International Journal of Industrial Engineering, 32(1), 209-226, 2025

THE IMPACT OF CORPORATE SOCIAL RESPONSIBILITY ON SUSTAINABLE DEVELOPMENT PERFORMANCE - MEDIATING EFFECT OF DUAL GREEN INNOVATION

Qiong Sun[1], Zhongsheng Wang[2], Yaxin Zhu[3], and Bin Liao[4, *]

[1]Department Business Administration
Beijing Union University
Beijing, China

[2]Department Business Administration
Capital University of Economics and Business
Beijing, China

[3]Department Applied Economics
University of International Business and Economics
Beijing, China

[4]Department Tourism Management
Beijing Union University
Beijing, China
[*]Corresponding author's e-mail: binl_lb@163.com

Green sustainable development remains the cornerstone of China's economic progress and the guiding principle for the transformation and advancement of its manufacturing sector. Aligned with China's objectives of achieving a "carbon peak" by 2030 and "carbon neutrality" by 2060, expediting the green development of manufacturing enterprises and enhancing their sustainable development performance are crucial to ensuring their long-term health and prosperity amid transformation and upgrading. This holds the key to realizing sustained and healthy growth for manufacturing enterprises as they navigate the process of transformation and advancement. According to stakeholder theory and natural resource-based theory, this study evaluates Chinese listed manufacturing enterprises, utilizing panel data spanning 2012-2021 to empirically analyze the relationship between CSR, dual green innovation, sustainable development performance, and redundant resources in these enterprises. A model is constructed to explain the effect of CSR on sustainable development performance. The findings demonstrate that CSR significantly cultivates both continuous and disruptive green innovation, elevating corporate sustainability performance. Continuous and disruptive green innovation represents positive mediating factors in this relationship. The moderating effect analysis indicates that non-sedimentary redundant resources exert a positive moderating effect between CSR and dual green innovation, while the moderating effect of sedimentary redundant resources between the two remains insignificant. Further exploration indicates that in the short term, continuous green innovation exhibits a more significant and positive effect on sustainability performance. Conversely, in the long run, disruptive green innovation demonstrates a greater positive effect on sustainability performance. Considering these conclusions and the specific characteristics and requirements of manufacturing enterprises, this paper proposes relevant recommendations to assist enterprises in effectively enhancing their sustainable development performance.

Keywords: Corporate Social Responsibility; Dual Green Innovation; Redundant Resources; Sustainability Performance.

(Received on September 4, 2024; Accepted on January 1, 2025)

1. INTRODUCTION

The global economy is accelerating its green transformation, with key sectors such as manufacturing industries, service industries, and medical institutions actively responding to this trend in order to address global challenges such as climate change, resource depletion, and environmental pollution. Compared to developed countries, China faces an imbalance between population and resources, economic foundations, and technical capabilities, leading to pressures on economic growth and environmental pollution issues. Consequently, pursuing a sustainability strategy that coordinates economic development with environmental protection has become an inevitable choice for Chinese enterprises (Li *et al*., 2019). Manufacturing

DOI: 10.23055/ijietap.2025.32.1.10475 **ISSN 1072-4761**

enterprises, as crucial contributors to the green transformation of China's economy, must embrace sustainability strategies not only to align with the inevitable demands of high-quality development but also to proactively address the contemporary societal, economic, and environmental challenges they face. However, the manufacturing sector's advancement of sustainability is hindered by the competing demands of market expansion and environmental protection, both vying for finite corporate resources. Therefore, resolving this resource allocation dilemma is essential to generate new avenues for economic growth while simultaneously enhancing environmental benefits. This necessitates that enterprises further strengthen their connections with stakeholders by safeguarding their interests and consolidating and expanding social networks, as well as continuously supplementing internal and external resources (Yu *et al*., 2015). Coordinating the interests between enterprises and stakeholders to promote integrated economic and environmental development is indispensable, making corporate social responsibility a crucial element (Xiao & Yang, 2020). Nevertheless, manufacturing enterprises face a more pressing need to evaluate the relationship between CSR and sustainability performance and to determine how this relationship can be leveraged to achieve higher levels of sustainable development. Therefore, this study will concentrate on assessing the effect of CSR on sustainable development performance and explaining its underlying mechanisms. The aim is to offer a theoretical foundation for Chinese manufacturing enterprises to attain green and sustainable development during this critical period of economic transformation.

Established studies have effectively bridged CSR and sustainable development across economic, social, and environmental dimensions, primarily employing two research methodologies to evaluate their interrelationship. Firstly, discursive research has been undertaken. Scholars at home and abroad have concentrated on exploring the relationships and differences between CSR and sustainable development (Montiel, 2008), contributing significantly to the construction of an evaluation index system (Wang *et al*., 2018) and management system (Xie *et al*., 2009). Secondly, empirical research has played a role. Some scholars hypothesize that fulfilling corporate social responsibility cultivates customer relationship maintenance and the promotion of innovative practices, representing a critical avenue for achieving sustainable development in enterprises (Belas *et al*., 2021). Studies also highlight a positive relationship between CSR and internal control, creating a synergistic effect on corporate sustainability (Wang & Han, 2016). A recent study has focused on the efficiency of corporate resource integration and allocation, exploring the impact effect of the "corporate social responsibility-green capability-sustainable development performance" nexus, but it has not examined how the innovation-driven mechanism of corporate social responsibility enhances sustainable development performance (*Rehman et al*., 2022). In essence, while acknowledging the positive effect of CSR on sustainable development, existing research lacks robust evidence regarding the enhancement of sustainable development performance. Moreover, there is a relative dearth of analysis into the pathways for such improvement. The economic and environmental attributes of sustainable development present challenges for academics in categorizing and exploring the driving factors and internal mechanisms that contribute to the advancement of sustainable development performance.

Green innovation, including both economic and environmental dimensions, is both a practical embodiment of corporate social responsibility and acting as a driving force for enhanced corporate performance (Xiao *et al*., 2022). Scholars have categorized green innovation into two dimensions: green process innovation and green product innovation. They hypothesize that the design of novel processes and the development of new products, both according to environmental consciousness, can empower enterprises to attain differentiated competitive advantages while optimizing energy utilization, thereby cultivating the enhancement of enterprise sustainable development performance (Xie & Zhu, 2021). Moreover, scholars have also classified green innovation into green technology innovation and green management innovation, contending that the coordination between these two forms of innovation can reduce pollution emissions at their source, reduce production costs, and significantly enhance the sustainable development performance of enterprises (Xi & Zhao, 2022). However, the market environment in which enterprises operate is characterized by complexity and dynamism, and their sustainable development confronts challenges such as resource limitations and the balancing of interests, evolving demand patterns, and market competition. A singular perspective that solely relies on the innovation dimension to explore green innovation is no longer sufficient to comprehensively and effectively address the intricacies of an enterprise's sustainable development (Xi & Zhao, 2022). In addition, the innovation dimension lies in the concept of innovation levels. Only through a hierarchical deconstruction of green innovation can we identify the internal logic governing sustainable development performance improvement at a theoretical level. Continuous green innovation and disruptive green innovation belong to different tiers of green innovation, which can be interpreted through the perspective of continuity or disruption in green technology and product development concerning the enterprise's sustainable development (Wang & Liu, 2020).

In addition, the implementation of a green innovation strategy is contingent upon an organization's internal resource conditions. According to lean production theory, the refined allocation of redundant resources aids enterprises in releasing resources that are either underutilized or overcommitted, thereby promoting innovation and enhancing efficiency. This also assists enterprises in flexibly addressing external risk pressures and encourages them to plan and implement innovative strategies. (Nohria & Gulati, 1996; Troilo *et al*., 2014). Conversely, proponents of agency theory hypothesize that redundant resources can lead to organizational slack, leading to a predilection for risk-averse decision-making and finally hindering innovation (Kim *et al*., 2008; Liu *et al*., 2014). Therefore, the relationship between corporate redundant resources and dual green innovation, particularly its potential to moderate the effects of CSR on dual green innovation and sustainable development performance, necessitates empirical analysis in specific situations.

In conclusion, This study employs a sample of listed manufacturing companies in China from 2012 to 2021 to delve into the practices and outcomes of corporate social responsibility (CSR) from the perspective of industrial engineering. The research incorporates dual green innovation as a mediating variable and redundant resources as a moderating variable. This facilitates the construction of an impact mechanism model explaining the effects and underlying mechanisms through which CSR affects sustainable development performance. The model clarifies the effect of different CSR dimensions on sustainable development, specifically considering their influence on sustainable green innovation and disruptive green innovation under varying levels of resource redundancy. Building upon the study's findings, relevant countermeasures are proposed. The recommendation underscores the pivotal role of industrial engineering in achieving an organic integration of corporate economic benefits with environmental protection, resource utilization, and ecological balance. It provides theoretical insights and practical foundations to assist manufacturing enterprises in addressing the dual challenges of economy and environment, thereby achieving green and sustainable development. The main innovations of this study are reflected in the following three aspects: (1) Based on the dual theory, the introduction of dual green innovation into sustainable development research transforms the enhancement of sustainable development performance from an abstract concept into a concrete pathway. This not only broadens and deepens the research scope and depth of green innovation theory but also enhances the applied value of dual green innovation in sustainable development theory. (2) It clarifies the temporal effects of incremental green innovation and radical green innovation in performance transformation, exploring the underlying logic for sustainable development performance to leap to a higher level. (3) Breaking away from the predominant research status that relies on surveys, this study assesses the diachronic changes in green innovation patents to measure incremental and radical green innovation. Furthermore, based on quantitative analysis, it reveals the impact of corporate social responsibility on dual green innovation and sustainable development performance.

2. THEORETICAL ANALYSIS AND HYPOTHESIS FORMULATION

2.1 Corporate social responsibility and dual green innovation

Enterprises are associated with society, meaning any enterprise isolated from its social network and disregarding green development principles will struggle to maintain long-term viability (Shi *et al*., 2009). This implies that enterprises must integrate social responsibility into their long-term development planning, representing a guiding light for the advancement and execution of green strategies (Xiao *et al*., 2021). CSR can stimulate dual green innovation through at least two avenues. Firstly, it steers enterprises towards dual green innovation through the green requirements of stakeholders. They impose higher green requirements on existing products, technologies, and services, prompting enterprises to engage in continuous green innovation to meet these demands (Zhang & Zhu, 2019; Yu *et al*., 2017). The diversified demand for green products, technologies, and services stimulates enterprises to undertake disruptive green innovation to develop new solutions to satisfy these needs (Xiao *et al*., 2021; Jia *et al*., 2023). Secondly, the resources offered by stakeholders propel dual green innovation in enterprises. Fulfilling corporate social responsibility helps to enhance interactions with stakeholders, thereby acquiring complementary and opportunistic resources through sharing and aggregation of resources (Xiao *et al*., 2021), which in turn promotes dual green innovation within enterprises.

Moreover, corporate social responsibility acts as a magnet for investors (Liu & Wu, 2010). When making investment decisions, investors consider not only the potential return on investment but also the target enterprise's social responsibility track record (Xiao *et al*., 2021). Companies with strong corporate social responsibility performance are more likely to garner investment support, further encouraging enterprises to pursue dual green innovation. Building upon the aforementioned analysis, this study hypothesizes that CSR cultivates dual green innovation through three mechanisms: demand-driven, resource-fueled, and investment incentives. In light of this, this study presents the following hypotheses:

H1a: CSR positively promotes continuous green innovation.

H1b: CSR positively promotes disruptive green innovation.

2.2 Dual green innovation and corporate sustainability performance

This study contends that dual green innovation represents a potent mechanism for balancing the economic and environmental gains of enterprises, thereby cultivating their sustainable development performance. On the one hand, sustaining green innovation addresses the existing demand from stakeholders by optimizing and optimizing established green products, technologies, and services. This allows enterprises to retain a larger market share and secure sustainable development performance with a higher return on investment (Jia *et al*., 2023). Conversely, disruptive green innovation targets the demand from stakeholders, facilitating the development and utilization of novel green products, technologies, and services through technological advancements and optimized management. This empowers enterprises to establish green technological barriers, capture new markets, and finally propel the enhancement of their sustainable development performance (Cao, 2015). In addition, both sustaining and disruptive green innovation can enhance the environmental governance capabilities of enterprises, aiding in the development and improvement of clean energy technologies (Xi & Zhao, 2022). This twofold effect alleviates resource and energy constraints on the sustainable development of enterprises while simultaneously enhancing their resource and energy efficiency, finally leading to improved sustainable development performance (Asiaei *et al*., 2023). In light of these arguments, the following hypotheses are proposed:

H2a: Continuous green innovation positively contributes to corporate sustainability performance.

H2b: Disruptive green innovation positively promotes corporate sustainability performance.

There are differences between sustaining and disruptive green innovation when viewed through a hierarchical perspective, particularly in terms of strategic positioning, resource allocation, and functional effects (Swift, 2016). Therefore, the degree of influence each exerts on the sustainable development performance of enterprises may be different. Sustaining green innovation prioritizes short-term objectives and aims to maintain developmental equilibrium by optimizing and optimizing existing green products, technologies, and services (Qiao *et al*., 2022). This type of innovation is more likely to yield value in a shorter timeframe. In contrast, disruptive green innovation emphasizes long-term goals and seeks to secure sustained competitive advantages through investments in research and development of novel green products, technologies, and services (Dong *et al*., 2022). This type of innovation carries higher risks and longer lead times, making it challenging to increase enterprise value rapidly. Based on this reasoning, the following hypothesis is put forth:

H2c: In the short run, sustaining green innovation contributes more to sustainability performance compared to disruptive green innovation.

H2d: In the long run, disruptive green innovation contributes more to sustainability performance than continuous green innovation.

2.3 Mediating effect of dual green innovation

In the course of fulfilling their social responsibilities, enterprises generate value for stakeholders through diverse avenues such as return on investment, product provision, service enhancement, information dissemination, and more. Through these actions, the social and economic effects of enterprises are solidified and amplified (Wen & Fang, 2008). Regarding the social effect of enterprises, fulfilling social responsibility cultivates recognition and support from stakeholders (Wen & Fang, 2008; Parmar *et al*., 2010; Freeman *et al*., 2021). These stakeholders, accordingly, facilitate the enterprise's dual green innovation through demand guidance, resource provisioning, and investment incentives. In terms of economic effects, CSR fulfillment facilitates the implementation and transformation of green innovation strategies, thereby promoting sustainable development performance (Jia *et al*., 2023; Cao, 2015). In essence, the more enterprises embrace their social responsibility, the more they are driven to actively pursue sustained green innovation and disruptive green innovation, finally leading to enhanced corporate sustainable development performance. In light of this, this study proposes the following hypotheses:

H3a: Sustainable green innovation plays a mediating role between CSR and corporate sustainability performance.

H3b: Disruptive green innovation plays a mediating role between CSR and corporate sustainability performance.

2.4 Moderating effect of precipitating redundant resources

In accordance with the natural resource-based theory, the nature and abundance of enterprise resources affect the risk perception of management decision-makers, affecting the green transformation process of enterprises in terms of resource structure and allocation (Fraj *et al*., 2013). Sedimentary redundant resources represent the portion of resources already committed to a specific production process and engaged in ongoing enterprise operations. This category of resources tends to be highly specialized and difficult to reconfigure (Tan & Peng, 2003), which limits corporate flexibility and simultaneously reinforces the risk-aversion consciousness of corporate managers (Cao & Feng, 2022). The poor liquidity of sedimentary redundant resources leads to increased management complexity and heightened innovation risks, which is detrimental to the swift transformation and utilization of resources (Wang *et al*., 2022). Moreover, such resources increase the company's sunk costs and operational risks (Wang & Hu, 2021), constraining the willingness of managers to make innovative decisions that are challenging. Therefore, the abundance of sedimentary redundant resources intensifies the risk aversion of managers, prompting businesses to lean towards conservative strategies, favoring low-risk persistent green innovation while eschewing high-risk disruptive green innovation. Based on this, this study proposes the following hypotheses:

H4a: The relationship between CSR and persistent green innovation is positively moderated by sedentary redundant resources.

H4b: The relationship between CSR and disruptive green innovation is negatively regulated by precipitating redundant resources.

2.5 Moderating effects of non-sedimentary redundant resources

Compared to sedimentary redundant resources, non-sedimentary redundant resources possess higher flexibility due to their non-committed investment in specific production processes (Su *et al*., 2009), enabling them to effectively alleviate corporate resource constraints and competitive pressures, and bolster the confidence of enterprises in exploration and risk-taking (Tan & Peng, 2003; Suzuki, 2018). On the one hand, non-sedimentary redundant resources enhance the managerial flexibility of enterprises, granting managers greater autonomy, thereby increasing their risk-taking propensity and ability to respond to unforeseen events (Sun *et al*., 2022); on the other hand, non-sedimentary redundant resources can assist enterprises in improving resource allocation efficiency and reducing innovation risks, while mitigating corporate path dependency and stimulating managers' focus on green innovation (Pan *et al*., 2021). Consequently, the abundance of non-sedimentary redundant resources makes corporate managers more willing to take risks, encouraging a preference for disruptive green innovations characterized by high risk and more challenging while reducing investment in incremental green innovations with lower risk profiles. Based on this rationale, this study proposes the following hypothesis:

H5a: Non-sedimentary redundant resources negatively moderate the relationship between CSR and persistent green innovation.

H5b: Non-sedimentary redundant resources positively regulate the relationship between CSR and disruptive green innovation.

Synthesizing the aforementioned research hypotheses, this study presents a mechanistic model illustrating the effect of CSR on sustainable development performance, as depicted in Figure 1.

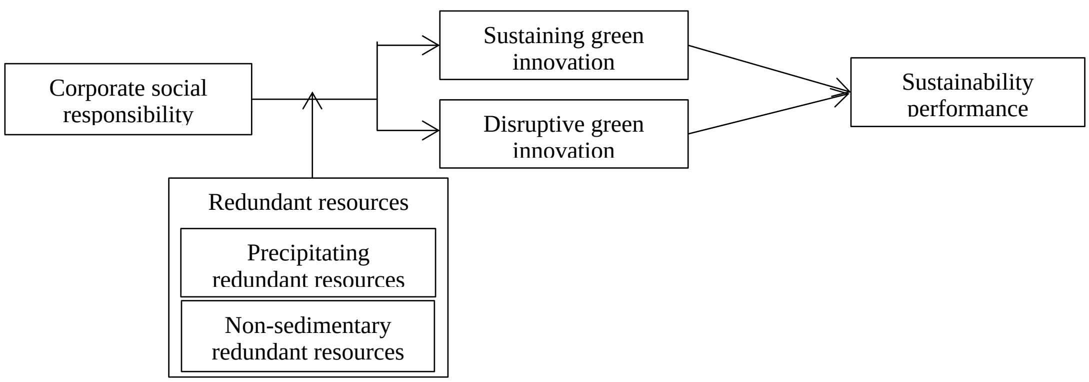


Figure 1. Theoretical model

3. RESEARCH DESIGN

This section primarily presents the data, variable measurement, and the construction of the empirical model. Specifically, Section 3.1 elaborates on the rationale for selecting manufacturing enterprises as the research subjects and the methods of data collection. Section 3.2 introduces the measurement methods for the main variables and the selection of control variables. Section 3.3 primarily establishes the econometric model to investigate the impact of corporate social responsibility on sustainable development performance.

3.1 Sample screening and data collection

Manufacturing enterprises, as critical contributors to China's green economic transition, encounter mounting pressure in both economic advancement and environmental stewardship. Therefore, they exhibit a greater need for external resource support. To address this, our study focuses on A-share listed manufacturing enterprises in the Shanghai and Shenzhen stock exchanges as the research sample. To ensure the reliability and comprehensiveness of the data, the following screening process was implemented: (1) Utilizing the CSMAR database and adhering to the 2012 industry classification standards established by the Securities and Futures Commission, a list of 3,438 listed manufacturing enterprises was compiled. (2) Enterprises categorized as ST or PT during the sample period were excluded, resulting in an optimized pool of 3,355 enterprises. (3) Further exclusions were made for enterprises lacking annual disclosures regarding green patent acquisitions, CSR reports, and other relevant variables in the sample period. Finally, a final sample size of 2,925 was derived from 325 listed companies operating in the manufacturing sector.

3.2 Variable measurement

The variable measurements in this article are all sourced from authoritative scales, and the specific content is as follows.

(1) Sustainable Development Performance. According to the studies of Xie, Fang and Li, Huiming (2005) and Tang, Yongjun *et al*. (2023), this study assessed corporate sustainability performance through a multi-step process. First, the ratio of total business revenue to sewage charges was computed utilizing the eco-efficiency method formula. Secondly, drawing upon established research (Xi & Zhao, 2022; Wang & Kang, 2023), the total return on assets is measured by EBIT*2/ (total assets at the beginning of the period + total assets at the end of the period). Finally, an entropy weight sum of these two measures was calculated to represent overall corporate sustainability performance (Xi & Zhao, 2022; Liu & Guo, 2023).

(2) Dual Green Innovation. According to Zeng *et al*. (2015), this study defines technological breakthroughs as new technological classifications or combinations in a specific timeframe. Consistent with recommendations for evaluating technological knowledge bases (Zhu & Xu, 2021), a three-year window was employed to measure technological change in R&D units. Persistent green innovation was operationalized as a dual variable, coded as 1 if an R&D unit possessed patents with the same green technology classification or combination as in the preceding three years and 0 otherwise. Similarly, disruptive green innovation was coded as 1 if an R&D unit held patents with different green technology classifications or combinations compared to the previous three years and 0 otherwise.

(3) Corporate Social Responsibility. This study assessed corporate social responsibility performance utilizing the approach outlined by Xiao and Li (2022), which leverages listed companies' CSR scores by Hexun.com. The comprehensive rating system of Hexun comprises 56 indicators across five primary dimensions: shareholder responsibility, employee responsibility, supplier and consumer responsibility, environmental responsibility, and social responsibility. These dimensions are further elaborated through 13 second-level indicators and 38 third-level indicators.

(4) Redundant Resources. In alignment with the methodologies of Yang *et al*. and Ji *et al*. (Yang *et al*., 2015; Ji *et al*., 2019), this study employed two measures of redundant resources. The expense-to-income ratio is a proxy for precipitated redundant resources (AS), while the current ratio measures non-sedimentary redundant resources (HDS).

(5) Control Variables. Recognizing the effect of an enterprise's fundamental characteristics on sustainable development performance, this study primarily controls for variables related to corporate financial characteristics, governance features, and market competition, selecting firm size (Size), firm age (Age), financial leverage (Lev), research and development intensity (R&DI), and market share (SOM) as control variables. Moreover, to account for regional and ownership heterogeneity, dummy variables for region and property rights were also introduced.

Table 1. Variable measures and data sources

<table>
<tr><th>Variable Name</th><th>Indicator</th><th colspan="2">Measurement method</th><th>Data sources</th></tr>
<tr><td rowspan="2">Sustainable Development Performance</td><td rowspan="2">Composite Indicator (Ews)</td><td>enterprise Operating Revenue/Pollution Fee</td><td rowspan="2">Entropy Weight</td><td rowspan="2">CNRDS Database and CSMAR Database</td></tr>
<tr><td>Pre-tax Profit * 2/(Beginning Total Assets + Ending Total Assets)</td></tr>
<tr><td rowspan="2">Dual-Element Green Innovation</td><td>Continuous Green Innovation (EGI)</td><td colspan="2">dual variable, value is 1 when the R&D unit generates patents in the same technological area as the enterprise's previous 3 years, otherwise 0</td><td rowspan="2">CNRDS Database and CSMAR Database</td></tr>
<tr><td>Disruptive green innovation (PGI)</td><td colspan="2">dual variable, value is 1 when the R&D unit generates patents in technical categories or combinations not present in the enterprise's previous 3 years, otherwise 0</td></tr>
<tr><td>Corporate Social Responsibility</td><td>Corporate Social Responsibility Score (CSR)</td><td colspan="2">The CSR score of a listed company measures its performance in corporate social responsibility</td><td>Hexun Database</td></tr>
<tr><td rowspan="2">Redundant Resources</td><td>Sediment Redundant Resources (AS)</td><td colspan="2">(Operating Expenses + Management Expenses + Financial Expenses)/Sales Revenue</td><td rowspan="2">CSMAR Database</td></tr>
<tr><td>Non-sediment Redundant Resources (HDS)</td><td colspan="2">Current Assets/Current Liabilities</td></tr>
</table>

Variable Name	Indicator	Measurement method	Data sources
Enterprise Size	Enterprise Size (Size)	Logarithmic value of total assets of the enterprise	CSMAR Database
Enterprise Age	Years Listed (Age)	Years from the year of listing to the selected year	CSMAR Database
Financial Leverage	Debt-to-Asset Ratio (Lev)	Total Liabilities/Total Assets	CSMAR Database
Market Competition	Research and Development Intensity (R&DI)	R&D expenses/Operating income	CSMAR Database
	Market Share (SOM)	The sum of the main business income of the current year / The main business income of the industry in the current year	CSMAR Database
Regional Attribute	Regional Dummy Variable (District)	Value of 1 for East Coast, value of 0 for Central and Western regions	CSMAR Database
Property Rights Attribute	Property Rights Dummy Variable (State)	State-owned enterprises are recorded as 1, non-state-owned enterprises as 0	CSMAR Database

3.3 Model design

To verify the hypotheses mentioned above, this study constructs the following regression models. Firstly, construct the model to examine the impact of Corporate Social Responsibility on Dual-Element Green Innovation. Where the dependent variable $\mathrm{Y} = \{\mathrm{EGI}, \mathrm{PGI}\}^{\mathrm{T}}$ measures Continuous Green Innovation and Disruptive green innovation; the independent variable (X = $=\{\mathrm{CSR}\}^{T}$ measures Corporate Social Responsibility, and the variables controls include $\{\mathrm{Size}, \mathrm{Age}, \mathrm{Lev}, \mathrm{R\&DI}, \mathrm{SOM}\}^{\mathrm{T}}$.

$$\mathrm{Y_{it}} = \beta_0 + \beta_1 \mathrm{X_{it}} + \beta_i \text{ Controls }_{it} + \varepsilon_{it} \quad (1)$$

Secondly, build a model to investigate the impact of Dual-Element Green Innovation on Corporate Sustainable Development Performance. Where the dependent variable (Y = {Ews}) measures Corporate Sustainable Development Performance; the independent variable ($\mathrm{X} = \{\mathrm{EGI}, \mathrm{PGI}\}^{\mathrm{T}}$) measures Continuous Green Innovation and Disruptive green innovation; and the control variables remain the same.

$$Y_{it} = \alpha_0 + \alpha_1 X_{it} + \alpha_i \; Controls\;_{it} + \varepsilon_{it} \quad (2)$$

Thirdly, create a mediation model to explore the mechanism of Dual-Element Green Innovation between Corporate Social Responsibility and Corporate Sustainable Development Performance. Where the independent variable ($\mathrm{X} = \{CSR\}^{T}$) measures Corporate Social Responsibility; the mediator variable ($\mathrm{M} = \{\mathrm{EGI}, \mathrm{PGI}\}^{\mathrm{T}}$ measures Continuous Green Innovation and Disruptive green innovation; and the control variables remain the same.

$$\mathrm{Y_{it}} = \mu_0 + \mu_1 \mathrm{X_{it}} + \mu_2 \mathrm{M_{it}} + \mu_i \text{ Controls }_{it} + \varepsilon_{it} \quad (3)$$

Finally, construct a model to study the moderating effect of Redundant Resources on Corporate Social Responsibility and Dual-Element Green Innovation. Where the dependent variable (Y) and the independent variable (X) are constructed as in model (1); the moderating variable ($\mathrm{M} = \{\mathrm{AS}, \mathrm{HDS}\}^{\mathrm{T}}$) measures Sediment Redundant Resources and Non-sediment Redundant Resources; and the control variables remain the same.

$$\begin{cases} \mathrm{Y_{it}} = \alpha_i + \theta_1 X_{it} + \theta_2 M_{it} + \theta_i \; Controls\;_{it} + \varepsilon_{it} \\ \mathrm{Y_{it}} = \gamma_0 + \gamma_1 X_{it} + \gamma_2 M_{it} + \gamma_3 X_{it} \times M_{it} + \gamma_k \; Controls\;_{it} + \epsilon_{it} \end{cases} \quad (4)$$

4. ANALYSIS OF EMPIRICAL RESULTS

4.1 Descriptive statistical analysis

In this study, to reduce the effect of outliers on the data analysis, continuity indicators exhibiting significant bias were subjected to a 1% Winsorization procedure. Table 2 presents the descriptive statistics for each variable. The sample enterprises demonstrate a mean sustainability performance of 0.229, a minimum value is 0.008, and a maximum value is 0.938, indicating a large degree of dispersion among the samples. The mean values for continuity green innovation and disruptive green innovation are 0.390 and 0.336, respectively. In addition, the average CSR score is 25.807. These findings suggest that disruptive green innovation among the sample enterprises leans towards the lower end of the spectrum, while the level of continuity green innovation is significantly higher. Table 3 displays the correlation coefficients of the main variables. Specifically, none of the coefficients exceed 0.5, and the variance inflation factor remains below 5, effectively ruling out the presence of multicollinearity.

Table 2. Descriptive statistics of variables

Variable	N	Mean	Standard Deviation	Minimum	Maximum
Ews	2,910	0.229	0.123	0.008	0.938
EGI	2,910	0.390	0.488	0	1
PGI	2,910	0.336	0.472	0	1
CSR	2,910	25.807	17.448	-1.550	77.150
AS	2,910	0.291	0.162	0.038	0.874
HDS	2,910	1.834	1.107	0.434	5.730
Size	2,910	23.040	1.344	19.840	27.550
Age	2,910	18.580	6.380	3	63
Lev	2,910	0.488	0.167	0.047	0.925
R&DI	2,910	0.019	0.032	0	0.349
SOM	2,910	0.029	0.069	0.001	1
District	2,910	0.557	0.497	0	1
State	2,910	0.435	0.496	0	1

Table 3. Results of correlation analysis of variables

Variable	(Ews)	(EGI)	(PGI)	(CSR)	(AS)	(HDS)
Ews	1	0.049***	0.113***	0.062***	-0.035*	0.029
EGI	0.084***	1	0.256***	0.414***	-0.022	0.142***
PGI	0.131***	0.256***	1	0.461***	0.014	0.460***
CSR	0.032*	0.429***	0.483***	1	-0.118***	0.318***
AS	-0.042**	-0.029	0.009	-0.079***	1	0.124***
HDS	0.057***	0.103***	0.475***	0.232***	0.093***	1

Note: The lower triangle shows Pearson correlation coefficients, and the upper triangle shows Spearman correlation coefficients; *** p<0.01, ** p<0.05, * p<0.1

4.2 Basic Regression Results Analysis

The validation analysis of the regulatory effect of this study is as follows :(1) The effect of corporate social responsibility on Dual Green Innovation. Aligning with hypothesis H1 and the specifications of Model (1) and considering the dual dummy variable nature of dual green innovation, Logit and Probit models were employed for regression analysis. This is due to the fact that compared to the Linear Probability Model, Logit and Probit models allow for the capture of the linear impact of independent variables on the probability of a binary dependent variable. The regression results are presented in Table 4.

Table 4. Regression results of corporate social responsibility on dual green innovation

Dependent Variable	Sustainable Green Innovation (EGI)		Disruptive Green Innovation (PGI)	
Model	M1 (Logit)	M2 (Probit)	M3 (Logit)	M4 (Probit)
CSR	0.059*** (0.003)	0.035*** (0.001)	0.067*** （0.003）	0.039*** (0.002)
Size	0.078* (0.043)	0.047* (0.026)	-0.019 （0.048）	-0.019 (0.028)
Age	0.006 (0.007)	0.004 (0.004)	-0.011 （0.008）	-0.006 (0.005)
Lev	-0.231 (0.312)	-0.135 (0.186)	-2.0245*** （0.338）	-1.116*** (0.195)
R&DI	-3.425** (1.454)	-2.012** (0.850)	-5.177*** (1.657)	-2.713*** (0.888)
SOM	-0.113 (0.730)	-0.059 (0.438)	0.511 (0.791)	0.376 (0.461)
Intercept	-3.708*** (0.887)	-2.226*** (0.531)	-0.809 （0.9678）	-0.357 (0.563)
Observations	2910	2910	2910	2910
R^2	0.149	0.148	0.210	0.208

Note: *** p<0.01, ** p<0.05, * p<0.1

Models M1 and M3 indicate a significantly positive effect of CSR on both sustaining green innovation and disruptive green innovation. This implies that CSR practices not only significantly contribute to enterprises' ongoing green innovation behaviors but also equally enhance their engagement in disruptive green innovation. The regression results of Models M2 and M4 further corroborate the positive effect of CSR on both types of green innovation (β=0.035, $p<0.01$; β=0.039, $p<0.01$). Therefore, research hypotheses H1a and H1b are supported.

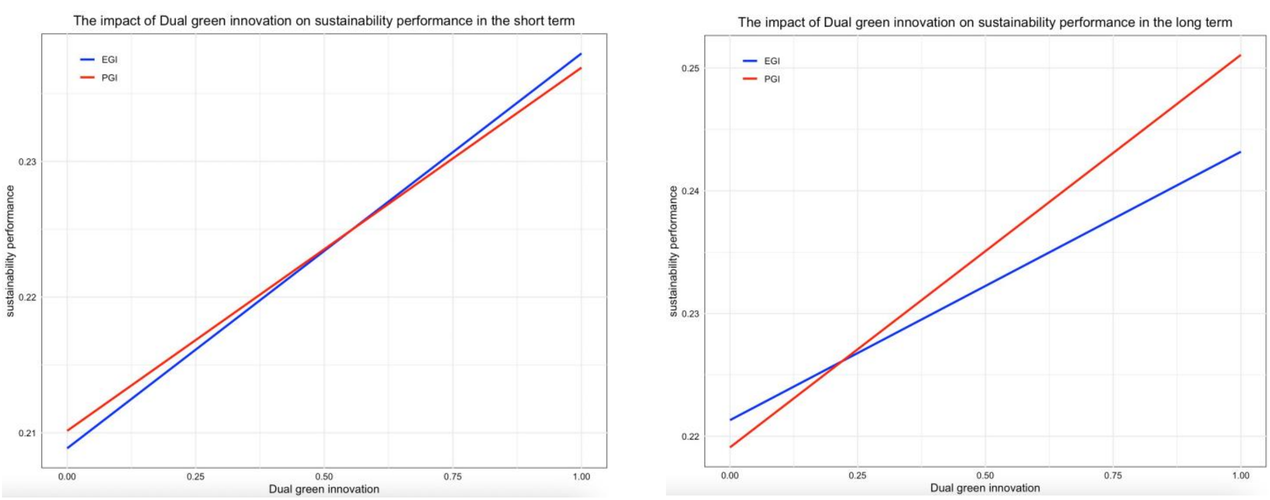
(2) The effect of dual green innovation on sustainable development performance verifies the difference between sustainable green innovation and disruptive green innovation on sustainable development performance in different time intervals. This study segments the manufacturing industry's innovation cycle into short-term and long-term periods. The research focused on "innovation cycles" typically defines these cycles based on innovation activities in 5 or 10-year intervals (Zheng *et al*., 2020), aligning our 5-year boundary between short- and long-term with established international practice. Therefore, this study employs a 5-year threshold to differentiate between short-term (5 years) and long-term (10 years) effects and evaluates them independently. The results are presented in Table 5. Models M5 and M6 specifically assessed the short-term effect of dual green innovation on corporate sustainability performance. The findings indicate that both forms of corporate dual green innovation exert a positive effect on sustainability performance in the short term (β_{EGI}=0.017, $p < 0.01$; β_{EGI}=0.008, $p < 0.1$). In addition, sustained green innovations demonstrate a more significant and positive effect on short-term sustainability performance compared to disruptive green innovations. Models M7 and M8 explored the long-term effects of dual green innovations on enterprises' sustainability performance. The results indicate that both types of corporate dual green innovation maintain a positive effect on sustainability performance in the long run (β_{EGI}=0.012, $p < 0.01$; β_{EGI}=0.017, $p < 0.01$). Intriguingly, the positive effect of disruptive green innovations on sustainability performance appears to be greater in the long term compared to sustaining green innovations. Thus validating hypotheses H2a, H2b, H2c, and H2d. To facilitate a more intuitive understanding, we utilized the R programming language to create visual representations of the impact of dual-dimensional green innovation on sustainable development performance over both the short and long terms, as depicted in Figure 2.

Table 5. Regression results of dual green innovation on sustainability performance
The long-term and short-term effects of sustaining green innovations on sustainability performance

Dependent Variable	**Sustainable Development Performance (Ews)**			
	Short-term (2012-2016)		**Long-term (2012-2021)**	
Model	**M5**	**M6**	**M7**	**M8**
EGI	0.017*** (0.004)		0.012*** (0.003)	
FGI		0.008*		0.017***

Dependent Variable	Sustainable Development Performance (Ews)			
	Short-term (2012-2016)		Long-term (2012-2021)	
Model	M5	M6	M7	M8
		(0.004)		(0.003)
Size	0.022*** (0.008)	0.024*** (0.008)	0.008* (0.005)	0.007* (0.004)
Age	-0.004** (0.002)	-0.004** (0.002)	-0.002 (0.001)	-0.002 (0.001)
Lev	-0.097*** (0.030)	-0.096*** (0.030)	-0.079*** (0.019)	-0.073*** (0.019)
R&DI	-0.119 (0.162)	-0.137 (0.164)	-0.057 (0.083)	-0.073 (0.083)
SOM	0.199 (0.128)	0.182 (0.128)	0.115 (0.074)	0.101 (0.074)
Intercept	-0.165 (0.187)	-0.200 (0.188)	0.097 (0.104)	0.105 (0.104)
Observations	1455	1455	2910	2910
F	16.620	16.400	20.540	20.660
R^2	0.811	0.809	0.706	0.707
Individual Effects	Yes	Yes	Yes	Yes
Time Effects	Yes	Yes	Yes	Yes

Note: *** p<0.01, ** p<0.05, * p<0.1



(a) Short-term (b) Long-term

Figure 2. The Impact of Dual-Dimensional Green Innovation on Sustainable Development Performance: (a) Short-term and (b) Long-term

4.3 Mediating effect test

After verifying the mediating effect of this study, the results are as follows: Hypothesis H3 is tested with the hierarchical mediator variable regression analysis methodology proposed by Wen Zhonglin *et al*. Table 6 displays the regression results of model (3). Models M9 and M10 specifically evaluate the mediating role of persistent green innovation and disruptive green innovation in CSR's effect on sustainability performance, respectively, with the calculation process and results detailed in Table 7. The coefficients and standard deviations pertaining to the effect of CSR on dual green innovation and the combined effect of both on sustainability performance are derived from the results presented in Tables 4 and 6.

Table 6. Regression results of mediating effect

Dependent Variable	Sustainable Development Performance (Ews)			
	Estimate	(S.E)	Estimate	(S.E)
Model	M9		M10	
EGI	0.012***	0.003		
PGI			0.017***	0.003
CSR	0.001	0.001	0.001	0.001
Size	0.007	0.005	0.007*	0.004
Age	-0.002	0.001	-0.002	0.001
Lev	-0.078***	0.019	-0.073***	0.019
R&DI	-0.055	0.083	-0.072	0.083
SOM	0.113	0.074	0.100	0.074
Intercept	0.104	0.104	0.108	0.104
Observations	2910		2910	
F	20.470		20.580	
R^2	0.706		0.707	
Individual Effects	Yes		Yes	
Time Effects	Yes		Yes	

Note: *** p<0.01, ** p<0.05, * p<0.1

Integrating the results from Tables 4, 6, and 7 leads to the following conclusions: Utilizing corporate social responsibility as the independent variable, sustainable development performance as the dependent variable, and sustainable green innovation as the mediating variable indicates a significant mediating effect in the model (Z=4.028>1.96). Similarly, when employing disruptive green innovation as the mediating variable, the mediating effect remains significant (Z=5.582>1.96). This suggests that the positive effect of corporate social responsibility on sustainable development performance is realized through two pathways: sustainable green innovation and disruptive green innovation in the enterprise. Therefore, both hypothesis H3a and hypothesis H3b are confirmed.

Table 7. Mediation effect test table for dual green innovation

	β	S_β	Z_β	μ	S_μ	Z_μ	$Z_{\beta\times\mu}$	$\sigma_{\beta\mu}$	Zm
CSR→EGI→Ews	0.059	0.003	23.240	0.012	0.003	4.269	99.212	24.629	4.028
CSR→PGI→Ews	0.067	0.003	26.827	0.017	0.003	5.925	158.949	28.474	5.582

4.4 Moderating effect test

After verifying the regulatory effect of this study, the results are as follows:

(1) Moderating Effect of Sedimentary Redundant Resources on CSR: Hypothesis H4, analyzed through Model (4) and presented in Table 8, evaluates the moderating role of sedimentary redundant resources on the relationship between CSR and green innovation. The results indicate no significant effect of the interaction term between sedimentary redundant resources and CSR (CSRÏAS) on either persistent green innovation (β=0.011, p>0.1) or disruptive green innovation (β=-0.034, p>0.1). The variance inflation factors (VIFs) are all less than 5, indicating that there is no issue of multicollinearity among the explanatory variables. Hypothesis H4 is not supported. This finding aligns with the suggestion by Yang Jing *et al*. (2015) that green innovation necessitates high resource flexibility due to the redesign of existing production processes and technologies. Since sedimentary redundant resources tend to be specialized and less flexible, the non-significant results are reasonable.

Table 8. Test of the moderating effect of precipitating redundant resources on CSR and dual green innovation

Dependent Variable	**Sustainable Green Innovation (EGI)**		**Disruptive Green Innovation (PGI)**	
Model	**M11**	**M12**	**M13**	**M14**
CSR	0.059*** （0.003）	0.059*** (0.003)	0.063*** (0.004)	0.063*** (0.004)
AS	0.221 （0.287）	0.248 (0.293)	0.064 (0.321)	-0.006 (0.329)
CSR×AS		0.011 (0.019)		-0.034 (0.021)
Controls	YES	YES	YES	YES
Enterprise/Year fixed	YES	YES	YES	YES
Intercept	-3.754*** （0.946）	-3.762*** (0.946)	-4.009*** (1.092)	-3.988*** (1.092)
Observations	2910	2910	2910	2910
R^2	0.148	0.148	0.341	0.342

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 9. Test of the moderating effect of non-depletable redundant resources on corporate social responsibility and dual green innovation

Dependent Variable:	**Sustainable Green Innovation (EGI)**		**Disruptive Green Innovation (PGI)**	
Model	**M14**	**M15**	**M16**	**M17**
CSR	0.059*** （0.003）	0.058*** (0.003)	0.059*** (0.004)	0.066*** (0.005)
HDS	0.021 （0.045）	0.010 (0.047)	1.355*** (0.099)	1.469*** (0.105)
CSR×HDS		0.005* (0.003)		0.023*** (0.007)
Controls	YES	YES	YES	YES
Enterprise/Year fixed	YES	YES	YES	YES
Intercept	-3.575*** （0.899）	-3.486*** (0.898)	-9.071*** (1.197)	-9.221*** (1.200)
Observations	2910	2910	2910	2910
R^2	0.148	0.149	0.444	0.448

Note: *** p<0.01，** p<0.05，* p<0.1

(2) Moderating Effect of Non-Sedimentary Redundant Resources on CSR: Hypothesis H5, analyzed utilizing Model (4) and displayed in Table 9, explores the moderating effect of non-sedimentary redundant resources on the CSR-green innovation relationship. The results indicate a significant positive effect of the interaction term between non-sedimentary redundant resources and CSR (CSRÏHDS) on both persistent green innovation (β=0.005, p<0.1) and disruptive green innovation (β=0.023, p<0.01). The variance inflation factors (VIFs) are all less than 5, indicating that there is no issue of multicollinearity among the explanatory variables. While Hypothesis H5b is tested, it is demonstrated that it contradicts the moderating effect proposed in Hypothesis H5a. This study suggests that enterprises abundant in non-sedimentary redundant resources, despite their higher risk tolerance, may leverage external resources acquired through corporate social responsibility fulfillment to supplement internal innovation resources. This enables them to strike a balance between persistent and disruptive green innovation in their overall innovation development strategies. Therefore, the observed results, while opposing the Hypothesis H5a prediction, possess a certain rationale. Figure 3 further illustrates that the effect of CSR on dual green innovation is amplified with higher levels of non-sedimentary redundant resources and reduced when these resources are scarce. Therefore, Hypothesis H5b is validated despite the contrasting findings concerning the moderating effect proposed in Hypothesis H5a.

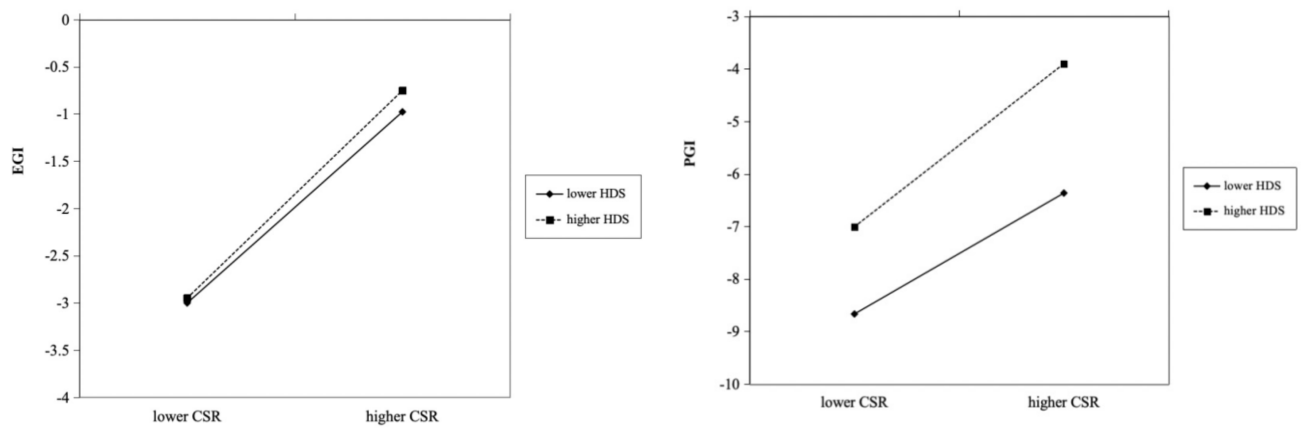


Figure 3. The moderating effect of non-sedimentary redundant resources on CSR and dual green innovation

4.5 Endogeneity and robustness test

Considering the potential effect of national environmental protection policies on corporate behavior and, therefore, on CSR practices, the presence of endogeneity bias is a concern. To address this, the study employs the first-order lagged terms of both CSR (Lcsr) and government environmental subsidies (CEG) as instrumental variables (focusing on the CSR→EGI pathway). The results of Model M19 presented in Table 10 indicate that CSR has a significantly positive effect on sustained green innovation (β =0.015, $p<0.01$), aligning with previous research findings.

In addition, the potential for reciprocal causation between dual green innovation and corporate sustainability performance necessitates addressing the endogeneity of dual green innovation in hypothesis H2 testing. A two-stage instrumental variable approach is employed for this purpose. Recognizing the close association between government environmental subsidies and dual green innovation, they are considered suitable instrumental variables. Specifically, the first-order lag terms of persistent green innovation (Legi) and disruptive green innovation (Lpgi), along with government environmental subsidies (CEG), represent instrumental variables for persistent and disruptive green innovation, respectively. Models M21 and M22 demonstrate that both sustaining green innovation and disruptive green innovation exert a significant positive effect on corporate sustainability performance (β=0.047, $p<0.05$; β=0.170, $p<0.01$), corroborating prior research.

To ensure the reliability of these findings, several robustness checks were conducted. Regarding hypothesis H1, considering the comparatively lower economic development of Xinjiang, Qinghai, and Gansu provinces, data from these regions were excluded to reduce sample bias. The results remained consistent with the original model. For hypothesis H2, sample enterprises' CSI ESG scores were employed as a proxy for corporate sustainability performance, and a mixed regression robust estimation method was applied, with results presented in Part III of Table 10. Model M24 indicates a significant positive coefficient (β=0.013, $p<0.05$) for the effect of sustained green innovation on sustainability performance, confirming a significant positive promoting effect. Similarly, model M25 demonstrates a significant positive effect of disruptive green innovation on sustainable development performance (β=0.023, $p<0.01$), further supporting the study's conclusions and demonstrating its robustness.

Table 10. Endogeneity and robustness test regression analysis

	Endogeneity Test I		**Endogeneity Test II**				**Robustness Test III**	
Dependent Variable	**CSR**	**EGI**	**EGI**	**PGI**	**Ews**	**Ews**	**Esg**	**Ews**
Stage	**First**	**Second**	**First**	**First**	**Second**	**Second**		
Model	**M18**	**M19**	**M20**	**M21**	**M22**	**M23**	**M24**	**M25**
EGI					0.047** (0.022)	0.170*** (0.026)	0.435** （0.193）	0.013** （0.005）
PGI							0.803*** (0.207)	0.023*** (0.005)
CSR		0.015***						

		(0.001)						
GES	33.939*** (4.494)		1.429*** (0.171)	0.271* (0.162)				
Lcsr	0.427*** (0.016)							
Legi			0.145*** (0.019)					
Lpgi				0.189*** （0.019）				
Intercept	-22.056*** (4.803)	-0.081 (0.199)	-0.480*** (0.176)	-0.205* (0.166)	0.183*** (0.049)	0.200*** (0.046)	45.882*** (1.741)	0.099** (0.041)
Control variables	控制	控制	控制	控制	控制	控制	控制	控制
Observations	2619	2619	2619	2619	2619	2619	2910	2910
R^2	0.439	0.174	0.068	0.080	0.025	0.039	0.127	0.030

Note: *** p<0.01, ** p<0.05, * p<0.1

5. RESEARCH CONCLUSION AND INSIGHTS

5.1 Research Conclusion

Drawing upon the natural resource base theory and stakeholder theory, this study evaluates the effect of CSR on dual green innovation and sustainable development performance. Utilizing a balanced panel dataset of Shanghai and Shenzhen A-share listed manufacturing enterprises from 2012 to 2021, and the research indicates the following key findings:

(1) CSR significantly cultivates both sustained and disruptive green innovation. By addressing stakeholders' higher demand for higher green requirements for existing products, technologies, and services, enterprises are incentivized to pursue continuous green innovation. Simultaneously, CSR encourages disruptive green innovation to meet the diverse green requirements of stakeholders for existing products, technologies, and services. Moreover, corporate social responsibility facilitates access to complementary resources, enhancing existing products, technologies, and services and propelling continuous green innovation. Besides, it unlocks opportunistic resources that enable enterprises to develop novel products, technologies, and services based on new ideas, thereby stimulating disruptive green innovation. The conclusion is equally applicable to European countries. The European Union's Corporate Sustainability Reporting Directive (CSRD) requires companies to promote sustainable development from the inside out and from the top down, integrating it into various aspects such as strategic planning, daily operations, risk control, and supply chain management upstream and downstream. This implies that when fulfilling Corporate Social Responsibility (CSR), European companies must consider not only internal green innovation but also the sustainability of the entire value chain. The 'strictest ever' ESG regulatory requirements faced by European companies necessitate the establishment or optimization of ESG management systems to meet higher market demands, which will enhance the positive relationship between corporate social responsibility and dual-dimensional green innovation (Lončar *et al.*, 2019).

(2) Dual green innovation significantly enhances sustainable development performance. Continuous green innovation, driven by a focus on stakeholders' existing demands, leads to product improvements, technological advancements, and service optimization. Therefore, enterprises can strengthen and expand market share while boosting revenue. Disruptive green innovation, on the other hand, addresses stakeholders' evolving needs, enabling enterprises to overcome technological barriers, enhance their competitive edge, and capture new markets, thus reaping benefits from additional market segments. In addition, both forms of green innovation contribute to enhanced resource and energy efficiency, leading to competitive environmental advantages and enhanced environmental performance. Specifically, the study indicates that sustained green innovation contributes more significantly to sustainability performance in the short term, while disruptive green innovation exerts a stronger effect in the long run.

(3) Non-sedimentary redundant resources positively moderate the relationship between CSR and dual green innovation. When such resources are abundant, enterprises exhibit a greater willingness to embrace innovation risks and are more inclined to fulfill their social responsibilities by investing acquired external resources into green innovation. Therefore, the positive association between CSR and dual green innovation is amplified.

5.2 Management implications

To ensure the scientific rationality of the management insights proposed, this study puts forward management implications based on an analytical framework that progresses from empirical conclusions to case exemplification and finally to the distillation of management insights.

Lenovo Group has actively responded to the national "dual-carbon" strategy by incorporating green and low-carbon goals into its development objectives. Through the implementation of Corporate Social Responsibility (CSR) principles, Lenovo has achieved its own low-carbon transformation and has propelled high-quality green development upstream and downstream in its supply chain. Lenovo's products and services, such as zero-carbon services, green factories, and green supply chains, directly address market demands for green products, guiding Lenovo to implement green innovation in product design, material selection, production processes, packaging, and logistics, thereby meeting stakeholders' requirements for environmental protection and sustainability. In the process of promoting green innovation, Lenovo Group introduced the "Green Development Scorecard" to manage suppliers and collaborated with them to secure complementary and opportunistic resources, fostering the construction and innovation of green supply chains, such as reducing energy consumption and carbon emissions in the assembly process of electronic components through the use of low-temperature solder paste technology. Furthermore, Lenovo Group's CSR practices have enhanced the company's image. By publishing sustainability reports, Lenovo has showcased its efforts and achievements in sustainable development, successfully attracting investment and providing financial support for its green innovation and long-term growth. These practices have not only improved Lenovo Group's sustainable development performance but also contributed to global environmental governance.

Based on the research conclusions and corporate practice cases, this study proposes management insights from the following aspects:

First, the government should progressively optimize the CSR governance system, establishing and enhancing relevant policies to leverage the effect of CSR in propelling dual green innovation. This includes formulating and continually enhancing laws and regulations related to CSR incentives, evaluations, rewards, and penalties. Through policy incentives and institutional constraints, enterprises will be motivated to cultivate a sense of social responsibility, directing their attention toward the internal and external requirements of green and sustainable development. Accordingly, this will activate the driving force behind dual green innovation in enterprises. Besides, the government should establish platforms for resource sharing among enterprises actively engaged in social responsibility. This would facilitate the exchange of green development expertise and the sharing of green innovation resources between polluting enterprises and their related enterprises, thereby offering robust social support for the green and sustainable growth of enterprises.

Secondly, enterprises should establish green innovation platforms that involve multiple stakeholders, collecting feedback and cultivating an innovation ecosystem centered around green requirements. Internally, enterprises should empower employees to participate in green innovation and implement reward mechanisms to encourage their contribution of ideas towards the enterprise's green development objectives. Externally, enterprises should broaden communication channels with government bodies, customers, suppliers, and other stakeholders. Regular green requirements research should be conducted, encouraging external stakeholders to express their green requirements from various perspectives. This will promote sustainable green innovation and disruptive green innovation of the enterprise.

Finally, enterprises must prioritize the rational allocation of non-sedimentary redundant resources to fully capitalize on their positive effect on the relationship between CSR and dual green innovation. Management should adopt differentiated resource allocation strategies based on the specific characteristics of each innovation type. For instance, in terms of the quantity and diversity of input resources, priority should be given to disruptive green innovation to achieve greater marginal gains and maximize overall utility.

5.3 Research shortcomings and prospects

This study is not without certain limitations that necessitates consideration: (1) The analysis focuses solely on the internal factor of redundant resources as a regulatory mechanism in the CSR-dual green innovation relationship. Future research could incorporate external factors, such as governmental policies and media scrutiny, to develop a more holistic theoretical model. (2) While this study has validated the model's effectiveness within Chinese manufacturing enterprises, it has not yet undergone extensive empirical testing in other industries or under the contexts of different countries. Therefore, future research should extend the model, as validated in this study within Chinese manufacturing firms, to other sectors such as service and technology, as well as to different countries, to test its generalizability and to deepen longitudinal analyses to more finely explore the model's dynamic changes and long-term trends over time.

FUNDING

This project is supported by The Project of Cultivation for young top-motch Talents of Beijing Municipal Institutions (BPHR202203211), 2024 Ministry of Culture and Tourism Ministerial Social Science Research Program (24DY10).

REFERENCES

Asiaei, K., O'Connor, N.G., Barani, O., et al. (2023). Green Intellectual Capital and Ambidextrous Green Innovation: The Impact on Environmental Performance. *Business Strategy and the Environment*, 32(1):369-386.

Belas, J., Çera, G., Dvorský, J. and Cepel, M. (2021). Corporate Social Responsibility and Sustainability Issues of Small-and Medium-Sized Enterprises. *Corporate Social Responsibility and Environmental Management*, 28(2):721-730.

Cao, C. (2015). Research on Green Innovation and Competitive Advantage of Resource-based Enterprises. *Shanxi University of Finance and Economics*.

Cao, C. and Feng, J. (2022). The Influence of Redundant Resources on the Selection of Green Innovation Models: An Integrated Perspective of Environmental Regulation. *Management Review*, 34(05):124-135.

Dong, B., Cheng, S. and Zhang, L. (2022). Review of Dual Innovation Research and Suggestions for Conducting China-Specific Studies. *Chinese Journal of Management*, 19(02):308-316.

Fraj, E., Martínez, E. and Matute, J. (2013). Green Marketing in B2B Organizations: An Empirical Analysis from the Natural-Resource-Based View of the Firm. *Journal of Business & Industrial Marketing*, 28(5):396-410.

Freeman, R.E., Dmytriyev, S.D. and Phillips, R.A. (2021). Stakeholder Theory and the Resource-Based View of the Firm. *Journal of Management*, 47(7):1757-1770.

Ji, H., Xu, G., Zhou, R., et al. (2019). Corporate Social Responsibility, Non-Depositable Redundant Resources, and Dual Technological Innovation. *Science and Technology Progress and Policy*, 36(15):69-76.

Jia, T., Yan, R., Wang, Y., et al. (2023). Customer Participation, Dual Green Innovation, and Firm Performance—The Moderating Role of Product Intelligence. *Science and Technology Progress and Policy*, 40(07):91-101.

Kim, H., Kim, H. and Lee, P.M. (2008). Ownership Structure and the Relationship between Financial Slack and R&D Investments: Evidence from Korean Firms. *Organization Science*, 19(3):404-418.

Li, W., Zhang, Y., Zheng, M., et al. (2019). Research on Green Governance and Evaluation of Listed Companies in China. *Management World*, 35(05):126-133+160.

Liu, F. and Wu, Z. (2010). Corporate Social Responsibility in International Investment: A Perspective from China. *Seeking Truth*, (10):106-108.

Liu, H., Ding, X., Guo, H. and Luo, J. (2014). How Does Slack Affect Product Innovation in High-tech Chinese Firms: The Contingent Value of Entrepreneurial Orientation. *Asia Pacific Journal of Management*, 31(1):47-68.

Liu, J. and Guo, L. (2023). The Impact of Digital Transformation on Corporate Sustainable Development Performance. *Financial Theory and Practice*, (12):1-13.

Lončar, D., Paunković, J., Jovanović, V., et al.(2019). Environmental and Social Responsibility of Companies Cross EU Countries ‑ Panel Data Analysis. *Science of the Total Environment*, 657: 287-296.

Montiel, I. (2008). Corporate Social Responsibility and Corporate Sustainability: Separate Pasts, Common Futures. *Organization & Environment*, 21(3):245-269.

Nohria, N. and Gulati, R. (1996). Is Slack Good or Bad for Innovation? *Academy of Management Journal*, 39(5):1245-1264.

Pan, R., Luo, J. and Yang, Z. (2021). The Study on the Manufacturing Enterprise Servitization and Enterprise Value under the Moderating Role of Redundant Resources and Absorptive Capacity. *Journal of Management*, 18(12):1772-1779.

Parmar, B.L., Freeman, R.E., Harrison, J.S., Purnell, A.C. and De Colle, S. (2010). Stakeholder Theory: The State of the Art. *Academy of Management Annals*, 4(1):403-445.

Qiao, P., Xie Ho. and Zhang, Y. (2022). The Impact of Dual Innovation on Firm Value: The Moderating Role of Leader Focus. *Science and Technology Progress and Policy*, 39(07):93-102.

Rehman, S.U., Bresciani, S., Yahiaoui, D., et al.(2022). Environmental Sustainability Orientation and Corporate Social Responsibility Influence on Environmental Performance of Small and Medium Enterprises: The Mediating Effect of Green Capability. *Corporate Social Responsibility and Environmental Management*, 29(6): 1954-1967.

Shi, J., Hu, L. and Fu, H. (2009). Corporate Social Responsibility, Social Capital, and Organizational Competitive Advantage: A Strategic Interaction Perspective—An Empirical Study Based on the Experience of China's Transformation Period. *China Industrial Economics*, (11):87-98.

Su, Z., Xie, E. and Li, Y. (2009). Organizational Slack and Firm Performance during Institutional Transitions. *Asia Pacific Journal of Management*, 26(1):75-91.

Sun, Y., Ding, Y. and Du, S. (2022). The Nonlinear Relationship between Redundant Resources, Resource Combination, and Entrepreneurial Opportunity Recognition. *Scientific Research Management*, 43(01):105-113.

Suzuki, O. (2018). Enabling or Constraining? Unraveling the Influence of Organizational Slack on Innovation. *Industrial and Corporate Change*, 27(3):555-575.

Swift, T. (2016). The Perilous Leap Between Exploration and Exploitation. *Strategic Management Journal*, 37(8):1688-1698.

Tan, J. and Peng, M.W. (2003). Organizational Slack and Firm Performance during Economic Transitions: Two Studies from an Emerging Economy. *Strategic Management Journal*, 24(13):1249-1263.

Tang, Y., Ma, X. and Ma, W. (2023). Audit of Natural Resource Assets by Leading Cadres upon Leaving Office, Social Capital, and Corporate Environmental Performance—A Quasi-Natural Experiment Based on Pilot Schemes. *Audit Research*, (02):20-32.

Troilo, G., De Luca, L.M. and Atuahene-Gima, K. (2014). More Innovation with Less? A Strategic Contingency View of Slack Resources, Information Search, and Radical Innovation. *Journal of Product Innovation Management*, 31(2):259-277.

Wang, B. and Kang, Q. (2023). Digital Transformation and Corporate Sustainable Development Performance. *Economic Management*, 45(06):161-176.

Wang, H. and Han, B. (2016). Social Responsibility, Internal Control, and Corporate Sustainable Development—An Empirical Analysis Based on A-share Main Board Listed Companies. *Journal of Beijing Technology and Business University (Social Sciences)*, 31(01):75-84.

Wang, J. and Liu, J. (2020). The Impact of Dual Green Innovation on the Competitive Advantage of Manufacturing Enterprises in China: The Moderating Role of Technological Turbulence. *Science and Technology Management Research*, 40(09):196-204.

Wang, X., Lei, N. and Li, X. (2018). Evaluation System of Social Responsibility, Corporate Organization, and Sustainable Business Performance. *Jianghan Forum*, (10):33-38.

Wang, X., Li, N. and Chen, Y. (2022). Redundant Resources Regulation, Digital Transformation, and High-Quality Development of Enterprises. *Journal of Shanxi University of Finance and Economics*, 44(08):72-84.

Wang, Y. and Hu, H. (2021). Redundant Resources and Entrepreneurial Orientation: The Moderating Effect of Institutional

Environment. *Scientific Research Management*, 42(08):35-42.

Wen, S. and Fang, Y. (2008). Empirical Research on the Relationship between Corporate Social Responsibility and Financial Performance: Panel Data Analysis from the Stakeholder Perspective. *China Industrial Economics*, (10):150-160.

Xi, L. and Zhao, H. (2022). Executive Dual Environmental Cognition, Green Innovation, and Corporate Sustainable Development Performance. *Economic Management*, 44(03):139-158.

Xiao, H. and Yang, Z. (2020). Sustainable Business Model Innovation: A Review and Prospect. *Foreign Economics and Management*, 42(09):3-18.

Xiao, H., Yang, Z. and Ling, H. (2022). Does Corporate Social Responsibility Have a Green Innovation Effect? *Economic Dynamics*, (08):117-132.

Xiao, X., Pan, Y. and Wang, Z. (2021). Does Corporate Social Responsibility Promote Corporate Green Innovation? *Economic Horizon*, 38(03):114-123.

Xie, F. and Li, H. (2005). Evaluation of Corporate Environmental Responsibility and Environmental Performance. *Modern Finance and Economics—Journal of Tianjin University of Finance and Economics*, (01):40-42.

Xie, K., Liu, S. and Liang, F. (2009). Corporate Social Responsibility and Sustainable Development Performance Management System. *Ecological Economy*, (10):44-47+51.

Xie, X. and Zhu, Q. (2021). How Does Corporate Green Innovation Practice Solve the Dilemma of "Harmonious Coexistence"? *Management World*, 37(01):128-149+9.

Yang, J., Liu, Q. and Shi, J. (2015). The Value Study of Corporate Green Innovation Strategy. *Scientific Research Management*, 36(01):18-25.

Yang, Y., Wei, J. and Luo, L. (2015). Who is Utilizing Government Subsidies for Innovation?—The Joint Moderating Effect of Ownership and Factor Market Distortion. *Management World*, (01):75-86+98+188.

Yu, H., Huang, X. and Cao, X. (2015). The Moderating Role of Corporate Social Capital in the Relationship between Corporate Social Responsibility and Corporate Performance. *Management Review*, 27(01):169-180.

Yu, W., Ramanathan, R. and Nath, P. (2017). Environmental Pressures and Performance: An Analysis of the Roles of Environmental Innovation Strategy and Marketing Capability. *Technological Forecasting and Social Change*, 117:160-169.

Zeng, D., Sun, J. and Dai, H. (2015). Technological Diversification, Technological Distance, and Dual Innovation of Enterprises: A Case Study of the Chinese Automobile Industry. *Science and Technology Progress and Policy*, 32(17):61-67.

Zhang, F. and Zhu, L. (2019). Enhancing Corporate Sustainable Development: Stakeholder Pressures, Organizational Learning, and Green Innovation. *Business Strategy and the Environment*, 28(6):1012-1026.

Zheng, W., Shen, R., Zhong, W. and Lu, J. (2020). CEO Values, Firm Long-Term Orientation, and Firm Innovation: Evidence from Chinese Manufacturing Firms. *Management and Organization Review*, 16(1):69-106.

Zhu, N. and Xu, Y. (2021). TMT Network Characteristics, Knowledge Creation, and Dual Innovation of Enterprises—The Moderating Role of Institutional Environment and Enterprise Nature. *Journal of Chongqing University (Social Science Edition)*, 27(05):74-86.