Review Journal of Social Psychology & Social Works
http://socialworksreview.com
ISSN-E: 3006-4724
ISSN-P: 3006-4716
Volume: 3
Issue: 1 (2025)

Environmental, Social and Governance (ESG) Performance and Green Innovation: An Investigation based on GMM

Zara Rafique[1], Dr. Umer Ayub[2], Uzma Karamat Baig[3], Sajid Khan[4], Dr. Humara Adnan[5]

[1]Assistant Professor at Lahore Garrison University and PhD Scholar at Dr. Hassan Murad School of Management, UMT Lahore, Pakistan. zararafique86@yahoo.com
[2]Associate Professor, Dr. Hassan Murad School of Management, UMT Lahore, Pakistan. umer.ayub@umt.edu.pk
[3]PhD Scholar at Dr. Hassan Murad School of Management, UMT Lahore, Pakistan. ukaramatbaig@gmail.com
[4]In-Charge (Health, Safety & Environment Laboratory), The Benazir Bhutto Shaheed University of Technology & Skill Development, Khairpur Mirs, Pakistan. sajidkhan@bbsutsd.edu.pk
[5] Assistant Professor, Department of Mathematics, Comsats University Islamabad, Pakistan. humaira_ali@comsats.edu.pk

Abstract

Enhancing sustainability requires corporate initiatives to improve green technology; as a result, academics are interested in ways to encourage green innovation. The impact of environment, social, and governance (ESG) ratings on business green innovation in China is investigated in this study. This research examines the influence and mechanism of ESG ratings on green innovation using data of Chinese listed enterprises between 2013 and 2022. The researchers use Bloomberg ESG rating, CNRDS and CSMAR database for collection of data regarding all variables. The researchers conduct descriptive statistics, correlation matrix, and GMM (Generalized Method of Moments) model tests. According to the research, green innovation increase with ESG ratings. Additionally, empirical data suggests that the impact of ESG ratings on green innovation also encourages corporate joint green patents and the quality of green innovation. Businesses with superior ESG performance have been more overtly promoting their green innovation. ESG ratings are a significant factor in enhancing corporate green innovation, according to empirical data. The findings offer useful information to businesses, investors, and legislators on the important role that ESG ratings play in encouraging green innovation and offer plan of action to improve corporate performance.

Keyword: Sustainability; Green innovation; ESG; GMM; Green Technology

Introduction

Although industrialization reliant on fossil fuels has markedly enhanced human productivity, the unpredictability of the ecological environment has been aggravated by the consequent greenhouse gas emissions, prompting inquiries into the attainment of environmental sustainability. Green innovation has enhanced an essential solution to environmental concerns and a key strategy for energy transformation and breakthroughs in industrial technologies. Nonetheless, an extended investment cycle

and a significant failure rate are characteristics of green innovation (Halmstrom, 1989). Administrators, constrained by short-term performance expectations, are often hesitant to engage in green innovation due to its association with increased costs and thus worse short-term financial outcomes. Moreover, shareholders in developing capital markets such as China are unable to effectively monitor management due to significant information asymmetry, hindering corporate green transformation. Given the importance of corporate green innovation, much research has been conducted to examine the variables affecting green innovation from the perspective of corporate managers or policymakers' behavior. For example, certain studies have examined the influence of policymakers with explicit goals on environmental governance and sustainable development (Horbach, Rammer, & Rennings, 2012), whereas other studies have investigated the motivations of companies that both generated environmental matters and innovated in eco-friendly practices (Bendell, 2017).

This study seeks to enhance the understanding of the pillars of corporate green innovation by examining the influence of environmental, social, and governance (ESG) ratings on green innovation, in contrast to earlier studies. Given the deep-rooted concept of sustainable advancement in society, ESG has garnered heightened interest in the financial markets, applicable to both mature economies and emerging ones such as China. Initially, China's rapid economic expansion adversely affected the environment, hindering the inclusive and equitable society development. Consequently, the government has prioritized the establishment of an ecological society, and the idea of ESG corresponds with this policy aim. A plethora of regulations designed to improve firm ESG information disclosure and performance has developed in the capital market due to governmental lobbying. In 2018, the China Securities Regulatory Commission established a foundational framework for ESG information disclosure for publicly listed firms and required that these companies include ESG information into their investor communications by 2022. In May 2023, the administration underscored that central state-owned companies must examine and establish a robust ESG framework to enhance ESG performance. The implementation of an ESG system relies on independent third-party organizations in the capital market that present ESG ratings for companies, with governmental emphasis. Two separate theoretical predictions exist about the influence of corporate ESG ratings on green innovation, a compelling subject due to the importance of both ESG and green innovation for sustainable environmental practices. On the one hand, corporate green innovation initiatives may benefit from ESG ratings. First, shareholders can better track company green innovation with the use of ESG ratings. According to Zhang et al., (2021), shareholders are highly motivated to keep an eye on and enhance businesses' green innovation. Inclusive and diverse information employed in ESG ratings may successfully minimize the distorted impact of corporate strategy disclosure, even if the monitoring effect is inextricably linked to the improved information environment. Investors may thus improve their capacity to keep an eye on management and encourage corporate green innovation with the use of ESG rating data. Second, companies' green innovation efforts may result in lower short-term profits. In the lack of information on innovation performance, shareholders may blame this underwhelming performance on managers' lack of effort, which deters managers from engaging in green innovation (Jang & Yuan, 2018; Li et al.,2018).

ESG rating data may boost shareholders' confidence in managers' innovation choices and provide a comprehensive understanding of short-term performance, which encourages managers to innovate in a green way. However, corporate green innovation may suffer as a result of ESG ratings. According to some earlier research, ESG ratings are useless because they may only help companies ostentatiously comply with external shareholders' demands in order to gain various benefits or sway public opinion; they may not actually have a significant impact on improving their corporate sustainability behaviour

(Liu, Lu, & Ju, 2022). Therefore, the market pressure imposed by ESG ratings may cause managers to engage opportunistically in green invention efforts, creating the phenomena known as "green washing" or "green patent bubbles," which actually negatively impacts businesses' green innovation. Ultimately, it becomes an empirical question whether corporate green innovation is impacted by ESG ratings. China is the biggest rising economy and one of the world's biggest producers and users of energy. Over the last two periods, China has had significant economic progress, but it has also had serious issues with resource use and pollution. The Chinese government has taken the initiative to improve global environmental, governance, lead the creation of a low-carbon economy, and implement regulations to promote corporate green innovation after realizing that resource-dependent production is unsustainable. Even though earlier studies have shown that being "green" can improve a company's performance in developed nations (Kletner et al., 2014; Leonnidou et al., 2013), businesses in emerging economies still find it difficult to make the decision to go green due to a lack of institutional support and ineffective guidance (Brik et al., 2011). Therefore, it offers an appropriate environment for investigating whether ESG ratings influence corporate green innovation in the Chinese context. Furthermore, the Chinese capital market's ESG rating methods provide a chance to research how ESG ratings affect the development of green innovation in developing nations.

According to Li et al. (2018), emerging economies tend to have less transparent information settings and fewer avenues for shareholders to communicate with corporations about the reasons behind their ethical business practices (Rettab et al., 2009). ESG ratings may lessen the information asymmetry around corporate green innovation efforts by educating shareholders about businesses' ESG initiatives. Utilizing a sample of A-share listed companies from 2013 to 2022, we do a GMM generalized method of moments model test and utilize Bloomberg ESG rating. Green innovation benefits from ESG ratings, according to the assessments. Furthermore, empirical data suggests that corporate joint green patents and the quality of green innovation are also enhanced by the benefits of ESG ratings on green innovation. Additionally, companies with higher ESG performance have made more of an effort to showcase their green innovation. The aforementioned empirical data demonstrates the significant contribution that ESG ratings provide to enhancing corporate green innovation. The other part of the paper is organized as; Section 2, the hypothesis is developed and the relevant literature is reviewed. The sample, data, and study strategy are presented in Section 3. The primary analysis are reported in Section 4, and Section 5 brings the article to a close.

Literature Review

According to Xu et al. (2021), a company's responsibility, as seen through the lens of ESG and within the framework of neo-classical theory, is to expand profits via the legal and moral usage of resources, seeing any other actions that impede the maximization of shareholder value as undesirable. Meanwhile, according to neoclassical theory, the profits from ESG initiatives won't outweigh their expenses (Friedman, 2007). A company's overall sustainability, social responsibility, and governance issues are embodied in ESG. Generally speaking, social responsibility or environmental expenditures that go beyond the legally required minimum requirements are seen as adding to expenses and lowering corporate value. According to Kim and Lyon (2015), "the entire environmental regulation paradigm is built on the idea that firms must be forced into environmental improvements, as they would otherwise find these improvements expensive or unprofitable and hence would not undertake them voluntarily." On the other hand, contemporary corporate philosophy often asserts that ESG may support a business's long-term growth. According to Stakeholder Theory, for example, businesses should provide value for all parties involved, including customers, workers, local communities, natural resources, and the

environment, in addition to shareholders (Freeman, 1984). This idea states that in order to gain competitive advantages and long-term financial gains, businesses should take environmental efforts into account while developing their business plans. According to neoclassical theory, green innovation discourages new investments since it requires more capital and has a longer payback time. It also argues that investment gains do not outweigh expenses. However, according to contemporary corporation theory, green innovation investment may hinder short-term business performance and discourage managers from making green innovation investments and disclosing green innovation information because of the larger investment, longer return period, externalities brought about by the two attributes of "innovation" and "green," and higher risk involved (Zhai et al., 2022). Nonetheless, firms must get over management shortsightedness and make active investments in green innovation if they want to improve long-term financial success. According to current views, a company's creation of ESG ratings may encourage green innovation inside the organization. First, according to Stakeholder Theory and Signal Transmission Theory, a company's image and reputation are shaped by its ESG performance (Flammer, 2015; Barnea & Rubin, 2010). Social responsibility reports offer non-financial information, which lessens the information asymmetry between managers and investors (Cui et al., 2018). They also ease financing constraints and expand funding sources (Lenz et al., 2017), all of which lay the groundwork for the growth of green innovation. Second, according to Resource Dependence Theory, ESG is more of an investment than a cost, providing benefits to investors, employees, and other stakeholders (Claessens, 2006).

A company's green innovation is boosted when it exhibits strong social responsibility performance, which draws top talent to engage in productive activities (Kostant, 1999; Barnea & Rubin, 2010). Given its lengthy process, high degree of uncertainty, and costly transitional expenses, green innovation is crucial for a corporation's sustainable growth (Berrone et al., 2013). However, businesses must make crucial decisions when it comes to environmental conservation issues. This choice involves deciding whether to engage in proprietary research and development to find novel solutions or to buy already-existing green technology equipment straight from the market. First off, purchasing pre-made green technology equipment may help a business immediately improve its environmental impact while lowering the risks and resource use that come with research and development. This strategy, meanwhile, could limit the business's ability to develop green technologies on its own and create sustainable competitive advantages. Second, developing green technology internally includes higher risks and a significant upfront expenditure, but it may provide the business longer-lasting competitive benefits and more in-depth market knowledge. Lastly, since green innovation has positive externalities, businesses that participate in it are unable to fully benefit, which enables rivals to copy or profit from the advances at a reduced cost (Nie et al., 2021). As a result, businesses must carefully consider both choices' cost as well as their long-term and short-term (risk-adjusted) advantages.

Green innovation has been divided into two main categories in previous study and practice: non-inventive green innovation (like utility model patents) and inventive green innovation (like green patent technologies) (Xu et al., 2021; Wang et al., 2023). Generally speaking, creative green innovations play a crucial role in sustainable corporate growth by greatly increasing a company's technical sophistication and production efficiency (Quan et al., 2021;Fang et al., 2017). However, innovative green ideas often come with a higher cost and a higher risk and complexity of research and development than non-inventive green technologies. It becomes crucial to work on raising ESG ratings and fixing management problems, particularly for "bad" firms that are having operational difficulties. Given the demand to achieve environmental protection criteria, creating non-innovative green inventions becomes a viable

option. Notwithstanding their lower technical substance, non-inventive green innovations may significantly cut financial inputs and enhance business operations due to their comparatively reduced R&D complexity and risk. Therefore, in order to meet legal and regulatory standards, "bad" corporations may choose to invest in the development of such inventions. Green innovation is more flexible for "good" businesses, who have previously shown excellent operational success. These businesses will spend more in green innovation as they work to improve their ESG ratings, which will encourage both non-imaginative and inventive green innovation. These businesses' dominant positions in the market might be further solidified by the technical and production efficiency benefits of creative green technologies, which would be consistent with their long-term sustainable growth plans.

Ha: The green innovation level of corporation will increase with the creation of ESG ratings.

Methodology

Sample and data

Due to the constraints of corporate green innovation and ESG data, we have chosen Chinese A-share businesses listed on the Shanghai and Shenzhen stock exchanges from 2013 to 2022 as the study sample. The information on corporate green innovation is derived by correlating the research data of green invention patents as well as utility model patents granted by the China National Intellectual Property Administration with the green patent data of publicly listed firms in the CNRDS database. The data related green patent is primarily consisting of four categories: individually acquired green invention patents, independently acquired green utility model patents, total acquired green invention patents, also total acquired green utility model patents. The ESG data originates from Bloomberg's Environmental, Social, and Corporate Governance database. Entirely remaining data is obtained from the CSMAR database.

Dependent Variable

This study's dependent variables consist of five indicators: 1) The total count of green patents acquired, indicating the company's overall green innovation capacity; 2) The number of independently obtained green invention patents, signifying the company's autonomous high-quality green innovation level; 3) The number of collaboratively obtained green invention patents, representing the company's general autonomous green innovation level; 4) The count of collaboratively acquired green utility model patents, reflecting the company's cooperative high-quality green innovation level; 5) The number of collaboratively obtained green utility model patents, indicating the company's general cooperative green innovation level. To mitigate the lag effect of ESG on green innovation also the endogeneity arising from opposite connection, the dependent variables in this analysis are advanced by one period.

Independent Variable

ESGi,t represents the Bloomberg ESG rating of firm i in year t. Bloomberg's data points are weighted based on their significance and sourced from business publications, including annual reports, CSR reports, and corporate websites, therefore representing the spectrum of information released to investors. According to the aggregated data points are modified for industry circumstances, Bloomberg assessments that the disclosure score varies from 0.1 (minimum) to 100 (maximum). The Bloomberg ESG rating is a composite index intended to assess a enterprise's performance in three essential domains: environmental, social as well as governance. The score evaluates environmental variables, including energy utilize, waste management, and emissions control. These measures indicate a company's dedication and effectiveness in environmental methods and management of resources. The social score

includes aspects like as labor standards, accountability of product, and community involvement. This section evaluates the company's influence and impacts to its workers, consumers as well as communities in which it functions. The governance score emphasizes many facets of corporate governance, comprising board multiplicity and independence, executive remuneration rules, and the company's openness and shareholder rights.

Control Variables

In accordance with Waang et al. (2024), we account for firm size (Size), financial leverage (Lev), and return on assets (ROA). Table 1 delineates and computes the main variables.

Table 1. Explanation of variables

Variable	Description	Symbol	Computation Method
Dependent Variable	Green innovation	GI	Natural logarithm of the total quantity of independent green innovation patents acquired by the firm in the subsequent year plus one.
Independent variable	Performance of ESG	ESG	Current year's ESG ratings of the firm in the Bloomberg Database.
Control Variables	Size of Company	SIZ	Natural logarithm of the book value of the company's assets at the conclusion of the current year.
	Return on Assets	ROA	At the end of the period, net profit divided by total assets.
	Firm leverage	FL	Total Equity/Total Debt

Methodology

Descriptive Statistic

Descriptive statistics provide a varied representation of data. It comprises complete observations, mean, median, minimum, maximum, and standard deviation. The researchers employ descriptive statistics to encapsulate the data and articulate the principal themes succinctly. Table 2 below presents the descriptive statistics for assessing the ESG influence on green innovation in China. Green innovation is the dependent variable. The independent variables is ESG (Environmental, Social, and Governance). The control variables are firm size, return on assets (ROA), and firm leverage.

Table 2: Descriptive Summary

Variable	N	Mean	Median	Maxi	Mini	S.D
GI	900	5.6233	4.365	27.74	-13.58	4.7553
ESG	900	15.159	13.29	47.85	-44.45	10.561
FSZ	900	8.0585	6.46	9.795	6.8077	.5513

ROA	900	.0794	0.023	.482	.0367	.0402
LEV	900	.4285	0.324	2.383	0	.4277

The Table represents the descriptive statistics of China. GI is green innovation, this is dependent variable. ESG is independent variable, while SIZE for firm size, ROA is return on assets, and LEV for leverage, representing the control variables.

Correlation Matrix

Researchers often propose that the correlation between variables should not above 70% (Greene, 2003; Gujarati, 2012). Any result beyond 70% should raise concerns about the presence of multicollinearity. Table 3 displays the correlation matrix for China.

Table 3: Correlation Matrix

Variable	1	2	3	4	5	6	7	8
GI	1							
ESG	0.189	1						
E	0.143	0.375	1					
S	0.177	0.149	0.394	1				
G	0.353	0.4809	0.427	0.293	1			
FSZ	0.198	0.077	-0.296	0.000	-0.158	1		
ROA	0.335	-0.073	-0.080	-0.027	0.096	-0.160	1	
FL	-0.373	0.489	0.42	0.213	-0.044	0.395	0.105	1

This table presents the correlation coefficients among variables with their significance levels. Variables are described in Table 2. ***, ** and * represents values statistically significant at 1%, 5% and 10% respectively.

Generalized Moments Method (GMM)

GMM is used to address the problem of endogeneity. Endogeneity refers to the situation when the regressors are associated with the error term. The primary sources of endogeneity incorporate omitted variables, simultaneity, and measurement mistakes. Furthermore, the Durbin-Wu-Hausman test is used to detect the existence of endogeneity. Consequently, GMM is used to address the endogeneity issue by including instruments. The instruments serve as supplementary explanatory variables that are associated with the primary explanatory variables of the model, however are uncorrelated with the error term included. Additionally, the lagged dependent variable introduces the issue of autocorrelation. Similarly, the time-invariant characteristics of a company may be associated with the independent variables, sometimes referred to as fixed effects. The distinctive model of the research is as follows:

$$GI_{i,t} = \alpha + \delta 0 GI_{i,t-1} + \delta 1 ESG_{i,t} + \delta 2 FS_{i,t} + \delta 3 ROA_{i,t} + \delta 4 LEV_{i,t} + \varepsilon_{i,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Equation (1) shows the association between green innovation level and ESG ratings, β represents the slope (beta coefficient), whereas εi,t denotes the error term.

Estimation results for China

Table 4 presents the estimate results for China with the 2-step system GMM estimator. The GI serves as a proxy for green innovation. The lagged dependent variable GIt-1 is significant and positive, indicating the dynamic character of the employed model, which is influenced by green innovation and its choices. In Model 1, ESG and ROA are statistically significant and positively correlated with GI. FSZ has a negligible correlation with green innovation. Leverage has a negative correlation with GI. It suggests that ESG and ROA improve the amount of firm green innovation in China. The size of the company is statistically negligible and does not affect GI. The firm's leverage has an inverse relationship with GI.

Table 4: Estimation Results for China

Regressors	ROA	P-value
GIt-1	.6551458***	0.000
ESG	.00243**	0.015
FSZ	0.71	0.480
ROA	.0064839***	0.000
LEV	-1.054116***	0.000
Constant	808.4896***	0.001
F-test	37479.85***	0.000
AR-1	-2.78***	0.001
AR-2	-0.24	0.811
Hansen	26.84	0.418
Groups Numbers	90	-
Instruments Numbers	53	-
Observations	810	-

The Table depicts the results of two step system GMM for the green innovation of china. The significance levels are as follow, *** significance at 1%level, ** significance at 5% level, * significance at 10% level.

Table 4 shows illustrates the presence of negative first-order serial correlation (AR-1), whereas the second-order serial correlation (AR-2) indicates that no second-order serial correlation was identified throughout the research. Furthermore, the Hansen test findings for all models indicate that the valid instruments null hypothesis cannot be rejected, confirming that the instruments are legitimate and there is no potential link between the error component and the instruments. The results indicate that there are 90 groups and 53 instruments.

Results and Discussion

Enhancing corporate ESG performance is of paramount importance due to the global push for environmental sustainability. Green innovation is a transformative technology that has shown effective in assisting firms in transitioning to sustainable development within production and innovation contexts. Zhang and Liu (2023); Jing and Zhang (2024). This research study using multivariate analysis to assess the impact of ESG ratings on the degree of green innovation in China. The conclusions correspond with stakeholder theory, demonstrating that ESG ratings stimulate green innovation, which subsequently improves corporate success. Prior research (Jamal et al., 2024; Mohammad & Wasiuzaman, 2021; Jamal et al., 2023; Muslicheh, 2020; Ahmad et al., 2021) has shown an increasing correlation between ESG criteria and green innovation. The institutional theory asserts that a business's external and internal environment, together with its corporate culture, are crucial for achieving comprehensive sustainability. For the sake of this notion, the organization may be compared to an institution with a shared objective. The research by Develle (2021) and Zhang et al. (2022) shown that the ESG component exhibits significant performance results. Broadstock et al. (2021) and Muslichah (2020) have investigated the ESG influence on green innovation. An successful ESG rating bolsters investor trust, hence enhancing ESG performance and subsequently elevating the firm's worth, according to Arniati and Muslichah (2023). The results demonstrate that the size of a business company favourably influences the green innovation of Chinese companies. Li et al. (2021) and Mohammad and Wasiuzzaman (2021) affirmed that business size is positively related with green innovation. The firm's leverage shown a substantial correlation with GI. The findings suggest that corporations with more leverage would attain superior profitability, whereas smaller enterprises are anticipated to demonstrate enhanced productivity.

Conclusion

Environmental, social and governance pillars are crucial in the realization and attainment of corporate goals. It is often said that companies conduct their activities with the objective of achieving economic profit. However, the corporations are increasingly cognizant of the non-financial benefits that may accrue in the long term. The primary aim of this research analysis is to assess the ESG influence on the degree of green innovation in China. This study used Chinese A-share businesses listed on the Shanghai and Shenzhen stock exchanges from 2013 to 2022 as the research sample. The ESG data originates from Bloomberg's Environmental, Social, and Corporate Governance database. All remaining data is obtained from the CSMAR database. This research used GMM for the examination of panel data. The GMM study findings for China indicate that ESG and ROA improve the amount of green innovation. Firm leverage diminishes the degree of green innovation in China. Firm size has a negligible correlation with green developments.

Recommendations

Considering how various stakeholders might profit from and make good use of these results, this study attempts to better link the research findings with economic realities based on the previously described research conclusions.

G**overnment Level:** To create a market and regulatory environment that supports green innovation, the government should first expedite the extensive use of AI by encouraging the adoption of smart and green manufacturing projects. Second, rather of implementing rules for intelligent transformation that are universally applicable, the government should create regulations that are specific to various industries and firm sizes, with a greater emphasis on supporting SMEs' use of green technology. Differentiated subsidies should be implemented by the government, with adjustments made based on the demands of

green innovation and the company's ESG ratings. Last but not least, the government should set up efficient monitoring and evaluation systems to make sure that subsidies are allocated to green innovation initiatives appropriately and to routinely review the results of these initiatives. This minimizes resource waste and increases the effectiveness of policies.

Enterprise Level: To promote digital transformation and attain sustainability, firms should aggressively utilize green innovations. Businesses may improve operational efficiency and business agility while lowering environmental consequences by creating green programs that are environmentally sustainable. Ahmad, N., Mobarek, A., & Roni, N. N. (2021). Revisiting the impact of ESG on financial performance of FTSE350 UK firms: Static and dynamic panel data analysis. Cogent Business & Management, 8(1), 1900500. Apergis, N., Poufinas, T., & Antonopoulos, A. (2022). ESG ratings and cost of debt. Energy Economics, 112, 106186.

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