Journal of Infrastructure, Policy and Development 2024, 8(14), 9144.
https://doi.org/10.24294/jipd9144

Article

Corporate executive portfolio and green innovation: Same-sex repulsion or opposite-sex attraction?

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CITATION

Cao X, Ma H, Wang L. (2024). Corporate executive portfolio and green innovation: Same-sex repulsion or opposite-sex attraction?. Journal of Infrastructure, Policy and Development. 8(14): 9144. https://doi.org/10.24294/jipd9144

ARTICLE INFO

Received: 15 September 2024
Accepted: 12 October 2024
Available online: 21 November 2024

Abstract: Enterprise green innovation drives sustainable development and contributes to the realization of a 'beautiful China'. It enhances resource utilization, reduces energy consumption, and achieves economic-environmental objectives through technological advancements. This paper examines the impact of the gender composition of a company's CEO and CFO on green innovation by empirical research method using the data of the firms listed on Chinese capital market from 2015 to 2022. Our findings indicate that: (1) Male CEOs and CFOs are more likely to promote green innovation compared to their female counterparts; (2) Leadership teams comprising opposite-sex pairs tend to weaken the promotion of green innovation. These conclusions are consistent across state-owned enterprises and within the manufacturing sector. This study provides a novel perspective on enterprise green innovation, offering insights for companies regarding their green innovation strategies and for policymakers in shaping relevant policies.

Keywords: CEO; CFO; gender heterogeneity; green innovation

1. Introduction

In recent times, there has been a notable increase in the concentrations of greenhouse gases, leading to climate anomalies and the melting of glaciers (Li et al., 2024). It is clear that economic growth has resulted in the excessive use of natural resources (Weng et al., 2015), exacerbating environmental issues (Apergis et al., 2021). Consequently, the impact of human activities on the environment has garnered significant global attention (Guinot et al., 2020). Research indicates that green innovation can effectively mitigate the conflict between rapid economic growth and substantial environmental pollution (Wu et al., 2022), thereby positively influencing environmental sustainability (Bhutta et al., 2021). The Chinese government has committed to achieving specific targets known as the '3060 double carbon target', which includes reaching a 'carbon peak' by 2030 and attaining 'carbon neutrality' by 2060 (Huang et al., 2022). To achieve this objective, it is essential for both developed and developing nations to establish strategic goals while governments implement policies related to green innovation (Wu et al., 2022). These policies should effectively address environmental concerns and promote the adoption of green technology solutions (Zhang et al., 2022) to alleviate pressures arising from environmental pollution and limited resources while simultaneously enhancing carbon emission performance (Xiao et al., 2024).

As integral members of society, enterprises bear the responsibility of contributing to societal well-being and prioritizing social welfare and public interests (Sheehy, 2015). In the contemporary landscape, a continuous influx of various regulatory,

normative, and imitative pressures is evident (Ning et al., 2021), with the economic activities of enterprises being highly scrutinized. An increasing number of consumers are favoring environmentally friendly products (Yang et al., 2019) and are demanding that companies take proactive measures to balance production with environmental sustainability (Guinot et al., 2020). Enterprises should concentrate on the sustainability of both the economic system and society at large (Saunila et al., 2018), engage in sustainable economic practices (Marquis et al., 2015), and foster the development of a greener industrial structure. The implementation of green innovation within enterprises not only enhances organizational and economic performance but also positively influences the environmental performance of the organization (Li et al., 2022).

The decision-making processes and outcomes of a company can be significantly influenced by the individual characteristics of its executives (Osei et al., 2024). This influence extends to the strategic decision-making and implementation processes related to green technology innovation within an enterprise, albeit to a certain extent (Wang et al., 2020). However, existing research primarily focuses on the chairman or CEO (Chief Executive Officer) when examining corporate executives. In reality, both the CEO (Chief Executive Officer) and CFO (Chief Finance Officer) play crucial roles in driving a company's operations. CEO and CFO are two important executives of the company. CEO is mainly responsible for the daily important business decisions of the company. CFO is mainly responsible for the company's financial decision-making and accounting information quality, CFO belongs to the CEO. In general, the CEO will involve professional financial decisions to the CFO, but also has an important impact on financial decisions. From the incentive mechanism of enterprise green innovation, it can be seen that the promotion of enterprise green innovation is mainly caused by managers information management behavior, information transparency and investment decision-making. The level of cooperation between these two key executives is pivotal in determining the company's growth trajectory. Therefore, it is essential to explore whether there is a correlation between the gender combinations of CEOs and CFOs and enterprise green innovation. Unfortunately, current research lacks a comprehensive analysis of this topic. Consequently, this study examines data from China's listed companies from 2015 to 2022. Initially, it analyzes how male CEOs and CFOs individually influence corporate green innovation. Furthermore, it investigates how opposite-sex combinations between CEOs and CFOs affect corporate green innovation, aiming to uncover the internal mechanisms that link gender combinations among key operational executives with corporate green innovation.

Excellent senior management team can change their strategic thinking in time in the face of increasing environmental uncertainty. In order to realize the interaction between strategic intention and environment, enterprises have the ability to adapt to and shape the environment and adjust the strategy in time. This ability is regarded as that enterprises have strong flexible resources. In the complex development of reality, this ability is usually affected by executives of different genders. Executives of different genders and positions often have deviations in opinions when making decisions on enterprises. Male executives are more radical, while female executives are more conservative. The executive power of CEO is greater than that of CFO. Hambrick (1995) believed that the richer the knowledge structure of enterprise

managers and the more democratic the decision-making team, the more likely the relevant development strategies are to be correct and perfect. Therefore, the types of executives in different combinations and the weakening of the interaction of opposite-sex executives on green innovation have certain research significance. Chinese enterprises should establish an efficient management team to further promote the green innovation of enterprises.

In the process of China's economy from high-speed growth to high-quality development, the corporate governance structure and system have undergone obvious changes. Among them, more and more female executives enter management, which has a greater impact on corporate governance and economic activities. The research report of MSCI released the changing trend of the proportion of female executives. In the five years from 2016 to 2021, the global average proportion of female directors jumped from 19.1% to 29%, of which China, the United States and the United Kingdom increased by 5%–10%. The report shows that during the period when China's economy has shifted from a high-speed growth stage to a high-quality development, 'she' power has shown an upward trend in the senior management team of listed companies in China, and the gender diversity of executives has been improved. The existence of enterprises is no longer just a male-led senior management structure. Female executives also play an important role in corporate decision-making and corporate governance. To a certain extent, it has improved the situation that it is difficult to exert their own advantages due to the low proportion of female executives in the past. Therefore, the study of the impact of gender diversity of executives on corporate green innovation cannot be ignored.

The primary contributions and innovations of this paper are as follows: (1) Expanding the existing literature on the characteristics of chairman and CEO executives to include the combination of core operating executives, specifically the CEO and CFO; (2) Compared with the existing literature, it broadens the research on the internal influencing factors of green innovation, thus supplementing and improving the existing enterprise green innovation knowledge system; (3) Introducing the concepts of "homosexual attraction" and "heterosexual attraction" in social science, providing empirical evidence to support the promotion of enterprise green innovation within an oriental cultural context.

This study is organized into several distinct sections. The second section primarily consists of a literature review that systematically examines the concept of green innovation, along with its influencing factors and consequences, while also analyzing its relationship with company executives. The third section presents the research hypothesis, details the data sources and sample selection, defines the relevant variables, and constructs a model. The fourth section conducts an empirical analysis of the impact of executive gender and gender differences on corporate green innovation. Finally, conclusions and countermeasures are proposed, along with corresponding research conclusions and suggestions based on the findings of the empirical analysis.

2. Literature review

2.1. Green innovation

Green innovation encompasses a variety of technical and non-technical activities designed to conserve resources and minimize pollution in the ecological environment (Triguero et al., 2013). This innovative approach seeks to strike a balance between economic competition and environmental sustainability (Guinot et al., 2020). Primarily, green innovation involves the development of both hardware and software directly related to the production of environmentally friendly products (Chen et al., 2006).

Various factors influence the advancement of eco-friendly innovation, both internally and externally. Internally, enterprises tend to experience accelerated development in green innovation when confronted with intense competitive pressure (Stucki et al., 2019) and higher levels of foreign direct investment (Song et al., 2015). Furthermore, factors such as the relative benefits, compatibility, and simplicity of corporate economic activities (Ha et al., 2022), along with the organizational structure (Schaltegger et al., 2017) and financial capacity (Ardito et al., 2019) of enterprises, significantly affect green innovation. Conversely, external factors, including China's initiatives for low-carbon cities (Zhong et al., 2020), environmental regulations (Li et al., 2021; Zhong et al., 2022), government subsidies (Xu et al., 2019), and the implementation of green taxes (Li et al., 2021), also impact corporate eco-friendly innovation. When enterprises encounter these environmental regulatory policies, they meticulously consider the cost implications of non-compliance and the variations in eco-friendly innovation practices prior to making decisions.

Green innovation has emerged as a vital strategic tool for enterprises (Chiou et al., 2011). It not only enhances the environmental performance of businesses (Rehman et al., 2021) but also enables them to gain a competitive advantage (Nadeem et al., 2020) and create long-term value (Alsayegh et al., 2020), all while increasing profitability (Tu et al., 2021). Furthermore, green innovation encourages businesses to adhere to environmental regulations (Guinot et al., 2020), establish legitimacy (Li et al., 2017), and fulfill environmental protection requirements to avoid penalties from government regulatory authorities (Chang, 2011). Consequently, this approach supports the sustainable innovation and development of enterprises.

2.2. Research on corporate executives and green innovation

Based on existing studies, the factors influencing executives' implementation of environmentally friendly innovations in businesses are diverse and complex. In addition to executives' international experience (Chen et al., 2023), expertise in information technology (Su et al., 2023), and educational attainment (Zhang et al., 2022), various personal attributes also affect corporate initiatives toward green innovation.

Firstly, the reputation of executives (Sun et al., 2024) plays a critical role in the decision-making process. Executives with a strong reputation are more likely to prioritize green innovation and consider it an integral component of their corporate development strategies. However, excessive overconfidence (Chang et al., 2023; Wang, 2021) may lead executives to overlook environmental protection issues or underestimate their importance. Conversely, humility (Sun et al., 2021) can encourage

executives to place greater emphasis on sustainable development and adopt appropriate measures.

A high level of cognitive ability can positively influence the promotion of green innovation. Executives with a profound understanding of ESG (environmental, social, and corporate governance) (Wang et al., 2022) and green cognition (Liu et al., 2024) are more likely to recognize the benefits of fostering green innovation within organizations. They proactively implement measures to mitigate any negative impacts. Furthermore, their extensive marketing experience (Huang et al., 2023) and academic background (He et al., 2021) equip them to better understand market demands and technological advancements. As a result, they can effectively translate these insights into successful strategies for advancing green innovation.

Research conducted by Quan et al. (2021) and Cheng et al. (2024) has demonstrated that overseas experience and an international background are associated with heightened levels of green innovation. Exposure to diverse cultures and business environments enables these executives to acquire global best practices, which they can subsequently implement in the local market.

In addition to personal characteristics, various organizational factors can significantly influence a company's green innovation. For example, government regulations that restrict executive compensation (Li et al., 2024) may incentivize executives to prioritize long-term sustainable development over immediate profit maximization. Furthermore, incorporating gender diversity in the composition of management teams can enhance the range of perspectives and facilitate the exchange of ideas (He et al., 2019; Lakhal et al., 2024), thereby fostering positive advancements in the company's environmental initiatives. Additionally, factors such as executives' hometown identity (Ren et al., 2021), turnover rates (Zhang et al., 2023), and tenure (Liu et al., 2024) can also exert varying degrees of influence on corporate green innovation.

2.3. Literature review and research framework

Green innovation has the potential to reduce environmental contamination, conserve energy, and promote sustainable development by aligning environmental protection with corporate competitiveness. Innovation initiatives typically exhibit characteristics such as long cycles, substantial investments, and considerable risks. As a result, the extent to which companies engage in innovation activities depends on managers' assessments of the associated risks and anticipated returns (Brav et al., 2018). The diversity among executives influences the innovation activities of firms, and the personal traits and cognitive abilities of these executives can affect decision-making regarding green innovation to varying degrees. While existing literature extensively examines the effects of various personal characteristics and cognitive abilities of business executives on green innovation, it predominantly focuses on the roles of the chairman, CEO, and other key decision-makers, overlooking the actual operations of the company. Consequently, there exists a research gap concerning the influence of the CEO and CFO on corporate green innovation, as well as the impact of gender diversity among operational executives on corporate green innovation.

In light of this, this paper proposes a research framework, as illustrated in **Figure 1**, which employs Chinese listed companies as a case study to examine the impact of gender differences between the CEO and CFO on corporate green innovation.

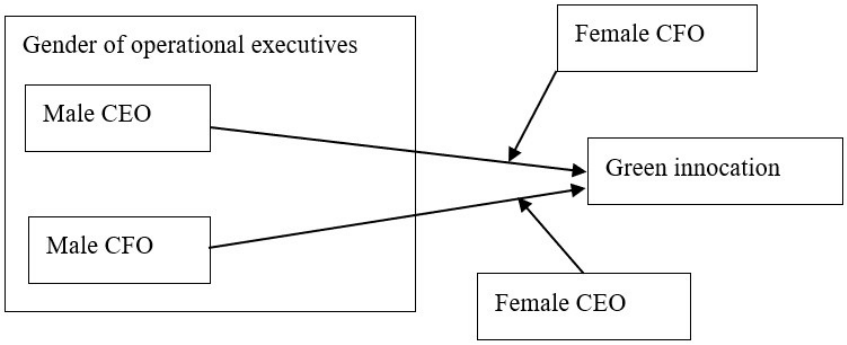

Figure 1. Research frame diagram.

3. Theoretical analysis and research hypothesis

3.1. The gender of operating executives and green innovation of enterprises

According to the executive echelon theory (Hambrick et al., 1984), the values, cognition, and other factors of executives influence corporate strategic decisions. The competence of executives positively impacts corporate decision-making (Jia et al., 2014). Executives with a research background are more likely to engage in activities that enhance sustainable performance, environmental performance, and environmental reporting (Shahab et al., 2020). Furthermore, the values of executives also significantly affect corporate decision-making; for instance, liberal executives tend to prioritize corporate social responsibility more than their conservative counterparts (Chin et al., 2013).

According to the theory of risk preference, gender differences in risk behavior manifest to varying degrees across different dimensions. Male executives tend to exhibit greater optimism in corporate decision-making (YAU et al., 2017), adopt riskier approaches (Peltomäki et al., 2021), and demonstrate heightened self-confidence, decisiveness, and competitiveness (Fitzsimmons et al., 2014). Furthermore, male executives show a stronger appetite for risk in investment choices, debt issuance, and mergers and acquisitions (Harris et al., 2019). In contrast, female executives are more likely to adopt conservative strategies and prefer to maintain higher levels of corporate cash (Zeng et al., 2015). They also tend to exercise caution in risk measurement (Hurley et al., 2020). Research indicates that female executives are negatively correlated with violations of company information disclosure (Zhao et al., 2020) and discretionary accruals (Kim et al., 2017). Additionally, they may demonstrate a conservative approach to the company's green innovation strategy. Thus, it can be inferred that male executives are more inclined to embrace green innovation strategies within corporate activities.

H1: Men promote corporate green innovation more effectively than women when serving in executive roles.

Specifically, we further analyze executive positions through two distinct hypotheses:

H1a: Male CEOs are more likely to promote corporate green innovation than their female counterparts.

H1b: Male CFOs are more likely to promote corporate green innovation than their female counterparts.

3.2. The combination of enterprise operation executives and enterprise green innovation

The CEO and CFO are central figures among business executives, each exerting distinct influences on the company's strategic decision-making and implementation. The CEO serves as a pivotal leader, responsible for executing the company's strategies and achieving its goals (Osei et al., 2024). In contrast, the CFO, as the primary authority on accounting information and financial management (Wang et al., 2019), typically oversees the formulation and execution of financial strategies (Habib et al., 2013) to ensure the attainment of the company's financial objectives. While the CEO is charged with the overall operation and strategic direction of the company, the CFO plays a crucial role in the financial domain. It is widely believed that the CEO wields greater power than the CFO (Huang et al., 2022).

When the genders of the CEO and CFO differ, it is common to encounter varying perspectives and opinions, complicating the decision-making process (María et al., 2019). This divergence can lead to differing viewpoints within the decision-making team (Wang et al., 2022). In terms of decision-making, male CEOs and CFOs are generally more adventurous and exhibit greater confidence in innovation-related decisions, whereas their female counterparts tend to adopt a more conservative and robust investment approach. Regarding competitive awareness, female CEOs and CFOs are often more risk-averse and may perform less favorably than males in an environment that promotes green innovation competition. In terms of leadership style, male CEOs and CFOs are inclined to be more arbitrary and autocratic, while female leaders tend to embrace a more democratic approach. These differing leadership styles provide varying incentives for green innovation patent applications. Consequently, the gender combination of the CEO and CFO influences corporate green innovation from multiple perspectives. Based on these observations, we propose the following hypothesis:

H2: When the other executive is of the opposite sex, it has a reverse effect on the influence of male executives on corporate green innovation compared to a male-male combination. Furthermore, this can be broken down into two more specific assumptions:

This observation can be further delineated into two specific assumptions:

H2a: A heterosexual CFO inversely moderates the impact of a male CEO on corporate green innovation.

H2b: A heterosexual CEO inversely moderates the impact of a male CFO on corporate green innovation.

4. Research design

4.1. Sample selection and data sources

The data concerning green innovation is sourced from CNRDS (China Research Data Services), while additional financial data is obtained from CSMAR (China Stock Market & Accounting Research Database). The impetus for enhancing enterprises' awareness of green innovation can be traced back to the "China-U.S. dollar joint statement on climate change" issued in Beijing in November 2014, marking a significant development in this area. Furthermore, given that the latest patent data from CNRDS is available only up to 2023 and considering the time lag between green innovation and patent application by enterprises, this paper focuses on A-share listed companies in Shanghai and Shenzhen from 2015 to 2022. These companies have begun to align with international accounting standards, serving as the initial research sample. The original samples were filtered according to the following criteria: (1) Excluding ST, *ST, and PT listed companies[1] for the year; (2) Excluding companies from the financial industry; (3) Eliminating companies with missing data for relevant variables. To mitigate the influence of outliers, this paper employs a 1% level Winsorization for all continuous variables. Ultimately, the sample comprises 3235 enterprises and 20,862 observations.

This paper employs Excel and Stata 17.0 to process and analyze the collected sample data. It classifies the industry according to the two-digit industry code outlined in the CSRC's "Industry Classification Guidelines for Listed Companies" (2012 revised edition).

4.2. Main research variables and definitions

(1) Dependent variable

Corporate green innovation (*Green*) serves as the dependent variable in this study. According to the research conducted by Haščič and Migotto (2015), an enterprise's ability to implement such innovations can be assessed by the rate at which it submits patents related to eco-friendly technologies. This encompasses both inventions specifically designed for environmental purposes and utility models that contribute to sustainability efforts. To address the skewed distribution patterns in the data, our analysis employs the natural logarithm of the cumulative count of submitted patents pertaining to eco-innovations, with one added to this count. Consequently, we define *Green* innovation within a company using the following formula: Ln (1 + total count of eco-patent submissions).

(2) Independent variable

(i) Gender of CEO (*CEOGender*): Construct a dummy variable where 1 represents a male CEO and 0 represents a female CEO.

(ii) Gender of CFO (*CFOGender*): Construct a dummy variable where 1 represents a male CFO and 0 represents a female CFO.

(3) Moderator Variable

The variable "Gender difference" (*Dgend*) is utilized as a moderator factor. If the CEO is male and the CFO is female, or if the CFO is male and the CEO is female, the value is set to 1; otherwise, it is set to 0.

(4) Control Variable

The literature by Zhao et al. (2020), Han et al. (2023), and Huang et al. (2022) presents several factors that may influence the green innovation efforts of enterprises. These factors are examined through the lenses of enterprise characteristics, operating conditions, and governance structures. Specifically, the analysis includes capital structure (*Lev*), the proportion of independent directors (*Indep*), cash flow (*Cash*), profitability (*ROA*), total asset turnover (*Turn*), return on investment (*TobinQ*), the proportion of the largest shareholder (*Top1*), and ownership concentration (*Cr10*). Additionally, dummy variables for industry and year are incorporated into the model to control for their potential impact on the results.

All names and definitions of variables are detailed in **Table 1** below.

Table 1. Definitions of variables.

	Variable	Variable Declaration
Dependent Variable	Green	Ln (1 + the number of green patent applications)
Independent Variable Moderator Variable	CEOGender	If CEO is man, the value is 1, otherwise 0
	CFOGender	If CFO is man, the value is 1, otherwise 0
	Dgend	When the CEO is male and the CFO is female, or when the CFO is male and the CEO is female, the value is 1, otherwise 0
Control Variable	Lev	Ratio of total liabilities to total assets at year-end
	Indep	The ratio of independent directors to the total number of board members
	Cash	The ratio of monetary capital to total assets
	ROA	Return on total assets
	Turn	The ratio of operating income to total assets
	TobinQ	The ratio of market value to replacement cost of assets
	Top1	The ratio of the number of shares held by the largest shareholder to the total number of shares in the enterprise
	Cr10	The proportion of the number of shares held by the top ten shareholders to the total number of shares in the enterprise
	Year	Dummy variables, divided by statistical year
	Industry	Virtual variables, according to the industry of the enterprise

4.3. Model construction

In light of the previously discussed theoretical analysis and the cross-sectional data collected, this paper develops a data model to examine the relationship between the gender heterogeneity of CEOs and CFOs and corporate green innovation. Subsequently, the research hypothesis is tested. The equation is structured in the following basic form: The test model for H1a and H1b:

$$Green_{it} = \alpha_0 + \alpha_1 CEOGender_{it} + \alpha_2 \sum Controls_{it} + \varepsilon_{it} \quad (1)$$

$$Green_{it} = \beta_0 + \beta_1 CFOGender_{it} + \beta_2 \sum Controls_{it} + \varepsilon_{it} \quad (2)$$

Among them: $Green_{i,t}$ is the dependent variable, it indicates the green innovation of enterprise i in the t year; $CEOGender_{i,t}$, $CFOGender_{i,t}$ are independent variables, respectively representing the gender of the CEO and CFO of

the operating executives; $\sum Control_{i,t}$ is a set of control variables at the enterprise level; $\varepsilon_{i,t}$ is the model residual term.

The test model of H2a and H2b:

In order to verify the moderating effect of gender difference, we constructed the following models: the interaction term of the gender of the CEO gender and gender difference (*CEOGender*Dgend*) and the interaction term of the gender of the CFO and gender difference (*CFOGender*Dgend*).

$$Green_{it} = \gamma_0 + \gamma_1 CEOGender_{it} + \gamma_2 CEOGender_{it} \times Dgend_{it} + \gamma_3 \sum Controls_{it} + \varepsilon_{it} \quad (3)$$

$$Green_{it} = \delta_0 + \delta_1 CFOGender_{it} + \delta_2 CFOGender_{it} \times Dgend_{it} + \delta_3 \sum Controls_{it} + \varepsilon_{it} \quad (4)$$

This paper aims to investigate the influence of CEO and CFO gender on corporate green innovation through empirical analysis. The objective is to assess both the statistical and economic significance of the regression coefficients for Equations (1)–(4), as well as to examine the moderating effect of the gender combinations between the CEO and CFO in this context.

5. Empirical results and analysis

5.1. Descriptive statistics

Table 2. Descriptive statistics.

Variable	N	Mean	SD	p50	Min	Max
Green	20,862	0.200	0.310	0.000	0.000	0.690
CEOGender	20,862	0.930	0.250	1.000	0.000	1.000
CFOGender	20,862	0.660	0.470	1.000	0.000	1.000
Dgend	20,862	0.360	0.480	0.000	0.000	1.000
Lev	20,862	3.420	3.020	2.450	1.000	70.090
Indep	20,862	0.380	0.050	0.360	0.140	0.800
Cash	20,862	0.180	0.120	0.150	0.000	0.940
ROA	20,862	0.040	0.080	0.040	−2.830	0.790
Turn	20,862	0.610	0.510	0.510	−0.050	13.910
TobinQ	20,862	2.140	1.900	1.650	0.620	92.300
Top1	20,862	33.630	14.540	31.230	1.840	89.990
Cr10	20,862	33.620	14.540	31.220	1.840	89.990

Note: **Table 2** shows the descriptive statistics of the sample. The variable definitions are shown in **Table 1**.

Table 2 presents descriptive statistics for the independent variables, dependent variables, moderating variables, and control variables. Among the 20,862 samples, the highest value for enterprise green innovation is 6.910, corresponding to approximately 995 patents. The lowest value is 0, indicating significant variation in green innovation among enterprises. Regarding CEO gender (*CEOGender*), the sample mean is 0.930, suggesting that 93% of the CEOs of listed companies are male. Similarly, the sample mean for CFO gender (*CFOGender*) is 0.660, indicating that 66% of the CFOs of

listed companies are male. These findings underscore the ongoing dominance of male executives in Chinese listed companies.

5.2. Correlation analysis

Table 3 presents the Pearson correlation coefficients among the primary variables examined in this study. It is clear from the table that, in the context of univariate analysis, there exists a significant positive correlation between CEO gender (*CEOGender*) and CFO gender (*CFOGender*) with corporate green innovation (*Green*). This finding suggests that when both the CEO and CFO are male, corporate green innovation is positively influenced, thereby providing preliminary support for hypotheses H1a and H1b. Conversely, a significant negative correlation is observed between corporate green innovation and gender difference (*Dgend*) at the 1% significance level. This initial finding implies that gender differences may impede the advancement of green innovation. Furthermore, among the control variables included in the analysis, the majority exhibit significant associations with corporate green innovation at the 1% significance level.

Table 3. Pearson correlation matrix.

Variable	Green	CEOGender	CFOGender	Dgend	Lev	Indep	Cash	ROA	Turn	TobinQ	Top1	Cr10
Green	1.000											
CEOGender	0.026***	1.000										
CFOGender	0.016**	0.034***	1.000									
Dgend	−0.019***	−0.137***	−0.849***	1.000								
Lev	−0.084***	−0.020***	−0.047***	0.040***	1.000							
Indep	0.008	−0.053***	0.002	0.011	0.015**	1.000						
Cash	0.011	−0.036***	−0.013*	0.019***	0.274***	0.012*	1.000					
ROA	0.039***	−0.010	−0.008	0.015**	0.161***	−0.009	0.166***	1.000				
Turn	−0.006	0.015**	0.034***	−0.029***	−0.152***	−0.011	0.030***	0.050***	1.000			
TobinQ	−0.044***	−0.012*	−0.026***	0.021***	0.182***	0.034***	0.166***	0.092***	0.010	1.000		
Top1	0.000	−0.009	0.003	0.002	−0.032***	0.044***	0.041***	0.127***	0.047***	−0.081***	1.000	
Cr10	0.000	−0.009	0.002	0.002	−0.032***	0.044***	0.040***	0.127***	0.047***	−0.081***	1.000***	1.000

Note: Pearson correlation coefficient is shown in **Table 3**. *, ** and *** are significant at the 10%, 5% and 1% levels respectively.

5.3. Empirical research

5.3.1. Statistical tests

In order to prevent the influence of multicollinearity on the core explanatory variables, the VIF test is used to detect the independence of each explanatory variable. The VIF test results are shown in **Table 4**.

Table 4. VIF test results.

Variable	VIF	1/VIF
Top1	1087	0.000920
Cr10	1087	0.000920
Lev	1.160	0.865
Cash	1.120	0.891
ROA	1.070	0.935
TobinQ	1.060	0.940
Turn	1.040	0.965
Indep	1.010	0.993
CFOGender	1	0.996
CEOGender	1	0.995
Mean	VIF	242.5

It can be seen from the results that the variance expansion coefficient of the core explanatory variables is not greater than 5, and the value of the control variables is 1, so there is no multicollinearity between the explained variables and the core explanatory variables.

5.3.2. Main regression hypothesis testing

To investigate the impact of gender diversity among business executives on corporate green innovation, this study employs the Ordinary Least Squares (OLS) model developed by the authors (year) and incorporates fixed effects for the regression analysis. The results of the multiple regression are presented in **Tables 5**–**8**.

(1) Gender of CEO (*CEOGender*) and corporate green innovation (*Green*)

Table 5 presents the regression results for CEO gender (*CEOGender*) and corporate green innovation (*Green*). Column (1) displays the results without control variables, while Column (2) incorporates relevant control variables. Column (3) adds year fixed effects based on the results from Column (2), and Column (4) further controls for industry effects. The regression coefficients for CEO gender (*CEOGender*) are 0.032, 0.033, 0.034, and 0.020, respectively. These coefficients indicate a positive correlation and are statistically significant at both the 1% and 5% levels, suggesting that male CEOs are associated with an increase in green innovation within companies.

From Column (4), the regression result for CEO gender (*CEOGender*) is 0.020, indicating that male CEOs are associated with a 37.5% increase in corporate green innovation. Compared to Columns (1), (2), and (3), the positive impact of male CEOs on corporate green innovation remains consistent when controlling for variables such as years and industries. This suggests that male CEOs are more likely to invest in green

innovation activities, facilitating the adoption of green patents within their companies. Additionally, male CEOs contribute to an overall increase in risk preference among the senior management team, which leads to the implementation of high-risk and high-investment green innovation projects, thereby supporting H1a.

Table 5. CEO gender and corporate green innovation.

Variable	(1)	(2)	(3)	(4)
	Green	Green	Green	Green
CEOGender	0.032***	0.033***	0.034***	0.020**
	(3.784)	(3.843)	(4.034)	(2.466)
Lev		−0.010***	−0.010***	−0.012***
		(−13.609)	(−13.466)	(−16.318)
Indep		0.070*	0.059	0.024
		(1.770)	(1.497)	(0.624)
Cash		0.100***	0.094***	0.095***
		(5.218)	(4.858)	(4.954)
ROA		0.209***	0.205***	0.157***
		(7.824)	(7.678)	(6.012)
Turn		−0.015***	−0.015***	−0.002
		(−3.455)	(−3.598)	(−0.362)
TobinQ		−0.006***	−0.006***	−0.009***
		(−5.375)	(−4.656)	(−7.429)
Top1		−0.006	−0.006	−0.006
		(−1.145)	(−1.161)	(−1.270)
Cr10		0.005	0.005	0.006
		(1.082)	(1.111)	(1.341)
Constant	0.169***	0.186***	0.158***	0.092***
	(20.442)	(10.031)	(7.944)	(3.386)
Year	No	No	Yes	Yes
Industry	No	No	No	Yes
N	20,862	20,862	20,862	20,862
R-squared	0.001	0.013	0.016	0.074

Note: **Table 4** shows the regression results of CEO gender and corporate green innovation. *, ** and *** are significant at 10%, 5% and 1% respectively. The *t* value is in parentheses.

(2) Gender of CFO (*CFOGender*) and corporate green innovation (*Green*)

Table 6 presents the regression results for the empirical model (2) mentioned above. Specifically, Column (8) displays the regression outcome of CFO gender (*CFOGender*) on corporate green innovation (*Green*), after controlling for additional variables, as well as industry and year fixed effects. The regression coefficient for CFO gender (*CFOGender*) is 0.008, indicating a positive correlation at the 10% significance level. This suggests that male CFOs consistently have a favorable impact on corporate green innovation. The findings support H1b, demonstrating that male executives contribute to the advancement of green innovation within enterprises. Furthermore, the results imply that male CFOs tend to make riskier financial decisions

for companies, and an increase in male representation correlates with this trend. Consequently, the number of green patent applications has risen, thereby enhancing green innovation within enterprises.

Table 6. CFO gender and corporate green innovation.

Variable	(5)	(6)	(7)	(8)
	Green	Green	Green	Green
CFOGender	0.011**	0.008*	0.009*	0.008*
	(2.310)	(1.763)	(1.938)	(1.822)
Lev		−0.010***	−0.010***	−0.012***
		(−13.557)	(−13.410)	(−16.259)
Indep		0.062	0.051	0.019
		(1.565)	(1.284)	(0.484)
Cash		0.098***	0.091***	0.094***
		(5.100)	(4.738)	(4.881)
ROA		0.209***	0.205***	0.157***
		(7.810)	(7.665)	(6.004)
Turn		−0.015***	−0.015***	−0.001
		(−3.446)	(−3.592)	(−0.334)
TobinQ		−0.006***	−0.006***	−0.009***
		(−5.352)	(−4.632)	(−7.407)
Top1		−0.006	−0.006	−0.006
		(−1.205)	(−1.225)	(−1.319)
Cr10		0.006	0.006	0.007
		(1.141)	(1.175)	(1.389)
Constant	0.192***	0.214***	0.188***	0.107***
	(51.836)	(12.949)	(10.399)	(4.124)
Year	No	No	Yes	Yes
Industry	No	No	No	Yes
N	20,862	20,862	20,862	20,862
R-squared	0.000	0.013	0.016	0.074

Note: **Table 5** shows the regression results of CFO gender and corporate green innovation. *, ** and *** are significant at the levels of 10%, 5% and 1% respectively. The *t* value is in parentheses.

5.3.3. Hypothesis test of moderating effect

(1) Male CEOs and female CFOs

Table 7 presents the regression results for the empirical model (3) discussed previously. Column (9) displays the results prior to the inclusion of control variables, while Column (10) shows the results following their inclusion. Column (11) presents the results when controlling for the year, without accounting for the industry, and Column (12) displays the results after incorporating fixed effects for both the year and the industry.

The table indicates that the regression coefficients for CEO gender (*CEOgender*) are positively correlated at a significant level of 1%. In contrast, the coefficients for the interaction term representing the gender difference between the CEO and CFO

(*CEOGender*Dgend*) are −0.011, −0.009, −0.010, and −0.010, which reflect a negative correlation at significant levels of 5% or 10%, respectively. This finding suggests that when the CEO is male and the CFO is female, the promotion of corporate green innovation is diminished, thereby confirming hypothesis H2a.

This result indicates that women's conservative attitudes toward decision-making are influential. When women join the executive team, their presence diminishes the influence of male CEOs in fostering corporate green innovation.

Table 7. Moderating effects of gender differences on corporate green innovation (1).

Variable	(9)	(10)	(11)	(12)
	Green	Green	Green	Green
CEOGender	0.036***	0.036***	0.038***	0.024***
	(4.149)	(4.123)	(4.350)	(2.819)
CEOGender*Dgend	−0.011**	−0.009*	−0.010**	−0.010**
	(−2.322)	(−1.865)	(−2.066)	(−2.092)
Lev		−0.010***	−0.010***	−0.012***
		(−13.541)	(−13.392)	(−16.243)
Indep		0.070*	0.059	0.024
		(1.768)	(1.491)	(0.614)
Cash		0.100***	0.094***	0.095***
		(5.220)	(4.855)	(4.932)
ROA		0.209***	0.205***	0.158***
		(7.833)	(7.688)	(6.031)
Turn		−0.015***	−0.016***	−0.002
		(−3.503)	(−3.654)	(−0.409)
TobinQ		−0.006***	−0.006***	−0.009***
		(−5.344)	(−4.607)	(−7.389)
Top1		−0.006	−0.006	−0.006
		(−1.174)	(−1.193)	(−1.303)
Cr10		0.005	0.006	0.007
		(1.111)	(1.144)	(1.375)
Constant	0.169***	0.186***	0.158***	0.091***
	(20.444)	(10.025)	(7.917)	(3.361)
Year	No	No	Yes	Yes
Industry	No	No	No	Yes
N	20,862	20,862	20,862	20,862
R-squared	0.001	0.013	0.017	0.074

Note: **Table 6** shows the moderating effect of gender difference on enterprise green innovation, where *, ** and *** are significant at the levels of 10%, 5% and 1% respectively; The *t* value is in parentheses.

(2) Male CFOs and female CEOs

Table 8 presents the regression results for the empirical model (4) discussed earlier. Column (13) illustrates the impact of gender differences on corporate green innovation prior to the inclusion of control variables. Column (14) displays the results

after control variables have been incorporated. Column (15) presents the findings when controlling for the year, excluding industry effects. Finally, Column (16) shows the results after incorporating fixed effects for both year and industry.

Table 8. Moderating effects of gender differences on corporate green innovation (2).

Variable	(13)	(14)	(15)	(16)
	Green	Green	Green	Green
CFOGender	0.013***	0.011**	0.011**	0.010**
	(2.793)	(2.287)	(2.498)	(2.235)
CFOGender*Dgend	−0.037***	−0.040***	−0.042***	−0.030***
	(−3.388)	(−3.606)	(−3.831)	(−2.812)
Lev		−0.010***	−0.010***	−0.012***
		(−13.561)	(−13.414)	(−16.262)
Indep		0.069*	0.058	0.024
		(1.743)	(1.468)	(0.623)
Cash		0.100***	0.093***	0.095***
		(5.204)	(4.840)	(4.940)
ROA		0.210***	0.206***	0.158***
		(7.854)	(7.710)	(6.042)
Turn		−0.015***	−0.016***	−0.002
		(−3.487)	(−3.637)	(−0.393)
TobinQ		−0.006***	−0.006***	−0.009***
		(−5.359)	(−4.624)	(−7.399)
Top1		−0.006	−0.006	−0.006
		(−1.188)	(−1.207)	(−1.306)
Cr10		0.005	0.006	0.007
		(1.125)	(1.158)	(1.377)
Constant	0.192***	0.211***	0.185***	0.105***
	(51.849)	(12.750)	(10.177)	(4.043)
Year	No	No	Yes	Yes
Industry	No	No	No	Yes
N	20,862	20,862	20,862	20,862
R-squared	0.001	0.013	0.016	0.074

Note: **Table 7** shows the moderating effect of gender difference on enterprise green innovation, where *, ** and *** are significant at the levels of 10%, 5% and 1% respectively; The *t* value is in parentheses.

The regression coefficient for CFO gender (*CFOGender*) is significantly positive at both the 1% and 5% levels of significance. Furthermore, the coefficient for the interaction term between CFO and CEO gender differences (*CFOGender*Dgend*) is significantly negative at the 1% level. This finding indicates that when the CFO is male and the CEO is female, the promotion effect of corporate green innovation is diminished, thereby supporting H2a. This result implies that, relative to the CFO, the CEO wields greater power and influence in decision-making. However, the presence

of a female CEO appears to foster a more cautious and prudent decision-making process, which may inhibit corporate green innovation to some extent.

5.4. Robustness test and endogenous test

5.4.1. Replace the dependent variable

Table 9. Regression results of alternative independent variables.

Variable	(17)	(18)	(19)	(20)
	Green0	Green0	Green0	Green0
CEOGender	0.052***	0.034***		
	(4.123)	(2.819)		
CEOGender*Dgend	−0.013*	−0.014**		
	(−1.865)	(−2.092)		
CFOGender			0.015**	0.014**
			(2.287)	(2.235)
CFOGender*Dgend			−0.057***	−0.043***
			(−3.606)	(−2.812)
Lev	−0.015***	−0.018***	−0.015***	−0.018***
	(−13.541)	(−16.243)	(−13.561)	(−16.262)
Indep	0.101*	0.034	0.099*	0.035
	(1.768)	(0.614)	(1.743)	(0.623)
Cash	0.145***	0.136***	0.145***	0.137***
	(5.220)	(4.932)	(5.204)	(4.940)
ROA	0.302***	0.228***	0.302***	0.228***
	(7.833)	(6.031)	(7.854)	(6.042)
Turn	−0.022***	−0.003	−0.021***	−0.003
	(−3.503)	(−0.409)	(−3.487)	(−0.393)
TobinQ	−0.009***	−0.013***	−0.009***	−0.013***
	(−5.344)	(−7.389)	(−5.359)	(−7.399)
Top1	−0.008	−0.009	−0.008	−0.009
	(−1.174)	(−1.303)	(−1.188)	(−1.306)
Cr10	0.008	0.009	0.008	0.009
	(1.111)	(1.375)	(1.125)	(1.377)
Constant	0.268***	0.131***	0.305***	0.151***
	(10.025)	(3.361)	(12.750)	(4.043)
Year	No	Yes	No	Yes
Industry	No	Yes	No	Yes
N	20,862	20,862	20,862	20,862
R-squared	0.013	0.074	0.013	0.074

Note: **Table 8** shows the regression results obtained by replacing the independent variables. *, ** and *** are significant at the levels of 10%, 5% and 1% respectively. The *t* value is in parentheses.

In the above analysis, this paper employs the total number of corporate green innovation patent applications, adjusted by adding one logarithm, as a measure of

corporate green innovation. To ensure the reliability of the results, the paper re-regresses the explanatory variables and assesses whether the enterprise engaged in green innovation during that year. If green innovation occurred, it was coded as 1; otherwise, it was coded as 0. The test results below are presented in Columns (17)–(20) of **Table 9**. After controlling for year and industry effects, the regression coefficients for the CEO's gender (*CEOGender*) and the CFO's gender (*CFOGender*) are 0.034 and 0.014, respectively. These coefficients exhibit a significant positive correlation with green innovation (*Green*) at the 5% statistical level, thereby confirming hypotheses H1a and H1b. The regression coefficients for the interaction terms between gender and gender difference (*CEOGender*Dgend* and *CFOGender*Dgend*) for the CEO and CFO are −0.014 and −0.043, respectively, after controlling for year and industry. These coefficients are negatively correlated at significant levels of 1% and 5%, respectively. The test results indicate no significant disparity between the regression outcomes and previous empirical findings after substituting the dependent variable, thereby reaffirming hypotheses H2a and H2b.

5.4.2. Replacement model

The Ordinary Least Squares (OLS) model was initially utilized, incorporating fixed effects in the regression analysis. To ensure the reliability of the results, the data was subsequently re-evaluated using both the Logit and Probit models. The regression outcomes for the Logit model are presented in Columns (21) and (22) of **Table 10**, while the results for the Probit model are displayed in Columns (23) and (24) of the same table.

The regression results indicate that, following the model replacement, the gender of the CEO (*CEOGender*) is significantly positively associated with the outcome at the 1% level, while the gender of the CFO (*CFOGender*) shows significant positive associations at the 5% and 10% levels, respectively. This further corroborates the regression coefficients of the gender and gender difference interaction terms (*CEOGender*Dgend* and *CFOGender*Dgend*) outlined in hypotheses H1a and H1b. Additionally, after controlling for year and industry effects, a negative correlation between the CEO and CFO is observed, significant at the 1%, 5%, and 10% levels. This finding enhances the robustness of hypotheses H2a and H2b.

Table 10. Regression results of the replacement model.

Variable	(21)	(22)	(23)	(24)
	Green	Green	Green	Green
CEOGender	0.177***		0.114***	
	(2.612)		(2.839)	
CEOGender*Dgend	−0.064*		−0.044**	
	(−1.832)		(−2.107)	
CFOGender		0.067*		0.046**
		(1.953)		(2.236)
CFOGender*Dgend		−0.228***		−0.147***
		(−2.644)		(−2.871)

Table 10. (*Continued*).

Variable	(21)	(22)	(23)	(24)
	Green	**Green**	**Green**	**Green**
Lev	−0.127***	−0.127***	−0.065***	−0.065***
	(−15.546)	(−15.566)	(−15.862)	(−15.889)
Indep	0.208	0.210	0.145	0.146
	(0.712)	(0.720)	(0.827)	(0.835)
Cash	0.845***	0.846***	0.458***	0.459***
	(5.612)	(5.622)	(5.123)	(5.135)
ROA	1.845***	1.847***	1.060***	1.062***
	(7.436)	(7.443)	(7.336)	(7.345)
Turn	−0.055	−0.055	−0.027	−0.027
	(−1.351)	(−1.345)	(−1.132)	(−1.122)
TobinQ	−0.101***	−0.101***	−0.059***	−0.059***
	(−7.935)	(−7.940)	(−8.174)	(−8.179)
Top1	−0.039	−0.040	−0.027	−0.027
	(−1.151)	(−1.156)	(−1.279)	(−1.284)
Cr10	0.042	0.042	0.029	0.029
	(1.230)	(1.234)	(1.355)	(1.360)
Constant			−1.075***	−1.007***
			(−8.048)	(−7.841)
Year	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes
N	20,862	20,862	20,695	20,695

Note: **Table 9** shows the regression results of the replacement model. *, ** and *** are significant at the levels of 10%, 5% and 1% respectively. The *t* value is in parentheses.

6. Further research

6.1. Research on state-owned enterprises

China employs a socialist market economy characterized by a predominance of state-owned enterprises. These enterprises play a crucial role in ensuring economic stability and facilitating industrial upgrading. Understanding their operational mechanisms, development strategies, and the challenges they face is essential for achieving high-quality economic development. State-owned enterprises bear significant responsibility for maintaining national security and stability, while also driving industrial upgrading, technological innovation, and green innovation. Their contributions are vital in the pursuit of the "3060 dual carbon goal". Beyond economic objectives, state-owned enterprises also carry extensive social responsibilities and political mandates. Consequently, analyzing the practices and performance of state-owned enterprises in the realm of green innovation is of considerable importance.

Table 11. Regression results of state-owned enterprises sample.

Variable	(25)	(26)
	Green	Green
CEOGender	0.051***	
	(2.746)	
CEOGender*Dgend	−0.025***	
	(−3.076)	
CFOGender		0.027***
		(3.329)
CFOGender*Dgend		−0.046**
		(−2.025)
Lev	−0.016***	−0.016***
	(−9.317)	(−9.295)
Indep	0.177***	0.175***
	(2.757)	(2.732)
Cash	−0.040	−0.041
	(−1.121)	(−1.149)
ROA	0.319***	0.319***
	(4.704)	(4.696)
Turn	0.014*	0.014*
	(1.854)	(1.883)
TobinQ	−0.012***	−0.013***
	(−5.527)	(−5.582)
Top1	−0.005	−0.005
	(−0.926)	(−0.930)
Cr10	0.006	0.006
	(1.018)	(1.024)
Constant	0.000	0.025
	(0.005)	(0.613)
Year	Yes	Yes
Industry	Yes	Yes
N	6689	6689
R-squared	0.128	0.127

Note: **Table 10** is the regression results based on the sample study of state-owned enterprises. *, ** and *** are significant at the levels of 10%, 5% and 1% respectively. The *t* value is in parentheses.

This study examines state-owned enterprises as sub-samples to investigate the relationship between the gender of operating executives (CEO and CFO) and green innovation within these enterprises. The regression results presented in **Table 11**, specifically in Column (25) and Column (26), indicate that the coefficients for the gender of state-owned enterprises, namely CEO gender (*CEOGender*) and CFO gender (*CFOGender*), on corporate green innovation (*Green*) are 0.051 and 0.027, respectively. These coefficients are significantly and positively correlated at the 1%

level. In contrast, the coefficients of the interaction terms (*CEOGender*Dgend* and *CFOGender*Dgend*), which represent the gender differences between the CEO and CFO, are negatively correlated at the 1% and 5% significance levels. This finding suggests that when both the CEO and CFO of state-owned enterprises are male, there is a significant positive impact on the company's green innovation activities. However, the presence of an executive of the opposite gender diminishes the positive influence of male executives on corporate green innovation.

6.2. Research on manufacturing enterprises

The trade war between China and the United States initiated by the U.S. has drawn global attention to the evolution of the manufacturing sector. In response, nations are actively seeking ways to enhance the green innovation capabilities of their manufacturing enterprises. Green innovation is vital for reducing resource consumption, minimizing pollution, improving the environmental characteristics of products, and promoting a transition towards sustainable practices. As a result, it enhances the competitiveness of enterprises. In light of current global climate change and governmental emphasis on sustainable development, the green innovation strategy within the manufacturing industry has become an essential approach. Therefore, investigating the green innovation practices of manufacturing enterprises is of significant importance for achieving green transformation, enhancing competitiveness, and contributing to global sustainable development. This topic warrants further exploration.

This paper examines a sub-sample of manufacturing enterprises, as detailed in Columns (27) and (28) of **Table 11** below. The findings indicate a significantly positive association between the gender of the CEO (*CEOGender*) and corporate green innovation (*Green*) within these enterprises, at a significance level of 5%. The coefficient for the interaction term of CFO gender and gender difference (*CFOGender*Dgend*) is −0.036, which is significant at the 1% level. It is evident that in manufacturing enterprises, when the CEO is male, the company's green innovation activities are enhanced. Furthermore, the presence of a heterosexual CEO moderates the impact of a male CFO on corporate green innovation in a negative direction.

Table 11. The regression results based on the sample study of manufacturing enterprises.

Variable	(27)	(28)
	Green	Green
CEOGender	0.025**	
	(2.233)	
CEOGender*Dgend	−0.006	
	(−1.051)	
CFOGender		0.006
		(1.071)
CFOGender*Dgend		−0.036***
		(−2.621)

Table 11. (*Continued*).

Variable	(27)	(28)
	Green	Green
Lev	−0.013***	−0.013***
	(−14.464)	(−14.499)
Indep	0.051	0.052
	(1.030)	(1.055)
Cash	0.141***	0.142***
	(5.634)	(5.658)
ROA	0.165***	0.165***
	(4.169)	(4.172)
Turn	0.015**	0.016**
	(2.037)	(2.046)
TobinQ	−0.010***	−0.010***
	(−6.648)	(−6.642)
Top1	−0.006	−0.006
	(−1.214)	(−1.216)
Cr10	0.006	0.006
	(1.236)	(1.238)
Constant	0.193***	0.211***
	(7.595)	(9.133)
Year	Yes	Yes
Industry	Yes	Yes
N	13,991	13,991
R-squared	0.024	0.025

Note: **Table 11** is the regression results of the subsample study based on manufacturing industry. *, ** and *** are significant at the levels of 10%, 5% and 1% respectively. The *t* value is in parentheses.

7. Conclusions, implications and limitations

7.1. Conclusions

This paper investigates the influence of gender diversity among CEOs and CFOs on enterprise green innovation by analyzing data from China's Shanghai and Shenzhen A-share listed companies during the period from 2015 to 2022. The study constructs a model using the Ordinary Least Squares (OLS) method, incorporating time and industry fixed effects to verify the relationship. The findings indicate that male CEOs and CFOs significantly enhance green innovation within enterprises. However, the positive impact of male CEOs on green innovation diminishes in the presence of a female CFO, while the influence of male CFOs on green innovation is also reduced when a female CEO is present. This indicates that the combination of executives exhibits a mutually exclusive effect on enterprise green innovation, as confirmed by the adjustment effect of gender heterogeneity. The results remain robust even after controlling for potential endogeneity and conducting relevant robustness tests. Furthermore, in state-owned enterprises, male CEOs and CFOs promote green

innovation, whereas female executives exhibit a contrary effect. In the manufacturing sector, male CEOs have a significant influence on green innovation, while female CEOs may undermine the positive impact of male CFOs.

7.2. Implications

Firstly, the government should strengthen the implementation of policies and guide enterprises in developing training strategies that consider gender differences. This can be achieved by promoting green innovation. Additionally, the government should create diverse leadership policies to encourage gender balance within the top management teams of enterprises. This can be accomplished by establishing gender diversity indicators and integrating them into government subsidies, tax incentives, or project collaborations. Furthermore, the government should motivate enterprises to develop internal mechanisms, such as female leadership development programs and flexible working systems, to attract and retain female executives. Collaboration among the government, enterprises, universities, and training institutions can facilitate the creation of gender-specific leadership and green innovation training programs. Such initiatives will enhance women's leadership confidence and decision-making abilities, while promoting gender complementarity and cooperation.

Secondly, when selecting senior managers, enterprises should avoid extreme tendencies and consider both strategic objectives and gender-specific needs. It is essential to establish clear long-term and short-term strategies, particularly concerning green innovation. If green innovation is prioritized, the selection process must evaluate an individual's recognition and practical ability in this domain. While male executives may contribute positively to green innovation, it is crucial to avoid excessive bias. Enterprises should aim to achieve a balance in gender diversity and advantages, selecting a combination of genders that aligns best with strategic goals to effectively promote green innovation.

Thirdly, when evaluating investments, external investors should assess whether the gender composition of business executives aligns with the investment strategy and carefully consider the potential impact of this factor on the company's long-term development. Promoting gender equality and diversity within the top management team can cultivate a wealth of ideas and enhance innovation capabilities. Investors should prioritize long-term value over short-term profits. Furthermore, it is essential to monitor business operations and changes in executive leadership, particularly significant shifts in gender composition, to ensure that investment decisions remain consistent and effective.

7.3. Limitations and further study

This paper conducts a comprehensive analysis of the influence exerted by the gender combination of CEOs and CFOs among core operational executives on the green innovation strategies adopted by enterprises, providing empirical support based on the specific context of China.

However, the research has several limitations: While the impact of gender differences on the decision-making of core operating executives has been considered, other potential factors, such as academic background and lifestyle, may also influence

their decision-making and warrant further exploration. Future research can consider the impact of executive gender heterogeneity on corporate green innovation under the influence of various influencing factors, and how their interaction affects corporate green innovation.

In addition, the circumstances in Western developed countries differ from those in China; thus, more in-depth research and verification are necessary to determine whether such gender combinations similarly affect corporate green innovation in these regions. Future research can consider whether there is a bias in the impact of executive gender heterogeneity on corporate green innovation in the context of different cultures and different political systems based on data from European countries or the United States and Southeast Asian countries.

Author contributions: Conceptualization, XC and LW; methodology, HM; software, XC; validation, XC, HM and LW; formal analysis, XC; investigation, XC; resources, XC; data curation, XC; writing—original draft preparation, XC; writing—review and editing, LW; visualization, XC; supervision, LW; project administration, HM. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

Notes

[1] ST means "special treatment," which is used to warn investors about the company's risks. *ST represents a delisting risk warning, indicating that the listed company is at risk of being terminated by the exchange. PT stands for "special transfer." The listed company has incurred losses for three consecutive years, and its shares will be suspended. The Shanghai and Shenzhen Stock Exchanges provide special transfer services for such suspended stocks.

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