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[Marwan Mohammad Mansour](#)*, [Mohammad Fawzi Shubita](#), [Abdalwali Lutfi](#)*, [Mohammed W.A. Saleh](#), [Mohamed Saad](#)

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Article

Female Leadership and Green Innovation: Evidence from Asian Firms

Marwan Mohammad Mansour ^{1,*}, Mohammad Fawzi Shubita ², Abdalwali Lutfi ³,
Mohammed W.A. Saleh ⁴ and Mohamed Saad ⁵

¹ Middle East University, Jadara Research Center, Jadara University, Jordan

² Department of Accounting, Amman Arab University, Jordan

³ The University of Kalba, Applied Science Private University, United Arab Emirates

⁴ Department of Accounting Information System, Palestine Technical University, Palestine

⁵ Department of Accounting, College of Business, King Faisal University, Saudi Arabia

* Correspondence: malburenee@yahoo.com

Abstract: This study primarily aims to examine how female CEOs influence green innovation and whether firm size moderates this connection. Our paper focuses on CEOs, who are considered the strategic leaders of corporations because of their crucial role in making important decisions. This research paper examines how female CEOs influence green innovation (GI) in Asian industrial sector. Its main objective is to answer the following research questions: Are there differences in GI endeavors between Asian industrial firms with female CEOs and those with male CEOs? Does the size of the industrial firms have a positive moderating effect on the relationship between CEO gender and GI? Based on our research questions, the size of firms is likely a determining factor in the GI of female CEOs. This research employs rigorous econometric modeling to analyze a substantial dataset of Asian industrial listed companies spanning from 2013 to 2022. Our findings show a strong and positive correlation between the presence of female CEOs and GI in Asian industrial firms. It has been proven that industrial firms led by females CEOs are more inclined to have environmentally friendly practices. Furthermore, the size of the industrial firms amplifies the beneficial influence of female CEOs on the firm's chances of engaging in GI initiatives. Regarding the moderating effect of size, the size of companies significantly magnifies the impact of female CEOs on GI. The impact of female CEOs on GI is more prominent in larger firms than in smaller ones. Our outcomes stay robust to endogeneity issues using two-step GMM estimators. This study proposes that stakeholders, particularly in Asian countries, should promote the increased representation of females in CEO roles, particularly within large corporations. This is because women-led companies demonstrate superior performance in GI endeavors. Thus, regulators need to implement policies that promote the inclusion of women in CEO positions within large-scale enterprises. These policies may potentially strengthen the private sector's capacity to foster sustainable innovation.

Keywords: female CEOs; green innovation; industrial sector; GMM

1. Introduction

Environmental concerns have intensified the pressure to conserve and maintain natural resources [1]. Businesses are increasingly realizing that they need to be involved in accomplishing these greening objectives [2]. Modern corporations encounter a multitude of environmental challenges and pressures. Firm managers recognize that GI is crucial for sustainable development and can provide a competitive edge. GI is a vital and efficient solution for firms to address a changing environment and mounting pressure [3]. Business innovations driven by sustainability models have revolutionized manufacturing strategies, taking into consideration ecological risks such as Green Innovation (GI) [4]. While the innovation issue has been extensively studied in finance literature, little

attention has been given to the influence of CEO gender on GI [5,6]. The significance of this issue lies in past research suggesting that female Chief Executive Officers (CEOs) are more risk-averse than their male counterparts [2,7]. Additionally, firms must prioritize GI to stay ahead, but this endeavor is hazardous and prone to failure [8]. The implications are that female-led firms are less involved in eco-innovation [9].

However, there is an assertion that women commonly experience discrimination based on their gender in their professional paths, particularly in societies with a strong patriarchal influence [10,11]. Moreover, the glass ceiling viewpoint highlights that women encounter greater obstacles in attaining senior leadership roles because of diverse social and cultural influences [5,7]. According to Becker [12], discrimination causes discriminating individuals to have suboptimal demands and wages. As a result, those people must work harder to meet the limited requirements [2]. In this scenario, female CEOs are expected to engage in more green innovative activities than male CEOs in order to outperform their male colleagues and secure CEO positions [7,13–15].

In addition, the performance burden may escalate for women in executive positions at large companies [16]. It can be argued that gender-based discrimination is more pronounced in large corporations [17]. Gender stereotypes frequently assume that women are not assertive enough and lack the time to manage larger firms due to their domestic responsibilities [18], making them unsuitable for CEO positions in larger companies [2]. Moreover, larger firms are known to attract top talents, making managerial competition more challenging [19]. Female CEOs face more managerial competition from larger firms compared with smaller ones [20]. Hence, female CEOs of larger corporations may have a greater propensity to engage in eco-friendly innovative activities [2,11,21], as these activities can enhance their managerial performance.

Based on prior practical studies and combining the insights of diverse theories, including upper echelon, social role, and contingency theory, this study examines how CEO gender influences the adoption of eco-friendly innovations. To be more specific, this paper intends to address the following research questions: Is there a difference in GI levels between firms led by female CEOs and those led by male CEOs? Additionally, does a company's size have a positively moderate impact on the connection between CEO gender and GI? Based on our research questions, it is likely that the innovative performance of female CEOs depends on the size of their firms. Our motivation is the inability to generalize and the contradictory nature of conclusions drawn from existing studies on the connection between female CEOs and GIs. Additionally, adequate research is absent on the influence of female CEOs on eco-innovation in Asian companies.

We use data from the Refinitiv Eikon database to answer these questions, specifically regarding Asian industrial firms. This data allows us to assess the environmental practices of firms led by female CEOs. The reason for selecting the Asian industrial firms for this study is their significant ecological impact. Furthermore, it faces enormous pressure from stakeholders as sizable emitters of GHGs. With job creation and business support, the industrial sector has emerged as the primary force behind the global economy [60,87]. These progressions have downsides, such as depleting natural resources and disrupting ecological balance. This correlation has not been adequately studied in the literature.

This study makes three main contributions. First, the study successfully merges two conflicting streams of financial literature. Specifically, the first stream examines how CEO gender influences firm behavior and outcomes. Alternatively, another stream delves into the factors influencing GI, but it neglects to consider the role of CEO gender in this matter [9]. Second, the relationship between CEO gender and GI is contingent on the firm's size. These results could explain the conflicting findings seen in previous studies. In more detail, this study suggests that larger firms are more likely to experience significant advantages when they have female CEOs compared to small firms. Third, this study stands out from others in this area because it utilized a larger sample size and econometric solid techniques. Instead, many studies depended on primary data from surveys [2,9], and the lack of panel data hindered them from conducting the supplementary analysis for robustness. This study has practical implications, too. To foster more GI, stakeholders should promote the appointment of female CEOs in larger firms.

2. Theoretical Framework and Hypotheses Development

2.1. Green Innovation

The literature employs various terms to describe innovations that mitigate the impacts of business eco-friendly activities [22], including ecological/environmental innovation, sustainable innovation, and GI [3,23]. GI has become a popular concept among organizations, public authorities, stakeholders, and the media [7]. It encompasses various systems, techniques, and products that boost energy conservation and minimize eco-friendly impacts [24,101]. GI is typically classified into categories design, manufacturing, processes, production, and technology [25]. GI means designing or modifying products to minimize resource consumption or environmental harm [26]. Corporate GI's primary objective is to advance a sustainable future by resolving ecological challenges [27]. Adopting GI helps mitigate waste, pollution, and emissions and boosts business profitability by promoting innovative production practices and efficient resource utilization [28]. GI is generally believed to positively affect a company's competitive advantage [29]. Scholars assert that businesses can find a profitable win-win solution by embracing GI [3,30], which addresses environmental preservation and economic growth. The growing demand for environmentally friendly products has attracted considerable attention from academics and industry, making GI highly sought after [31]. Many studies have concentrated on understanding why corporations decide to implement GI [26]. One reason is that companies must prioritize GI to acquire legitimacy [28]. For example, a company that develops and enacts environmentally innovative policies sends a strong message to the market of its genuine commitment to improving the environment [5]. Another reason is that firms are more likely to adopt and implement GI when facing an ecological legitimacy crisis [24]. Thus, GI is seen as crucial in benefiting the environment and society while promoting efficient resource utilization and enhancing profitability [3].

2.2. Female CEOs and GI

The CEO of a company makes critical strategic decisions, such as entering and exiting markets, implementing innovations, and allocating resources [42,111,112]. According to the prior literature, the CEO is the highest-ranking executive in the corporation, handles strategy development, and substantially impacts decision-making [95,103]. Therefore, researchers assert CEOs hold a vigorous sway over companies' strategic adoptions and implementation, permitting them to influence eco-friendly plans and practices [10]. According to the upper echelons theory, top executives are vital in promoting environmental innovation [33]. The theory states that top-level manager's individual traits, including personality, culture, ethical values, and risk aversion, influence companies' strategic decisions because of differences in viewpoints and behavior between female and male executives.

Despite the frequent emphasis by market authorities on promoting female board representation [31,43,45,90], there is a noticeable lack of discussion regarding appointing female CEOs [7,44,46]. Furthermore, despite many businesses promising to increase female representation on their boards, the global underrepresentation of females in CEO positions continues [5,10,47]. According to analysis in S&P for US-listed companies, there were over 19 male CEOs for each female CEO in 2018. Moreover, according to [32], the study shows that women comprise only 0.8% of CEOs in Japan. According to CEO magazine, female CEOs only account for 5.4% of the total number of CEOs worldwide in 2023.

There has been limited research on the impact of women CEOs [5,33,34,95], despite a substantial amount of scholarly attention on the relationship between women on boards and corporate GI [22,23,28,34,48]. The effect of women differs depending on whether they hold CEO positions or serve as board members [7,14]. Board members, who are women, have a responsibility to monitor [31]. Nevertheless, when in CEO roles, they hold decision-making power [2,35]. The CEO holds the highest position in the company and plays a crucial role in its achievements [9]. The CEOs are actively involved in daily business activities and are responsible for making high-level managerial decisions, including those related to GI [6,11]. Formulating strategies and exerting strong decision-making power are critical responsibilities of the CEO within the organization [36,37,49]. As a result, experts

contend that CEOs play a significant role in shaping firms' strategic preferences and execution, thus giving them considerable power to impact environmental policies and practices. Contextually, researchers, e.g. [37,39], have argued that firms with more female CEOs might have an edge in gaining enhanced social and financial outcomes. Nevertheless, academic research on the impact of female CEOs on GI strategy remains underexplored [2].

The varying biological and social attributes of women and men can arguably elucidate the divergent behaviors exhibited by gender-based CEOs, which may include their propensity to tolerate risks during the decision-making process [15]. As a result, men are more inclined to take risks in order to accomplish their goals [4], as these risks can lead to greater rewards [33], satisfying their assertiveness and desire for control [53]. Therefore, several research studies indicate that men are more inclined to take higher economic risks compared to women, possibly due to the influence of higher testosterone levels in men, which drives them to strive for greater achievements [2]. In contrast, women frequently encounter discrimination based on their gender while trying to pursue their professional goals [5,6,9]. As a result, women face more significant challenges in attaining leadership positions within different organizations. A barrier known as the glass ceiling prevents women from achieving high-level managerial roles [14]. Moreover, those who accomplish this are likely to experience a decrease in their wages compared to men in the same position.

The upper echelon theory has long recognized that CEOs' personal traits play a significant role in explaining companies' behavior and results [7,34]. According to this theory [5,11], CEOs' characteristics influence how they interpret complex environments and enable them to make effective operational and strategic decisions in response [16,33]. CEOs play crucial roles that ultimately impact firms' behavior and outcomes [38]. Gender is likely to significantly impact GI and corporate outcomes. Eco-innovation heavily relies on CEOs' risk-related behaviors, which in turn affect the risky decisions involved [36–38].

In addition, the social role theory suggests that women possess inherent qualities such as kindness, empathy, and a greater sense of social responsibility than men [5,14,32]. Companies have a social responsibility to engage in GI [39], so women must actively participate in decision-making processes regarding GI [11]. This will help the company meet social expectations and fulfill its social responsibilities. If a woman held the CEO position in a company, her role would significantly influence decision-making. As a result, they would gain more authority in determining the firm's annual social responsibility budget, thereby considerably impacting the company's GI. Female CEOs can enhance cognitive diversity in businesses, fostering innovation through diverse perspectives, experiences, and leadership styles [51]. Diverse leadership teams promote creative problem-solving and open-mindedness [40,41]. This can drive GI implementation, including eco-friendly practices. Female CEOs prioritize sustainability and ethics, showing empathy and moral guidance [2,50]. This supports GI principles, aiming to balance profitability with sustainability [7,52]. Female CEOs can promote eco-friendly innovations with financial benefits.

The upper-echelon theory is supported by empirical studies [7,96], which show the influence of managers' idiosyncrasies on firms' performance as well as decision-making [42]. For example, based on French-listed companies, [7] argue that there is a connection between gender diversity among executives and an increase in GI. Similarly, [11] establish conclusive evidence supporting the notion that female CEOs are more ecologically conscious than male CEOs. Data from Chinese listed firms between 2008 and 2016 forms the basis of this finding. The findings of [2] study suggest that Indonesian firms under the leadership of female CEOs are more inclined to be innovative. On the contrary, according to [9], female-led companies are less inclined to invest in innovation than male-led companies. Additionally, [34] contend that the gender of the chairperson does not have a substantial impact on the level of eco-friendly innovation in Chinese manufacturing companies. According to a study by [55], women who owned businesses were more likely to introduce innovations globally than women in managerial positions. Also, the research conducted by [54] does not establish a significant connection between the presence of female CEOs and innovation in all French-listed companies from 2000 to 2018. Also, [6] discovered a negative impact of female CEOs on eco-innovation in China's publicly operated firms from 2008 to 2017. It is worth mentioning that the

findings of previous studies have displayed inconsistency. According to the literature discussed above, even though women CEOs are risk-averse, they are still willing to participate in environmentally friendly innovation projects because they know the importance of corporate social responsibility. In addition, scholars emphasize that female leaders tend to be more innovative and egalitarian in their approach to strategy-making, and they are more likely to embrace novel initiatives [2,96,113]. Female leaders demonstrate a stronger inclination towards the well-being of stakeholders [7,8]. Female CEOs have a more vital ability to integrate and balance the interests of diverse stakeholders, including the environment, alongside shareholders' interests [95]. Empirical research has shown that female leaders prioritize environmental issues their organizations face [9,15]. These CEOs' socialization responsibilities and career paths motivate them to prioritize relationship-building and contribute to a better community by advocating for eco-friendly initiatives [83]. As a result, the gender socialization perspective suggests that female CEOs are more likely than their male counterparts to advocate for sustainable practices [11]. Exploring the relationship between female CEOs and a company's green innovation is an intriguing aspect of this discussion. Taking these studies into account, we propose the following hypothesis;

H1: The presence of female CEOs in Asian listed firms is strongly correlated with increased GI.

2.3. *The Moderating Role of Firms' Size*

The contingency theory [56], suggests that the size of a company is a context-dependent factor [19] that can either facilitate or hinder various activities of firms, including decision-making and fostering creativity [3,17,57]. Thus, a company's size may significantly influence CEOs' involvement in making decisions for the company. The importance of firm-specific factors [2], such as firm size [11], in shaping the nexus between female CEOs and GI becomes evident and needs further investigation. Furthermore, as per the resource-based view theory [19], the success and competitive advantage of a firm are determined by its capabilities and resources [21]. Even though size has a substantial impact on a firm's activities [18], previous research has only considered it as a variable to control [7,30,58]. According to previous studies [3,19,20,24], the size of a firm can either facilitate or impede its willingness to adopt GI practices [88]. The presence of female CEOs in larger companies can have a multiplier effect on GI because of their access to abundant financial and nonfinancial resources [17].

Consequently, this study examines the influence of firm size on the connection between female CEOs and GI in Asian industrial firms for various reasons. Many compelling reasons make firm size a crucial factor [16]. For example, there is a direct association between the size of a firm and its commitment to research and development [59], which is seen as a crucial factor for GI [11]. Over time, researchers have consistently witnessed compelling empirical evidence supporting a strong correlation between the size of a firm and its investment in research and development [20], ultimately facilitating GI [2]. Increased profitability in larger corporations allows them to finance internal research and development and promote environmentally friendly innovation [19]. Financial institutions find it easier to provide funding for R&D and GI to larger firms due to their higher level of informational transparency [24]. Larger firms have the advantage of leveraging R&D investments and transforming them into eco-innovations [11]. [7] argue that large companies possess greater financial flexibility than smaller ones, which drives them to pursue innovative initiatives. Additionally, [22] discovered a positive correlation between larger companies and increased eco-friendly innovation.

The influence of CEOs in firm decision-making varies depending on the firm's size [7]. Larger companies have greater wealth and resources [24], which can enhance the impact of female CEOs on environmentally friendly innovations [11]. Since female CEOs in larger firms have access to greater resources, they can easily meet the demands of R&D. This, in turn, allows for the growth and success of eco-friendly innovations because of the economies of scale and scope that these female CEOs can effortlessly establish. Female CEOs in large corporations have a strategic advantage in accessing untapped opportunities. Also, larger companies may subject women to increased gender-based discrimination and stereotypes when vying for high-level managerial roles [2]. Take women, for

instance, who are commonly believed to lack the necessary traits for high-level managerial positions and are expected to prioritize their domestic duties, even though leading larger firms requires significant time and effort. To reach top positions in larger firms, women must outperform men and engage in risky activities like GI. Additionally, female CEOs in larger companies can effectively manage and mitigate risk by overseeing various research and development initiatives. External resources are more readily available to CEOs of larger companies [3]. With their firms holding a substantial market share, these CEOs have a competitive edge over others. This advantage allows them to attain returns easily and fosters their commitment to GI. Due to the lack of prior research or evidence, we categorize H2 as exploratory, considering the connection between female CEOs, firm size, and GI. Based on the reasons mentioned earlier, we anticipate that firm size will have a substantial moderating effect on this connection, leading us to propose the following hypothesis;

H2: The size of Asian industrial firms positively moderates the relationship between female CEOs and GI.

3. Research Methodology

3.1. Sample Selection and Data Collection

To test our hypotheses, we examined a large sample of publicly traded Asian industrial firms worldwide, specifically the most significant GHG emitters from 2013 to 2022. The latest year for which data was accessible is 2022, thus marking the end of the sample. We collected 35760 firm-year observations for 3576 Asian industrial firms as the initial sample (2013-2022). Data for this study was obtained using the Refinitiv Eikon database. Thomson Reuters Eikon “which was previously known as ASSET4” offers a diverse collection of financial information, including data from annual reports and other sources. Empirical research in the last few decades has heavily relied on this widely used database [3]. The database provided us with balanced panel data on the independent, dependent, and control variables of Asian industrial firms, which can be used for primary analysis and robustness checks. By utilizing this data, we can accomplish the study objective. The reliability and validity of these databases have been proven in prior research [4,23].

3.2. Variables Measurements

3.2.1. Green Innovation (GI)

Previous research has relied on the number of environmental patents to show GI. Yet, this measurement is inadequate as not all innovations are patented, and not all inventions are genuinely innovative [21]. Furthermore, certain patents are crucial and tied to innovative products and advancements, while others are insignificant. By following the method of [4], this study uses the Eikon GI score from the Refinitiv Eikon database as the dependent variable, which measures a firm's ability to decrease environmental expenses and burdens for its clients, generating fresh market prospects through advancements in ecological technologies, processes, or eco-friendly products. The Eikon eco-innovation score measures a company's GI level on a percentile scale, with 100 being the highest commitment level. Industry specifications are considered in the Eikon GI score. The company's score shows how much it innovates in sustainability compared to industry standards [61]. An objective assessment of the degree of GI is ensured by comparing a firm's score to that of all other firms in the same sector [49,62,101].

3.2.2. Predictor & Moderator Variables

We followed [7,11] in capturing the effect of female CEOs by using the dummies of females appointed to top management. Our key independent variable is female CEOs, shown by a binary variable coded as '1' for female CEOs and '0' for non-female CEOs. In addition, previous studies have shown that firm size is crucial in determining innovation, and they have measured it by the natural logarithm of total firm assets [7,11].

3.2.3. Control Variables

The present study utilized multiple control variables, including board mechanisms, and firm-specific characteristics [63–65,86]. Overall, incorporating control variables into the link between female CEOs and GI is crucial to establish a trustworthy and valid correlation. By considering additional influencing factors, we can effectively isolate the influence of female CEOs on GI, address potential biases [66], and derive more precise conclusions [67]. Therefore, we include various board-specific variables, such as board expertise (B_ Expertise), board tenure (B_ Tenure), and board gender diversity (BGD), to capture the quality of corporate governance [68,69,74,75,97].

Our model also accounts for leverage (LEV) since [25] report a significant negative relationship between LEV and GI because of the interest and bankruptcy costs [57]. Companies with high levels of financial debt often experience increased pressures to survive, preventing them from having additional resources to invest in ecologically friendly innovation [71]. To eliminate any potential influences that could skew the findings [70,71], profitability (ROA) is assessed as a measure of accounting performance [72]. Earlier studies e.g., [73] have employed women employees (WOMEN) as a means to assess gender equality in a country, aligning with the fifth Sustainable Development Goal [76]. The firm's age (AGE) plays a significant role in its innovation endeavors [34]. As time passes, institutional inertia grows stronger [9], posing a potential obstacle to companies adopting environmentally friendly innovations [24]. Consequently, younger firms are predicted to be more innovative than older firms [2,77]. More specific information about these variables can be found in Table 1.

Table 1. Definitions & Description of Study Variables.

Variable	Notation	Description
<u>Dependent variable:</u>		
Green Innovation	GI	The GI score of Eikon Refinitiv ranges from 0 to 100, reflecting the extent of GI activities in a company.
<u>Moderator Variables:</u>		
Firm Size	SIZE	Measured by the natural logarithm of total firm assets
<u>Independent variable:</u>		
Female CEOs	FCEOs	A binary variable that equals one for female CEOs and zero otherwise.
<u>Control Variables:</u>		
Board Expertise	B_ Expertise	The ratio of board members with accounting/finance expertise to the total number of directors.
Board Tenure	BTenure	The average years of service for each board member.
Board Gender Diversity	BGD	Proportion of female appointed to boards.
Leverage	LEV	Total debt to total assets
Firm performance	ROA	Net income/total assets

Women's Employees	WOMEN	Measured by the percentage of female employees to the total company employees.
Firm Age	AGE	Measured by the number of years since it was established

Source: Created by authors.

3.3. Statistical Model

Our study primarily aims to examine how female CEOs influence green innovation and whether firm size moderates this connection. Our hypotheses are tested using multivariate modeling techniques. Here are the estimations:

$$GI = \beta_0 + \beta_1 FCEO_{it} + \beta_2 SIZE_{it} + \beta_3 B_Expertise_{it} + \beta_4 B_Tenure_{it} + \beta_5 BGD_{it} + \beta_6 LEV_{it} + \beta_7 ROA_{it} + \beta_8 WOMEN_{it} + \beta_9 AGE_{it} + YEAR_{it} + INDUSTRY_{it} + \epsilon_{it} \tag{1}$$

$$GI = \beta_0 + \beta_1 FCEO_{it} + \beta_2 SIZE_{it} + \beta_3 FCEO*SIZE_{it} + \beta_4 B_Expertise_{it} + \beta_5 B_Tenure_{it} + \beta_6 BGD_{it} + \beta_7 LEV_{it} + \beta_8 ROA_{it} + \beta_9 WOMEN_{it} + \beta_{10} AGE_{it} + YEAR_{it} + INDUSTRY_{it} + \epsilon_{it} \tag{2}$$

In these equations, *i* stands for Asian industrial firms (1 to 3576), *t* represents the study period (2013-2022), and ϵ represents the error term. Table 1 contains the variable definitions. Equation 1 tests the first hypothesis that female CEOs promote green innovation; therefore, a positive coefficient β_1 is anticipated. In H2, the relationship between female CEOs and GI will be examined to assess the potential moderating effect of SIZE. To explore the second hypothesis, this study's second model incorporates an interaction term, FCEO*SIZE. This interaction showcases how female CEOs are linked to SIZE. Taken together, the firm's size could play a crucial role in shaping our baseline outcomes. To examine the relationship between female CEOs, GI, and firm size, we estimate Equation (2) in the following manner;

Confidence in the results was enhanced through tests carried out on each operationalized model. Several tests were conducted to ensure the reliability of the data [68,78]:

First, the test results for normality [8,80,81], as shown in Table 2, which involves skewness and kurtosis, are used to identify outliers. In order to achieve a normal distribution, the variables are winsorized at the 1% level [103,104].

Second, the variance inflation factor (VIF) was calculated to check for multicollinearity among the predictors, as illustrated in Table 3.

Third, the Heteroscedasticity was measured using the Breusch-Pagan (BP) /Cook-Weisberg test [41].

Finally, the choice between fixed or random effects in the panel data was determined using the Hausman test [60,68,102].

The panel data method is used because the dataset comprises cross-sectional and time-series observations [105]. Panel data provides more comprehensive and varied information and reduces issues with multicollinearity among explanatory variables, leading to more reliable outcomes [106,107]. One advantage of panel data design is that it allows for fixed-effects estimation, enabling researchers to account for unobservable firm-specific effects [108]. This approach also includes a feature that removes endogeneity caused by unobserved differences in model specifications [109]. The STATA 14 software was used to operationalize all the tests. To address the potential problem of omitted variable bias [79], we utilize a firm-fixed-effects regression to estimate both equations [38]. Unobservable firm-level characteristics could also influence the connection between female CEOs and GI. Characteristics that cannot be observed directly can be associated with a corporate GI and the chances of having female CEOs in top management. This issue is addressed by using the fixed-effects method. To estimate the equations, we utilize a company fixed-effects regression.

Table 2. Descriptive Statistics.

Variables	N	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
GI	3,576	0.1434	2.667	0.0764	0.9167	-1.459	4.393
FCEOs	3,576	0.0631	0.437	0	1	1.216	4.113
SIZE	3,576	21.55	1.719	14.84	26.755	-0.252	3.186
B_ Expertise	3,576	53.682	18.511	0	100	-0.319	2.961
B_Tenure	3,576	6.662	3.783	0.5	27.8333	1.509	5.86
BGD	3,576	13.674	11.417	0	75	0.892	3.999
LEV	3,576	0.281	0.226	0.047	0.908	1.033	3.501
ROA	3,576	0.0655	0.0438	0.0089	0.147	0.605	2.202
WOMEN	3,576	27.303	18.489	0.167	88.5	-1.282	5.804
AGE	3,576	41.788	29.5145	1	138	-0.524	3.645

Source: Created by authors.

Table 3. Correlation matrix.

Variable	GI	FCEOs	SIZE	B_Skill	B_Tenure	BGD	LEV	ROA	WOMEN	AGE
GI	1.000									
FCEOs	0.1696* 0.0000	1.000								
SIZE	-0.235* 0.0000	-0.271* 0.0000	1.000							
B_Expertise	-0.1244* 0.0000	-0.0953* 0.0000	0.1012* 0.0000	1.000						
B_Tenure	0.0277 0.0974	0.1000* 0.0000	-0.1932* 0.0000	0.0465* 0.0054	1.000					

BGD	0.1259 * 0.0000	0.420 0* 0.000 0	- 0.282 5* 0.000 0	- 0.133 6* 0.000 0	0.0456* 0.0064	1.000				
LEV	- 0.0993 * 0.0000	- 0.049 2* 0.003 3	0.155 7* 0.000 0	-0.009 0.591	-0.0239 0.1526	- 0.011 9 0.477 9	1.000			
ROA	0.1091 * 0.0000	0.067 1* 0.000 1	- 0.303 1* 0.000 0	- 0.053 8* 0.001 3	0.0691* 0.0000	0.133 1* 0.000 0	- 0.268 3* 0.000 0	1.000		
WOME N	0.1111 * 0.0000	0.333 8* 0.000 0	0.049 6* 0.003 0	0.082 1* 0.000 0	-0.0394* 0.0184	0.094 8* 0.000 0	0.062 1* 0.000 2	- 0.075 9 0.000 0	1.000	
AGE	- 0.3219 * 0.0000	- 0.293 3* 0.000 0	0.093 8* 0.000 0	0.085 8* 0.000 0	0.1507* 0.0000	- 0.163 9* 0.000 0	0.050 6* 0.000 0	- 0.062 8* 0.000 2	-0.185* 0.0000	1.00 0
VIF	--	1.51	1.35	1.29	1.21	1.06	1.1	1.19	1.26	1.16

Source: Created by authors. Note: * P < 0.05. (2-tailed).

4. Results and Discussion

Here, you will find the presentation of the obtained results and their reflections.

4.1. Descriptive Statistics and Correlations

Table 1 presents the descriptive data for the study variables. The green innovation (GI) score averages 14.34, with a minimum value of 7.64 and a standard deviation of 2.667. This variable has a maximum value of 91.67, indicating that some Asian companies invest significantly in GI. In our sample, Asian firms represented 6.31% female CEOs, as the independent variable. Regarding firm size (SIZE), the average value is 21.55, the minimum value is 14.84, and the maximum is 26.755. The literature supports the consistency of the control variables' statistics. On average, the board expertise (B_Expertise) value is 53.682 out of 100 points. The value ranged from 0 points, the lowest, to 100 points, the highest. The mean duration of board tenure is 6.662 years (B_Tenure). The average proportion of board gender diversity (BGD) is 13.674 out of 100 possible points. The lowest score was 0, whereas the highest score was 75. It suggests that certain companies in the sample excluded women from their corporate boards. The mean return on assets (ROA) among the Asian firms in our sample is 6.55%, and the average financial leverage (LEV) is 28.1%. It is worth noting that around 27.3% of

Asian companies' workforce comprises women. The firms' ages vary from 1 to 138 years, with an average of 41.78.

Pearson's correlations were employed to examine the bivariate connections among the chosen variables before conducting the official empirical examination [82]. Table 2 presents the correlation coefficients between the independent variables used in the regressions. Our regression analyses have no multicollinearity issue, as the highest correlation coefficient observed is 0.42 between SIZE and WOMEN. By conducting the VIF test, we measured the level of dependence among the model variables. The inference is supported by the VIF statistics, with the highest VIF value being 1.51. This research employed mean-centering of variables to address multicollinearity concerns before generating interaction terms [3,25], given the potential severity of multicollinearity issues in regression models [68].

4.2. Multivariate Regression Result

Our research questions depend on competing theoretical perspectives: (1) whether females CEO positively impact GI in Asian industrial firms; (2) whether the size of these firms has a moderating effect on the relationship between CEO gender and GI. Our estimated results, incorporating year and industry-fixed effects, can be found in Table 4. This paper focuses on GI as the dependent variable. Table 4 presents the outcomes of the multivariate estimations. The regression results are displayed in Model (1) without incorporating the interaction term between FCEOs and SIZE (H1), whereas Model (2) exhibits the results including the interaction term (H2). Table 4 demonstrates the significance of the F-Tests for the models, which are significant at $p < 0.01$ or better. Drawing from these findings, we can deduce the models' statistical validity. Furthermore, the R^2 values vary from 10.46% (model 1) to 17.12% (model 2).

In the first model, the findings from the entire sample indicate a strong and positive correlation between the presence of female CEOs and GI in Asian industrial firms. This supports H1, as the coefficient for female CEOs is positive and highly significant. Furthermore, this outcome shows that female CEOs enhance the drive for GI. While [11] support this finding, but [9] did not provide sufficient evidence to substantiate it. One possible interpretation of this discovery is that female CEOs within Asian companies demonstrate their effective leadership by actively participating in environmentally friendly innovation endeavors, surpassing their male counterparts to secure CEO positions [7], which aligns with a sociological perspective [2], discrimination makes women work harder to become top managers.

Another possible explanation for this is that having females as CEOs brings fresh perspectives and experiences that positively affect top management [5]. The argument suggests that female CEOs contribute to a firm's innovation capacity because of their ability to leverage human capabilities [7,35], diverse perspectives [77], and extensive networks [15], creating opportunities for promoting [14]. The findings propose that females' inherent maternal instincts compel them to be environmentally conscious and safeguard nature [37]. They confirm the social role theory that a female's upbringing influences her inclination to prioritize doing well and adopting green practices [5]. The results of this study align with the prevailing notion that women tend to be kind-hearted and nurturing [77]. Consequently, women in CEO positions make sure their business practices do not negatively impact any stakeholders [6], including the environment [11].

Control variables reveal that firm size (SIZE) is significantly and positively associated with GI, indicating that larger firms that allocate more funds to environmental protection are more likely to prioritize GI [2,22,24,38]. Moreover, there is a significant and positive relationship between GI and the control variables for corporate governance (B_Expertise, B_Tenure, and BGD). This implies that Asian firms with a high proportion of board expertise members, longer-tenured board members, and more female board members have significantly promoted GI [22,34,59,83,97]. Both financial leverage and female employees play a positive role in driving GI [91]. Limited resources in Asian firms prompt them to borrow for the purpose of GI and environmental preservation. Conversely, GI is significantly negatively impacted by ROA and AGE. The findings suggest that younger, less profitable Asian firms prioritize GI to boost their financial position, corporate image, and competitive advantage.

Model 2 in Table 4 presents the results for the second Hypothesis. The second model, presented in Table 4, outlines the interaction between female CEOs and firm size (FCEOs*SIZE). In their study, [19] asserted that the variables do not hold individual significance and therefore do not necessitate interpretation. Nevertheless, the positive coefficients for FCEOs and SIZE were observed in Table 4, alongside the statistically significant and positive interactive terms FCEOs*SIZE, which acted as determinants of the GI ($\beta = 0.327$, $t = 5.79$) at a significance level of 1% or better ; this suggests that the positive relationship between female CEO and GI is amplified by firm size. The empirical results clearly indicate that the size of a firm has marginal effects on the relationship between female CEOs and GI.

Table 4. Results of panel-data estimation (Fixed-effects Model).

Variables	Model (1)		Model (2)	
	H1		H2	
	Coef.	t	Coef.	t
Constant	-0.07	-11.01	4.0228	3.03*
FCEOs	0.107	2.11**	0.0265	1.66***
SIZE	0.0947	2.28**	0.144	2.26**
FCEOs*SIZE	-	-	0.327	5.79*
B_ Expertise	0.114	6.11*	0.186	5.99*
B_ Tenure	0.0666	2.36**	0.21	4.5*
BGD	0.1678	3.55*	0.214	3.81*
LEV	0.1632	3.46*	0.186	4.07*
ROA	-0.203	-2.67*	-0.0637	-3.2*
WOMEN	0.111	4.15*	0.157	4.81*
AGE	-0.231	-3.04*	-0.0636	-3.31*
Year Dummies	YES		YES	
Industry Dummies	YES		YES	
F-Test	38.65		1152.32	
Prob > F	0.0000		0.0000	
R-squared	0.1046		0.1712	
Breusch & Pagan	5302.08*		5373.47*	
Hausman Test	84.49*		72.66*	
Observations	3,576		3,576	

Source: Created by authors. *** P < 0.1, ** P < 0.05, and * P < 0.01. † P- insignificant.

Consequently, the interactive term displayed a significant and positive indication, reinforcing female CEOs' moderating impact on GI as firm size extends. In essence, the impact of female CEOs on GI is more prominent in larger firms than in smaller ones. Therefore, it can be concluded that female CEOs exhibited a heightened positive influence on promoting environmentally sustainable innovation [100]. Hence, this result supported the view that larger firms possess greater financial flexibility than smaller ones due to having more wealth and resources [2,3,92], which drives them to pursue innovative initiatives [3,19,20,24,88].

Thus, female CEOs in larger companies can effectively manage and mitigate risk by overseeing various research and development initiatives [59]. The correlation between larger firms and increased resource availability supports female CEOs in promoting GI. The adoption of environmentally friendly practices can be costly and necessitates significant resources and enduring dedication, advantages that are more accessible to larger firms [85,93,94]. Therefore, compared to smaller firms, female CEOs of larger firms have a more advantageous position in developing and executing policies related to ecological innovation. These findings provide support for the resource-based view theory [18], suggesting that the presence of capabilities and resources in larger companies with economies of scope and scale influences the inclination of female CEOs towards GI [11].

4.3. Robustness Checks- Endogeneity

Our existing firm's fixed-effects results on the relationship between female CEOs and GI may be biased because of endogeneity issues. To address this problem, we use alternative model specifications. This study applied a dynamic generalized method of moments (GMM) system estimator for accurate inference [30]. Dynamic GMM accounts for endogeneity arising from unobservable heterogeneity and simultaneity [84]. Many studies have recommended the dynamic GMM estimator as the optimal solution for tackling endogeneity and simultaneity in order to overcome this problem [62]. In the GMM estimator, lagged-level variables are employed as instruments for the differenced equation, while lagged differenced variables serve as instruments for the level equation [3].

This study seeks to obtain a valid and consistent result from the regression model by utilizing instrumental variables, including lagged values of the endogenous variable. Another benefit of utilizing the GMM estimator is that it can tackle issues such as reverse causality and the presence of time-invariant omitted variables that may not be adequately addressed by running a fixed-effect regression [41,85,110]. Following the methodology proposed by [89], we performed instrument validity tests. Table 5 confirms the significance of AR (1) with $p < 0.05$, indicating the importance of lags in controlling the model's dynamics, while the insignificance of the AR (2) value suggests no serial correlation in the second difference [62]. The insignificant p-value ($p > 0.10$) of the Hansen J test of over-identifying restrictions in Table 5 confirms our instrument validity. The results in Table 5 consistently show positive and statistically significant outcomes, confirming the reliability of our main findings and reducing endogeneity concerns.

Table 5. Two-step system GMM regression/ Arellano-Bond dynamic panel-data estimation.

Variables	Model (1)		Model (2)	
	H1		H2	
	Coef.	t	Coef.	t
Constant	0.216	7.12*	0.0487	1.99**
GI (t-1)	0.483	4.43*	0.528	3.48*
FCEOs	0.098	2.42**	0.133	3.58**

SIZE	0.108	1.88***	0.045	2.15***
FCEOs*SIZE	-	-	0.1747	4.31*
B_ Expertise	0.203	2.69*	0.1489	4.58*
BTenure	0.2101	2.73*	0.041	2.64**
BGD	0.0689	5.43*	0. 132	4.13*
LEV	0.0821	1.84***	0.074	1.88****
ROA	-0.063	-2.24**	-0.0586	-2.37**
WOMEN	0.17	5.84*	0.295	5.06*
AGE	-0.097	-2.33**	-0.054	2.72*
Year Dummies	YES		YES	
Industry Dummies	YES		YES	
Hansen J. Test	24.163†		35.974†	
AR (1)	0.0000		0.0042	
AR (2)	0.1192		0.2652	
Instrument	156		148	

Source: Created by authors. *** P < 0.1, ** P < 0.05, and * P < 0.01. † P- insignificant. (Regression with robust standard errors).

5. Conclusions

Ultimately, our research analyzes how female CEOs contribute to firms’ endeavors to achieve environmental sustainability through implementing green innovation. This holds particular significance for Asian emerging markets as they undergo industrialization to capitalize on substantial economic development prospects. Despite the adverse ecological effects of industrialization, firms can mitigate these effects by adopting green innovation technologies. A significant and positive correlation is observed between female CEOs and green innovation. The strength of relationships is more remarkable in larger Asian companies.

This research model improves upon previous studies on the influence of female CEOs on green innovation in Asian firms by considering the unique organizational structures found in emerging economies. The findings of this study have important implications for managers. This study challenges the glass ceiling effect by suggesting that women outperform men as top executives and that their Asian establishments should not hinder their advancement in top management. Thus, to sustain their green innovation strategy, Asian companies must actively recruit and advance females into top leadership positions. Female CEOs demonstrate a greater propensity for risk-taking through their active engagement in innovative pursuits than their male counterparts. The government and other stakeholders in Asian countries must facilitate the growth of women-led firms to promote eco-innovation. Companies headed by female CEOs have the potential to foster green innovation efforts on a national scale. The findings also provide social insights, emphasizing the significance of hiring females in diverse managerial roles. These procedures promote a comprehensive workplace culture that delegates females and supports professional progression. Governments should implement

quotas mandating a certain percentage of females in company leadership positions. Regulatory bodies must enforce the enabling approach to prioritize gender equality, which usually involves businesses following guidelines or giving reasons for not complying. Additionally, governance may provide tax incentives to organizations to prioritize gender diversity in leadership roles or grants supporting green innovation led by diverse teams, enabling females to access high-level positions. Moreover, customers and civil society organizations can apply normative pressure on firms to encourage the adoption of environmental innovation procedures. In addition, larger firms led by female CEOs actively participate in significantly more sustainable innovation initiatives. Therefore, it is imperative to establish policies that promote women's representation in CEO roles within large corporations. These policies are expected to potentially increase the capacity of private sectors to drive eco-innovation strategies.

This study depends on variables from the Thomson Reuters database, employed as a comprehensive metric for GI scores. Reliance on this single metric introduces significant limitations that may affect the depth and applicability of the findings [98,99]. While the Thomson Reuters database is a trusted source for companies' ecological innovation, patent applications can be a valuable alternative to GI. Standard certifications in ecological management can serve as a reliable indicator of eco-friendly innovation in this context. In addition, patent applications could be employed in future research to reinforce the earlier findings. To enhance future research, it is crucial to incorporate more qualitative and quantitative data, such as specific measurements of environmental impact reductions or the level of acceptance of green technologies. This method would enhance our comprehension of green innovation, enabling us to fully grasp corporate ecological strategies and expand our observation of various innovations. Incorporating this recommendation into future studies provides a framework for future researchers to improve upon and enhances the validity of future research findings. Additionally, it equips stakeholders with a comprehensive set of tools to evaluate and implement effective environmental strategies. To encourage a more extensive exploration of green innovation metrics, this recommendation suggests methodological enhancements for future researchers to consider. This will build upon the foundational work presented in this manuscript. Limited data access and institutional weaknesses pose significant challenges for researchers studying emerging economies such as Asian countries. Our study stands out from others in this area because it utilized a larger sample size and econometric solid techniques. Despite the strengths we observed, our study was not without limitations. The primary focus of this study was exclusively on female CEOs in Asian industrial companies. Consequently, substantial work remains to be undertaken to enhance our understanding of how the personal characteristics of female CEOs, such as age and educational background, influence green innovation. To improve the generalizability of our findings, future research should be conducted in a context different from that of Asian industrial companies. Future studies must also explore additional contextual factors, like capital structure, to gain a more comprehensive understanding of the connection between female CEOs and eco-friendly innovation.

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