green technology innovation can significantly reduce the cost of debt and equity capital and the total cost of capital. Hypothesis 1 is verified.

(2) Green Technology Innovation and Carbon Performance

To verify hypothesis 2, multiple linear regression analysis was carried out on models (8) - (10), and the results were shown in table 3. The total value of green technology innovation and disruptive green technology innovation have a significant positive impact on carbon performance at the level of 1%, and the progressive green technology innovation has a significant positive impact on carbon performance at the level of 10%, indicating that improving the level of green technology innovation can significantly improve the carbon performance of enterprises. Hypothesis 2 is verified.

(3) Carbon Performance and Capital Cost
<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 8</th>
<th>Model 9</th>
<th>Model 10</th>
<th>Model 11</th>
<th>Model 12</th>
<th>Model 13</th>
<th>Model 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>-0.119***</td>
<td>-0.122***</td>
<td>-0.072***</td>
<td>-0.117***</td>
<td>-0.024**</td>
<td>-0.024**</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>(-8.07)</td>
<td>(-6.82)</td>
<td>(-3.92)</td>
<td>(-7.95)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GTI</td>
<td>0.056***</td>
<td>-2.85</td>
<td>-0.024**</td>
<td>-2.85</td>
<td>-0.024**</td>
<td>-2.85</td>
<td>-0.024**</td>
</tr>
<tr>
<td>Size</td>
<td>0.081***</td>
<td>-3.8</td>
<td>-0.147***</td>
<td>-3.8</td>
<td>-0.147***</td>
<td>-3.8</td>
<td>-0.147***</td>
</tr>
<tr>
<td>Grow</td>
<td>0.037**</td>
<td>0.037**</td>
<td>0.035**</td>
<td>0.037**</td>
<td>0.035**</td>
<td>0.037**</td>
<td>0.035**</td>
</tr>
<tr>
<td>Lev</td>
<td>-0.106***</td>
<td>-0.103***</td>
<td>-0.108***</td>
<td>-0.106***</td>
<td>-0.103***</td>
<td>-0.108***</td>
<td>-0.106***</td>
</tr>
<tr>
<td>ROA</td>
<td>-0.121***</td>
<td>-0.120***</td>
<td>-0.114***</td>
<td>-0.121***</td>
<td>-0.120***</td>
<td>-0.114***</td>
<td>-0.121***</td>
</tr>
<tr>
<td>Profit</td>
<td>0.599***</td>
<td>0.600***</td>
<td>0.600***</td>
<td>0.600***</td>
<td>0.600***</td>
<td>0.600***</td>
<td>0.600***</td>
</tr>
<tr>
<td>B/M</td>
<td>-0.108***</td>
<td>-0.105***</td>
<td>-0.110***</td>
<td>-0.108***</td>
<td>-0.105***</td>
<td>-0.110***</td>
<td>-0.108***</td>
</tr>
<tr>
<td>Age</td>
<td>0.078***</td>
<td>0.078***</td>
<td>0.080***</td>
<td>0.078***</td>
<td>0.078***</td>
<td>0.080***</td>
<td>0.078***</td>
</tr>
<tr>
<td>Inb</td>
<td>0.077***</td>
<td>-3.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inr</td>
<td>0.037*</td>
<td>-1.74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: *, ** and *** are significant at the level of 10%, 5% and 1% respectively.

In order to verify hypothesis 2, multiple linear regression analysis was carried out on models (11) - (13), and the results were shown in table 3. The negative effects of carbon performance on total cost of capital, cost of debt capital and cost of equity capital are all significant at the level of 1%, indicating that enterprises’ active carbon emission reduction measures and improvement of carbon performance can significantly improve their carbon performance. Hypothesis 3 is verified.

(4) Mediating Effect of Carbon Performance

According to the first column of 2, the regression coefficient of capital cost to green technology innovation is 0.031, and it is significant at the level of 1%, indicating that the influence of green technology innovation on capital cost has an intermediary effect. It can be seen from the first and seventh columns of table 3 that the regression coefficient of carbon performance on green technology innovation is 0.031, the coefficient of capital cost on carbon performance is -0.117, and the coefficient of green technology innovation is -0.024, both of which are significant. Therefore, carbon performance plays a partial mediating effect.

(5) Moderating Effect of Board Characteristics

According to the regression result, the interaction term between green technology innovation and board independence and the regression coefficient between green technology innovation and board gender diversity are both negative and significant. Therefore, board
independence and board gender diversity play a moderating role in the influence of green technology innovation on carbon performance. The regulating effect of board linkage is not significant.

4.4 Robustness Test

Some studies have pointed out that the influence of green patents on enterprises has a hysteresis effect. Therefore, in the robustness test, the regression test is carried out on the green technology innovation variables with a lag of one stage, and the results have not changed substantially from the results above, which indicates that the conclusions of this study have certain robustness and reliability to a certain extent.

4.5 Discussion and Conclusion

We integrate the latest research and theory on green innovation and cost of capital. The direct effect, mediating effect and the moderating effect of the hypothesis in our study are supported. Green technology innovation influences the cost of debt capital and the cost of equity capital through the mediating role of carbon performance. Meanwhile, the characteristics of the board of directors play a moderating role in the relationship between green technology innovation and carbon performance.

The researchers found that green technology innovation can reduce carbon emissions through product innovation, process innovation and end-treatment technology innovation. As a manifestation of corporate responsibility and moral level, carbon performance is widely concerned by investors. Companies with good carbon performance can gain the trust of investors and thus reduce the cost of capital. Consistent with the above views, our results also support the hypothesis that green technology innovation and carbon performance are negatively correlated with firms’ cost of capital.

The results of our study are of practical significance to the development of green economy. Firstly, the government should strengthen the incentives and penalties for carbon emission reduction, link the effect of emission reduction to the economic costs of enterprises, and encourage heavy polluting enterprises to actively carry out green production. Secondly, enterprises should actively respond to national policies, fulfill the social responsibility of carbon emission reduction, and enhance the level of green technology innovation. Finally, companies should adjust the structure of the board of directors according to the actual situation and improve the effectiveness of the supervisory function of the board of directors. In the complex and changeable environment, companies should constantly improve their adaptability and strive to achieve coordinated development of environmental and economic benefits.

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References