THE IMPACT OF CORPORATE SOCIAL RESPONSIBILITY ON GREEN TECHNOLOGICAL INNOVATION: A STUDY ON THE MODERATING ROLE OF CORPORATE SOCIAL CAPITAL

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This study examines the impact of corporate social responsibility (CSR) on green technological innovation (GTI) and the moderating role of corporate social capital. It finds that CSR activities significantly foster GTI by creating a favorable internal environment through enhanced corporate culture and employee engagement. Moreover, different dimensions of corporate social capital, like vertical relational capital with suppliers and customers and horizontal relational capital with other companies, play complex moderating roles in the CSR-GTI relationship. The research underscores the importance of CSR in promoting sustainable corporate development and reveals the critical role of social capital in enhancing CSR and technological innovation.

Keywords: corporate social responsibility (CSR); green technological innovation; corporate social capital; relational capital; sustainable

Introduction

As the world's largest manufacturing nation, China faces complex challenges due to rising environmental standards and the trend of de-globalization. These challenges have driven the Chinese government and businesses to strengthen ecological civilization construction, especially through the implementation of "Made in China 2025" and other green economic strategies. In this context, corporate social responsibility (CSR) and green technological innovation (GTI) have become key tools, not only aiding businesses in adapting to environmental changes but also ensuring sustainable economic development. However, many Chinese enterprises still face challenges in implementing green technological innovation and fulfilling social responsibilities.

Although previous research has explored various factors affecting GTI, these are often viewed as isolated external or internal driving forces, such as environmental regulations,
government support, and corporate resources. This study aims to further explore the relationship between CSR and GTI, especially in the specific socio-economic context of China. It particularly focuses on the moderating role of corporate social capital (CSC) - the ability of a company to acquire resources through social networks - in the relationship between CSR and GTI.

Through this research, we hope to provide new theoretical and empirical evidence on the relationship between CSR and GTI, explore how CSC moderates this relationship, and consider the impact of corporate heterogeneity factors such as equity balance and listing duration. This will offer practical guidance and suggestions for Chinese enterprises on how to promote GTI through CSR activities, thereby driving the green transformation of the manufacturing industry.

Green Technological Innovation (GTI) refers to the management or technological innovation undertaken by companies to reduce the negative environmental impact of their products during production, usage, and disposal phases (Fussler & James, 1996). The concept of GTI has been broadly interpreted to include innovations in products, services, processes, environmental management systems, and the entire supply chain. The core of these innovation activities is to integrate resource conservation, ecological protection, and green development into all stages of technological innovation, aiming to achieve harmonious development of the economy, resources, environment, and ecology. Although GTI positively impacts corporate and societal sustainability, it also faces the challenge of balancing economic benefits with environmental protection (Endrikat et al., 2014).

Corporate social responsibility (CSR) refers to a company's voluntary commitment to its stakeholders, including the environment, community, and employees, while pursuing economic benefits (Carroll, 1991). The evolution of CSR has expanded from a sole focus on economic responsibilities to include legal, ethical, and philanthropic responsibilities (Carroll, 1979). Late 20th-century research has shown a diversified relationship between CSR and corporate performance, with an increasing trend of positive correlations, highlighting the significance of CSR in modern business management.

Corporate social capital is defined as the resources or the ability to acquire resources through social networks and connections (Putnam, 1997). These resources or capabilities, such as trust among network members and shared values, can facilitate technological advancement and knowledge innovation, enhancing a company's sustained competitiveness. The construction of corporate social capital involves relationships with various stakeholders, including customers, suppliers, governments, and communities.

This paper focuses on exploring the relationship between CSR and GTI and the role of corporate social capital in this context. Research shows that CSR can promote the development of GTI (Wang et al., 2018), with environmentally friendly policies and innovations helping businesses improve their environmental performance and social reputation.

Additionally, as a bridge connecting companies with the external world, corporate social capital significantly influences the promotion of GTI and the fulfillment of CSR. This literature review provides a deeper understanding of the dynamic relationships and interactions between CSR, GTI, and corporate social capital.
Research hypotheses

By comprehensively examining relevant theories and previous studies, we investigate the relationship between corporate social responsibility (CSR) and green technological innovation (GTI) and examine the moderating role of corporate social capital in this relationship. This process aims to deepen understanding of how companies can promote technological innovation through social responsibility practices and how social capital impacts this process.

The Relationship between Corporate Social Responsibility and Green Technological Innovation

Corporate social responsibility (CSR) is widely recognized for its positive impact on green technology innovation (GTI). CSR performance reflects satisfying the needs of internal and external stakeholders such as the government, shareholders, consumers, and employees, aligning and unifying the company's relationships (Carroll & Shabana, 2010).

CSR fosters innovation, especially in environmental protection by enhancing brand image and meeting stakeholder demands. Studies indicate that CSR promotes employees' innovative thinking, improves resource efficiency, reduces operational costs, and bolsters corporate reputation among consumers and investors. Effective CSR practices empower firms to access resources by reducing information asymmetry, thus propelling GTI (Dhaliwal et al., 2011).

Moreover, CSR initiatives also prompt environmental actions within the supply chain, promoting industry-wide green transformation. Given this, CSR plays a crucial role in driving GTI, particularly under the pressure of diverse stakeholder interests. Therefore, hypothesis H1 is proposed:

Hypothesis H1: Fulfillment of CSR positively enhances the level of GTI.

The Moderating Role of Corporate Social Capital

Corporate social capital strengthens connections with stakeholders like governments, customers, and suppliers, bringing necessary resources and information for promoting CSR and GTI. Social capital’s role in resource acquisition can intensify the link between CSR and GTI. It also helps in reducing financing risks and enhancing the capacity to implement CSR and GTI (Cheng & Chen, 2013). Additionally, social capital aids in internal coordination and identifying market opportunities, facilitating better integration of CSR and GTI. Hence, hypothesis H2 is proposed:

Hypothesis H2: Corporate social capital will positively moderate the relationship between corporate social responsibility and green technological innovation.

Corporate social capital (CSC), particularly the vertical relationship capital with suppliers and customers, significantly moderates the relationship between CSR and GTI. These relationships, by providing resources, enhancing trust, and facilitating information sharing, strengthen the positive link between CSR and GTI. Resource dependency theory suggests CSR as a strategic means for resource acquisition to promote green innovation (Carroll & Shabana, 2010).
CSC also bolsters CSR and GTI alignment by encouraging knowledge sharing, internal coordination, and improving market opportunity identification. Thus, hypotheses H2a, H2a1, and H2a2 are proposed:

Hypothesis H2a: Relationships with suppliers and customers enhance the positive impact of CSR on GTI.

Hypothesis H2a1: The relationship with suppliers positively moderates the relationship between corporate social responsibility and green technological innovation.

Hypothesis H2a2: The relationship with customers positively moderates the relationship between corporate social responsibility and green technological innovation.

Corporate Social Capital's (CSC) horizontal connections, such as relationships with competitors or partners, significantly influence the relationship between corporate social responsibility (CSR) and green technology innovation (GTI). Horizontal relationship capital promotes GTI by enhancing CSR practices and acquiring new knowledge or resources. Social network theory suggests that a firm's network position and relationships impact its ability to acquire knowledge and resources, thereby affecting GTI. Additionally, learning theory emphasizes that firms innovate by learning new technologies through interactions with other firms. Based on this, Hypothesis H2b is proposed:

Hypothesis H2b: Relationships with other businesses strengthen the positive impact of CSR on GTI.

The social relationship capital of corporate social capital (CSC), such as relationships with communities and governments, positively modulates the relationship between corporate social responsibility (CSR) and green technology innovation (GTI). These networks aid businesses in acquiring information, resources, and support, thereby enhancing CSR practices and propelling GTI. Additionally, interaction with external entities enables firms to learn new knowledge, fostering GTI development (Wang et al., 2018).
Moreover, such networks can influence the diffusion of innovation behavior, aligning more closely with external stakeholders' expectations and needs. Thus, Hypothesis H2c is proposed:

Hypothesis H2c: Relationships with other societal entities enhance the positive impact of CSR on GTI.

The model established based on these hypotheses is shown in Fig. 1.

**Research methodology and data**

**Data source and sample**

The study selected samples from A-share manufacturing companies listed on the Shanghai and Shenzhen stock exchanges in China from 2010 to 2018. Data sources included annual reports of listed companies, the CSMAR database, the China Research Data Service Platform (CNRDS), and the Runling Global Responsibility Rating Report.

The sample period considered the implementation of China's mandatory CSR reporting system. Companies classified as ST and *ST, as well as those with missing data on key research variables, were excluded. Additionally, variable data underwent Winsorize treatment at the 1% and 99% percentiles to reduce outliers' influence.

**Variable measurement methods**

(1). Measurement of Green Technological Innovation

The study used the total number of green invention and utility model patent applications as an indicator of GTI, reflecting the level of green technological innovation. The data was sourced from CNRDS's Green Patent Research Database (GPRD).

(2). Measurement of Corporate Social Responsibility

CSR measurement utilized the total score from Runling Global's CSR rating report, reflecting the level of CSR fulfillment.

(3). Measurement of Corporate Social Capital

CSC measurement involved key dimensions: vertical relationship capital, horizontal relationship capital, and social relationship capital. Vertical relationship capital primarily reflects relationships with customers and suppliers in the value chain, measured by customer satisfaction, loyalty, or referral rates, and supplier relationship strength assessed through cooperation stability, innovation capacity, or satisfaction. Horizontal relationship capital focuses on relationships with other businesses (e.g., competitors or partners), measuring the density, breadth, and depth of cooperation. Social relationship capital included relationships with other social entities like communities and governments, assessed by community involvement, government relationship quality, and corporate social influence.

(4). Selection and Measurement of Control Variables

The study included various control variables that could impact GTI, such as listing duration (ListAge), cash flow ratio (Cashflow), CEO-Chairman duality (Dual), major shareholder capital occupation (Occupy), independent director proportion (Indep), equity balance (Balance), and institutional investor shareholding ratio (INST).

These variables were selected for their significant impact on business operations, financial health, decision-making structure, and market confidence, as shown in prior research. Including these control variables allowed for a more accurate assessment of the impact of CSR and CSC on GTI.
Selection of the econometric model

(1) Model Selection

Data on green patent applications show significant right-skewness and high dispersion, with a non-normal distribution and many zero values. Considering these characteristics, especially the right skewness and high dispersion, this study opted for the zero-inflated (ZIP) regression model. Specifically, the zero-inflated negative binomial (ZINB) distribution was used, suitable for cases where the mean is less than the variance, helping reduce the overdispersion commonly seen in traditional Poisson models. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used for comparative analysis against traditional models like the Poisson Regression Model and Ordinary Negative Binomial Regression Model. AIC and BIC results indicated superior data fitting for the ZINB model, making it the chosen model for analysis.

(2) Main Effect Model

To study the impact of corporate social responsibility (CSR) on green technological innovation (GTI) and consider the potential time lag between corporate actions and their effects, this paper constructs a main effect model with a focus on data lag. In the model, the degree of CSR fulfillment is used as the explanatory variable, while the level of GTI serves as the dependent variable. To capture the potential impact of CSR on GTI, the lag of the CSR variable is considered. This approach more accurately reflects the influence of CSR activities on green technological innovation, as the effects of CSR activities may not be immediate but emerge over time. To investigate the effectiveness of CSR on GTI, for hypothesis H1, a regression model is constructed to examine the relationship between CSR fulfillment and GTI, as shown in Model 1.

In the model, represents individual companies, and represents the year. n is the number of years lagged (1, 2, 3). The dependent variable, denoted as , represents the level of green technological innovation of the company in year t+n. The explanatory variable represents the degree of social responsibility fulfillment of the company in the year. represents all control variables for the company in years, represents fixed time effects, and is the error term.

(3) Corporate Social Capital Moderation Model

To study the moderating effect of corporate social capital (CSC) on the relationship between corporate social responsibility (CSR) and green technological innovation (GTI), Model 2 is established:

Model 3, based on Model 1, introduces an interaction term between corporate social capital (CSC) and corporate social responsibility (CSR), denoted as CSR×CSC. If the coefficient of CSR×CSC in Model 3 is significant and has the same sign as the CSR coefficient, it indicates that CSC positively reinforces the relationship between CSR and GTI. Conversely, if the coefficient has an opposite sign and is significant, it suggests that CSC weakens the impact of CSR on GTI. If not significant, it indicates that CSC does not moderate the relationship between the two.

For investigating the different dimensions of CSC's moderating effects on CSR and GTI, Models 2-1, 2-2, 2-3, and 2-4 are established:

VCON1 represents the vertical dimension of relationships with suppliers, VCON2 with customers, HCON the horizontal dimension, and TCON the social relationship dimension. If the coefficients of interaction terms in Models 2-1, 2-2, 2-3, and 2-4 are significant and have the same sign as the CSR coefficient, it demonstrates that the vertical dimensions (relationships with suppliers and customers), the horizontal dimension, and the social
relationship dimension of CSC positively enhance the relationship between CSR and GTI. If the sign is opposite and significant, it suggests that these dimensions of CSC weaken the impact of CSR on GTI. If the coefficients are not significant, it indicates that these dimensions of CSC do not have a moderating effect on the relationship.

**Model testing**

Descriptive statistics show significant variance in green technological innovation (GTI) among the sampled companies, with an average of 18.39, a median of 2, a maximum of 1869, and a standard deviation of 84.75. The right-skewness and high dispersion of the data indicate an uneven distribution of green innovation activities. The average Corporate Social Responsibility (CSR) score is 38.70, with a median of 36.59 and a standard deviation of 11.27, reflecting variability in CSR practices among the companies. The correlation analysis reveals a positive correlation between CSR and GTI (correlation coefficient of 0.147***), suggesting a mutually reinforcing relationship between the two. Additionally, CSR showed varying degrees of correlation with variables such as relationships with suppliers (VCON1) and customers (VCON2).

In conducting the multicollinearity test, considering the statistical differences between the zero-inflated negative binomial (ZINB) regression model used and the traditional ordinary least squares (OLS) model, a cautious approach was taken. Although the Variance Inflation Factor (VIF) is primarily used to assess collinearity issues in OLS models, the study initially used the OLS model for a preliminary estimate, followed by VIF for collinearity testing based on these estimates. The results showed that all variables had a VIF value below 5, well below the threshold of 10 typically used to indicate significant multicollinearity, indicating no severe collinearity issues in the model. The highest VIF value for the largest shareholder's shareholding ratio (Top 1) was only 3.231, still within an acceptable range, suggesting the model's relative robustness against multicollinearity.

**Testing the impact of corporate social responsibility on green technological innovation**

Tab. 1 reports the results of Model 1, examining the impact of corporate social responsibility on green technological innovation. The empirical results show that the regression coefficient of CSR is 0.037, significant at the 1% level (Coef. = 0.037, p<0.01). This finding conclusively demonstrates that CSR positively influences green technological innovation, supporting Hypothesis H1.

**Testing the moderating effect of corporate social capital**

Tab. 2 reports the empirical test results of Models 2-1, 2-2, 2-3, and 2-4, which explore the moderating effects of different dimensions of corporate social capital on the relationship between CSR and GTI.

In Tab. 2, Model 2_1, VCON1 represents the relationship between enterprises and suppliers. The interaction term (CSR×VCON1), intr_VCON1, has a coefficient of 0.0004*, significant at the 10% level, consistent with the original hypothesis (H3a1). VCON1 shows a significant negative impact on GTI (coefficient = -0.0231, p<0.01), suggesting a negative effect in the absence of other variables.

However, when intr_VCON1 is considered, its impact on GTI becomes positive, albeit with lower significance and coefficient, implying that in the presence of CSR, VCON1 might positively affect GTI. CSR continues to have a significant positive impact on GTI.
THE IMPACT OF CORPORATE SOCIAL RESPONSIBILITY

(coefficient = 0.0391, p<0.01), indicating that enterprises exhibiting high social responsibility might perform better in green technology innovation despite the influence of supplier relationships.

Table 1 - Testing the impact of corporate social responsibility on green technological innovation

( made by the author)

<table>
<thead>
<tr>
<th>GTI</th>
<th>Coef.</th>
<th>St.Err.</th>
<th>t-value</th>
<th>p-value</th>
<th>95% Conf</th>
<th>Interval</th>
<th>Sig</th>
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<tr>
<td>CSR</td>
<td>0.037</td>
<td>0.004</td>
<td>9.12</td>
<td>0</td>
<td>0.029</td>
<td>0.045</td>
<td>***</td>
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<td>-0.04</td>
<td>0.964</td>
<td>-0.283</td>
<td>0.271</td>
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</tr>
<tr>
<td>Cashflow</td>
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<td>-1.49</td>
<td>0.137</td>
<td>-2.776</td>
<td>0.382</td>
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<tr>
<td>Dual</td>
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<td>0.121</td>
<td>-0.24</td>
<td>0.808</td>
<td>-0.267</td>
<td>0.208</td>
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<tr>
<td>INST</td>
<td>1.808</td>
<td>0.294</td>
<td>6.16</td>
<td>0</td>
<td>1.233</td>
<td>2.384</td>
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</tr>
<tr>
<td>Indep</td>
<td>3.5</td>
<td>0.951</td>
<td>3.68</td>
<td>0</td>
<td>1.636</td>
<td>5.365</td>
<td>***</td>
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<td>2.03</td>
<td>0.042</td>
<td>0.006</td>
<td>0.346</td>
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<td>Occupy</td>
<td>14.35</td>
<td>3.455</td>
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<td>0</td>
<td>7.578</td>
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<td>-4.45</td>
<td>0</td>
<td>-3.366</td>
<td>-1.308</td>
<td>***</td>
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<td>control</td>
<td>control</td>
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<tr>
<td>Constant</td>
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<td>-2.841</td>
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<td>-1.128</td>
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<tr>
<td>Constant</td>
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<td>-1.46</td>
<td>-0.522</td>
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<td>30.09</td>
<td>0</td>
<td>1.117</td>
<td>1.273</td>
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</table>

*** p<.01, ** p<.05, * p<.1

In Tab. 2, Model 2_2, VCON2 represents the relationship between enterprises and customers. The interaction term (CSR×VCON2), intr_VCON2, has a coefficient of -0.0000, not significant, contradicting the original hypothesis (H2a). VCON2 shows a significant negative impact on GTI (coefficient = -0.0017, p<0.01), indicating a potential negative effect on overall performance in the absence of other variables.

However, when intr_VCON2 is introduced, its impact on GTI is not significant, suggesting that the CSR's ability to alter VCON2's effect on GTI is not clear. CSR still shows a significant positive impact on GTI (coefficient = 0.0364, p<0.01), consistent with observations in Model 1, indicating that enterprises with high CSR may perform better in green technology innovation regardless of customer relationship strength.

Model 2_3 investigates the relationship with other businesses (HCON), revealing a negative interaction term (Coef.= -0.0294**), suggesting that strong relationships with other businesses might weaken the positive impact of CSR on GTI.

In Tab. 2, Model 2_3, HCON signifies the relationship between an enterprise and other enterprises, and intr_HCON (CSR×HCON) has a coefficient of -0.0294**, significant at the 5% level. This negative coefficient suggests that in some scenarios, HCON might weaken the positive impact of CSR on GTI, contrary to the original hypothesis (H2b).

While CSR still positively affects GTI (coefficient = 0.0334, p<0.01), this effect is weaker than in Model 1, implying that stronger relationships with other enterprises (HCON)
might diminish the positive influence of CSR on GTI. Yet, it also indicates that enterprises demonstrating high CSR can still perform well in green technology innovation despite the influence of relationships with other enterprises.

Table 2 - Testing the Moderating Effect of Corporate Social Capital
(made by the author)

<table>
<thead>
<tr>
<th></th>
<th>Models 2-1</th>
<th>Models 2-2</th>
<th>Models 2-3</th>
<th>Models 2-4</th>
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<td><strong>GTI</strong></td>
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<td>0.0364***</td>
<td>0.0334***</td>
<td>0.0367***</td>
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<td>-0.0231***</td>
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<tr>
<td>intr_VCON1</td>
<td>0.0004*</td>
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<td>VCON2</td>
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<td>intr_VCON2</td>
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<tr>
<td>HCON</td>
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<td>intr_HCON</td>
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<td>TCON</td>
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<td>2684</td>
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</table>

*** p<.01, ** p<.05, * p<.1

In Model 2_4 of Tab. 2, TCON represents the relationship between enterprises and the government. The interaction term (CSR×TCON), intr_TCON, has a coefficient of -0.0048, which is not significant and does not align with the original hypothesis (H2c).

However, CSR still maintains a significant positive impact on GTI (coefficient = 0.0367, p<0.01), consistent with observations in Model 1.

This suggests that despite potential influences like resource curses, enterprises with strong CSR commitments may still excel in green technology innovation.

**Robustness Tests**

To ensure the robustness and reliability of the research results, various robustness checks were conducted, including lagged variable regression, alternative regression models,
data substitution, and Bootstrap method testing. The lagged variable test indicated that CSR's positive impact on GTI remains significant after considering lag effects.

Alternative models, like Zero-Inflated Poisson (ZIP), yielded results consistent with the Zero-Inflated Negative Binomial (ZINB) model. Substituting measures for CSR and GTI also supported the main findings. Bootstrap method resampling further validated the robustness of the baseline regression results.

**Heterogeneity tests**

To understand the impact of CSR on GTI more deeply, heterogeneity tests were conducted. Considering the influence of corporate governance structure and market history on the CSR-GTI relationship, variables like CEO-Chairman duality, equity balance, and listing duration were chosen. The results showed significant differences in the CSR-GTI relationship across different company characteristics. The impact of CSR on GTI varied in companies with different governance structures and market histories, indicating that company characteristics significantly affect the relationship between CSR and GTI.

**Discussion**

In this study, we thoroughly analyzed the mechanisms through which corporate social responsibility (CSR) influences green technological innovation (GTI) and explored the moderating role of corporate social capital. The findings suggest that CSR activities significantly promote GTI development, aligning with Hypothesis H1.

CSR activities create a favorable internal environment for GTI by enhancing corporate culture and employee engagement. Active CSR practices stimulate employee innovation consciousness and increase their focus on green technology and sustainable development. For instance, participation in CSR projects equips employees with new knowledge and skills, fostering innovative thinking and actions.

Additionally, CSR activities help build a positive market image and brand value, attracting consumers and investors who prioritize sustainability. External factors, such as policy orientation and market demand changes, also influence the CSR-GTI relationship. Governmental support for environmental policies and market demand for green products encourage companies to invest more in green technologies. Thus, CSR acts as a bridge in promoting GTI, not only by enhancing internal motivation but also by addressing external challenges towards sustainable development.

In exploring the role of corporate social capital (CSC) in moderating the CSR-GTI relationship, we observe its complex effects. Vertical relational capital, like relationships with suppliers and customers, strengthens CSR's positive impact on GTI by enhancing resource and information flow.

Conversely, horizontal relational capital, such as relationships with competitors, might negatively modulate this positive relationship due to resource dispersion and blurred innovation focus. Additionally, social relational capital, involving ties with government and communities, has a more indirect and long-term moderating role and is less direct than internal and competitive factors. Therefore, precise management and application of CSC dimensions are essential for maximizing their potential in promoting green innovation.

For unsupported hypotheses, reasons include data limitations (e.g., sample selection bias), insufficient temporal, geographic, or industry coverage, external environmental
changes (e.g., market dynamics, policy shifts, technological advancements), and theoretical framework gaps. These factors might lead to certain hypotheses not holding true in specific contexts. Future research should consider these limitations, enhancing theoretical and methodological approaches for greater accuracy and applicability.

Overall, this study emphasizes the importance of CSR in driving sustainable corporate development and reveals the key role of social capital in fostering CSR and technological innovation.

Future research should focus on exploring the complex relationship between CSR and GTI, particularly in varying industries, cultural backgrounds, and market environments. It suggests using broader samples and diverse methodologies to deepen and generalize the findings. Additionally, exploring potential mediators and moderators between CSR and GTI could uncover more intricate mechanisms.

Finally, the study recommends examining CSR's role in emerging markets, different-sized enterprises, and the influence of technological advancement on the CSR-GTI relationship.

References:


THE IMPACT OF CORPORATE SOCIAL RESPONSIBILITY

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