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The Impact of ESG Performance on Green Innovation in Manufacturing Companies in East Asia (China, Japan, and South Korea)

Amalia Khoirun Nisa'[1]
Nurika Restuningdiah[2]
[1,2] *Accounting Department, Faculty of Economic, Universitas Negeri Malang, Indonesia*
email: nurika.restuningdiah.fe@um.ac.id

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Abstract: This research intends to assess the effect of the performance of ESG on the green innovation. in East Asian manufacturing companies (Japan, China, and South Korea). ESG performance data was obtained from Bloomberg, while green innovation was calculated based on the number of green patents registered in World Intellectual Property Organization (WIPO). The sample consisted of 1,279 publicly listed manufacturing companies selected using purposive sampling techniques during the period 2021–2023. The analysis technique used was Generalized Least Square (GLS) regression. The results showed that ESG performance had a positive effect on green innovation. The results of the study show that ESG implementation can be a strategic basis for management in formulating sustainability policies. Increased transparency, social responsibility, and good governance can strengthen companies' commitment to environmentally friendly innovation. The results of this study can be used by company management as a foundation for enhancing the quality of ESG disclosure and implementation to encourage sustainable green innovation.

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INTRODUCTION

East Asia is one of the fastest-growing economic areas worldwide (Hooke & Kaur, 2023). This growth is driven by massive industrialization and rapid urbanization (Opoku & Yan, 2019). However, this development has had a negative effect on the environment (Guo et al., 2022). These impacts include increased carbon emissions and excessive exploitation of natural resources (Acheampong & Opoku, 2023). High levels of industrialization and urbanization have made China the largest contributor to carbon dioxide emissions in East Asia (Xia et al., 2025). The country accounts for in excess of 80% of total emissions, v by Japan and South Korea (Xia et al., 2025). The manufacturing sector is directly responsible for global greenhouse gas emissions through the carbon footprint generated from the material production process (Román & Kabir, 2024). Industries such as paper, food, and metals are major contributors to emissions generated by the manufacturing sector (Panagiotopoulou et al., 2022). On the other hand, these countries v

a significant role as drivers of green technology innovation. This role is reflected in the high number of environmentally friendly technology patents produced (Urbaniec et al., 2021; A. Xu et al., 2024; Q. Xu et al., 2024). This research is important because of the high rate of environmental degradation in East Asia (Yuan et al., 2023). This condition is even more appropriate given East Asia's role in the global energy transition, even though its economy still depends on fossil fuels (UNE., 2023). Amid pressure to achieve sustainable development, many companies have claimed to implement green innovation as a form of real commitment to the environment (Martínez, 2024). However, implementation in the industrial sector has not yet resulted in real improvements to the environment (Xiang & Geng, 2024). The discrepancy between claims and actual impact shows that the effectiveness of green innovation in supporting sustainability still faces challenges.

Green innovation is a transformative effort that focuses on developing environmentally friendly technologies and production processes (Wang et al., 2023). This innovation aims to reduce pollution and waste, utilize resources efficiently, and support using renewable energy (Amaranti et al., 2024; Miao et al., 2024). The application of green innovation in China involves a green development strategy by tightening environmental regulations and developing carbon emission trading mechanisms. In addition, China also encourages the use of environmentally friendly technologies in various industrial sectors (Yang et al., 2022). Japan has set a net-zero carbon target for s through increased research and development (R&D), technology transfer, and the implementation of stricter industry standards (Tu et al., 2019; Yang & Lee, 2021). This aims to improve energy efficiency and reduce emissions. Meanwhile, South Korea is implementing a Green New Deal policy as a strategic step towards net-zero. This policy emphasizes the development of green industries, sustainable infrastructure development, and the transition to low-carbon energy (Lee & Woo, 2020). China, Japan, and South Korea have demonstrated their commitment to green innovation as an effort to overcome environmental challenges while promoting sustainable economic growth.

ESG is a scheme companies use to plan and operate (Bratamanggala & Hendayana, 2024). The environmental aspect emphasizes companies' efforts to manage environmental impacts such as carbon emissions, waste management, and energy efficiency. The social aspect assesses corporation's responsibility to the neighbourhood, regulators, and other stakeholders. This awareness strengthens the company's commitment to developing green innovation that not only meets technical standards but also considers social impacts such as public health and environmental justice (Kujala et al., 2022). Meanwhile, the governance aspect creates governance that supports sustainable decision-making, including investment in research and development of green innovation (Liu 2022). However, ESG is often applied symbolically or as a formality without being supported by real green innovation (Sun et al., 2024). Pressure from stakeholders encourages companies to focus on financial profits and consider ESG aspects in business-making decisions (Durlista & Wahyudi, 2023). The emergence of the green concept has encouraged more companies to accept evaluations from ESG rating agencies. Increased environmental awareness in society has made ESG performance an evaluation tool for assessing investment decisions, especially those considering environmental, social, and governance aspects (Tang, 2022).

According to stakeholder theory, good relationships between companies and stakeholders can result in more optimal financial performance (Awa et al., 2024). Companies that are proactively involved in green innovation can not only meet the needs of stakeholders, but also have the potential to improve financial performance (Semenova & Semenov, 2024). This condition reflects that corporation with excellent ESG performance are able to build competitive advantages and effectively meet the needs of stakeholders (Tan, 2024). By increasing green innovation, companies can attract investors, obtain the necessary resources, and strengthen relationships with stakeholders (Zhai et al., 2022).

ESG-based investments in East Asia show an upward trend in supporting innovation performance and technological advancement, particularly in three major countries, namely China, Japan, and South Korea (Wirawan & Filia, 2023). These countries show a strong commitment to ESG (Choi, 2021). In addition, China, Japan, and South Korea lead in the creation of patents related to green technology (Urbaniec et al., 2021). Patents produced by companies are used as indicators to measure the degree of green innovation (Xu et al., 2021). According to the Organization for Economic Cooperation and

Development (OECD), East Asian countries show a high level of ESG adoption. This condition reinforces the connection among ESG implementation and increased green innovation as an element of the sustainable development strategy in the region.

Research by Tang (2022) and Zhang et al. (2024) suggests a positive relationship between the performance of ESG and green innovation. Wang et al. (2023) state that ESG performance positively encourages sustainable green innovation. However, the influence of ESG performance on green innovation still causes differences of opinion among academics and practitioners. Wu et al. (2024) show that improved ESG performance incentivizes companies to invest in green innovation. On the other hand, several studies highlight the potential obstacles that may arise. Benito (2005) and Liu et al. (2023) argue that the implementation of green innovation can increase environmental costs, mainly due to the need to change production processes and use environmentally friendly technologies. In addition, ESG disclosure requirements can add to the administrative and compliance burden, thereby potentially reducing companies' interest in green investment. This is reinforced by the findings of Mishra et al. (2024) that the implementation of green innovation, particularly in the form of research and development (R&D) activities, requires large and long-term investments.

Earlier research has investigated the influence of ESG on green innovation within a single country, namely China (Wu et al., 2024; J. Xu et al., 2021). In accordance with the research suggestions of Wu et al. (2024), it is recommended that the scope of research be expanded to the Asian region. This study aims to examine the effect of ESG performance on green innovation in manufacturing companies in East Asia, namely China, Japan, and South Korea. This study provides information on the impact of ESG performance on green innovation in the East Asian manufacturing sector. Theoretically, this study reinforces the utilization of stakeholder theory in sustainability. In addition, this study can be used to evaluate companies and investors developing ESG-based sustainability strategies.

LITERATURE REVIEW AND HYPOTHESES

Stakeholder Theory

The stakeholder theory concept developed by Freeman (1984) states that corporations should not only aim to fulfill the interests of shareholders, but also have a accountability to generate value for all stakeholders, such as employees, the neighbourhood, the environment, consumers, and natural resources. Companies are responsible for implementing initiatives that focus on environmental protection, improving social benefits, and complying with good governance practices in order to increase company value (Sun et al., 2024). Companies that incorporate environmental aspects into their business strategies can gain a competitive advantage while creating sustainable economic benefits (Cudjoe, 2024). This theory underline the importance of building sustainable relationships between companies and stakeholders to increase company value, achieve business goals, and promote the welfare of all parties involved.

Companies integrate ESG principles into their business practices in an effort to strengthen relationships between stakeholders (Kujala et al., 2022). According to Cudjoe (2024), maintaining good relationships with stakeholders can support corporations obtain resources effectively and gain a competitive advantage. The increase in the number of companies integrating ESG principles into their business practices reflects efforts to strengthen relationships with stakeholders (Peng & Isa, 2020). Companies can protect the interests of stakeholders by communicating business information through ESG reports. This action reflects the corporation's environmental, social, and governance responsibilities, increasing stakeholder trust and company value (Pauzuolienė & Derkach, 2024).

In line with stakeholder views, several studies show that ESG involvement can increase employee productivity (Tan, 2024), decrease material and energy use (Hu et al., 2023), and develop a good connection with regulators, workforce, communities, and buyer (Desjardine et al., 2023). Companies that strive to reduce energy consumption will be more encouraged to innovate, especially in creating more efficient and environmentally friendly processes and products (Šūmakaris et al., 2021). In addition, pressure from stakeholders regarding products that harm the environment encourages companies to innovate in environmentally friendly practices. These conditions encourage companies to adopt sustainable production

practices and improve the quality of environmentally friendly end products (Park et al., 2024). Environmental monitoring by the community and government can encourage companies to improve the quality of their managerial processes continuously. This step aims to realize green innovation as part of environmental responsibility (X. Liu et al., 2024). The company's decision to increase the disclosure of ESG performance information reflects strategic efforts to strengthen its reputation and create long-term value for the company. This effort is realized through increased capacity for green innovation, as a response to stakeholder expectations (F. Zhang et al., 2020).

The Influence of ESG Performance and Green Innovation

ESG reflects an organization's ability to realize green innovation through four main aspects, namely: (1) internal motivation to reduce environmental impact, (2) commitment and ethics towards sustainability, (3) investment in research and development of ecologically hospitable technologies, and (4) readiness to adopt new technologies (Zhai et al., 2022). First, ESG practices do not only arise from stakeholder pressure, but also reflect the internal motivation of companies to reduce risk and increase long-term value (Bradford, 2021). This motivation also reflects the company's commitment to meeting stakeholder expectations regarding social and environmental responsibility (Martínez, 2024). This commitment encourages companies to produce green innovation as a form of strategic adaptation in response to the expectations of various parties affected by business activities, in order to create sustainable value (Wang et al., 2023). Thus, ESG contributes to shaping green motivation and environmental ethical commitment to support green innovation. Second, companies are responsible for protecting the environment, respecting stakeholder rights, and fulfilling social obligations expected by customers and investors (Awa et al., 2024). However, regulatory bodies also require corporations to raise the quality and completeness of information reporting (Mbanyele, 2022). These increased requirements aim to strengthen the perception of various stakeholders regarding the credibility of data and encourage capital flows towards sustainability-oriented markets (Espahbodi et al., 2019).

Third, companies with high ESG performance demonstrate a genuine commitment to and continued support for sustainable development (Miao et al., 2024). Companies demonstrate their commitment to meeting stakeholder expectations through environmentally responsible operations. In response, companies strengthen their R&D activities and implement environmentally friendly technologies. These activities aim to support the enforcement of green innovation (Tang, 2022). Fourth, the success of green innovation depends on technological readiness, namely the company's ability to adopt technology as a strategic asset (Xie et al., 2019). Without adequate resources, the implementation of green innovation will be difficult. Investment in relevant ESG aspects can provide access to important resources supporting green innovation development. For example, environmental aspects are related to environmentally friendly technology, social aspects support human resource capacity building, and governance plays a role in patent protection. In addition, implementing ESG can strengthen the corporate governance structure to encourage green innovation. For example, a board of directors that supports ESG practices plays a role in shaping the company's orientation towards sustainability (Pane & Neinggolan, 2024). Ultimately, these conditions can support the generation of green innovation by developing creativity and initiatives based on the concept of sustainability (Solesvik et al., 2022). The research hypothesis is as follows:

Ha: ESG performance has a positive effect on corporate green innovation.

METHODS

This research uses an explanatory design to examine the relationship between two variables: ESG performance as the independent variable and *green innovation* as the dependent variable. The research population includes publicly listed manufacturing companies in Japan, China, and South Korea. The samples is based on data published by the OECD, which shows that China, Japan, and South Korea are the most active countries in publishing green patents as *an output* of *green innovation.* In addition, the manufacturing sector was chosen as the object of research because it is responsible for direct greenhouse gas emissions globally, particularly from industries such as paper, food, and metals (Panagiotopoulou et

al., 2022). The manufacturing sector also has a high intensity of energy, water, and raw material use, which contributes to environmental damage (Kumar & Mani, 2022). This research was conducted during the period 2021-2023, in line with the increasing attention to sustainability and green practices in the manufacturing sector (Chukka et al., 2024). *The sampling method is purposive sampling*, which requires criteria in determining the sample, namely:

1. Manufacturing companies from Japan, South Korea, and China that are publicly traded.
2. The companies have complete ESG ratings from 2021-2023 in the Bloomberg database.
3. The companies publish green patents with IPC codes that comply with the Green Inventory Code through WIPO website from 2021 to 2023.

Table 1. Population and Sample Criteria

Criteria	Number
Public manufacturing companies from Japan, South Korea, and China	6,484
Companies that did not receive a Bloomberg ESG rating from 2021 to 2023	(3,852)
Companies that did not publish green patents from 2021-2023	(1,353)
Sample size	1,279
Final Sample Size (1,279 x 3)	**3,837**

Operational Research Variables

Dependent Variable: Green Innovation (Y)

Green innovation is a corporation effort to develop environmentally friendly processes or technologies (Rizki et al., 2023). In this study, green patents are the main output of green process innovation and an important manifestation of green innovation performance (Zhao et al., 2024). The researchers accessed the green patents of the sample companies on the website (https://patentscope2.wipo.int/search/en/advancedSearch.jsf) "IPC Green Inventory" in the *patent scope* section. Then, they searched for patents of sample companies that had ESG score data. The *patent scope* page of the searched company displays patent information, including the patent name, applicant name and location, and International Patent Classification (IPC) code. Next, the IPC code of each patent is matched with the list of codes included in green patents according to WIPO provisions on the website (https://www.wipo.int/classifications/ipc/green-inventory/home). In addition, researchers also conduct additional verification by reading the patent description to ensure that the patent supports sustainability aspects. According to research by Favot et al. (2023), WIPO's "IPC Green Inventory" is the best methodology because it can identify 80% of green patents. WIPO divides green patent IPCs into seven classes: "alternative production/energy, transportation, energy conservation, waste management, agriculture/forestry, administrative regulations or design aspects, and nuclear power generation". IPC codes are summed up annually for each company, and *natural logarithms* are used to measure *green innovation.* According to Brunnermeier & Mark (2003), plus 1 is used in the formula to avoid log(0) and stabilize the data distribution. The formula, the same as that by Chang et al. (2024) and Xu et al. (2021), is as follows:

$$GI = Ln\ (total\ number\ of\ green\ patents + 1)$$

Independent Variable: ESG Performance

ESG is a business strategy focusing on how companies consider environmental, social, and governance issues in their internal operations (Gillan et al., 2021). The ESG assessment data used in this research were sourced from the Bloomberg assessment agency. The researchers used ESG Scores that range from 0 to 100, with higher scores indicating better achievement in ESG practices (Kartika et al., 2023). Thus, a higher ESG disclosure score reflects better sustainability performance managed by the company. Conversely, a lower ESG disclosure score indicates that the company performs poorly in ESG implementation.

$$ESG = ESG\ Score\ from\ Bloomberg$$

Control Variables

Control variables are used to ensure that the analysis reflects the connection between independent and dependent variables without influencing other variables (Wysocki et al., 2022). There are three control variables: Leverage, Firm size, and GDP.

Leverage is a company's ability to pay debts using capital (Kalash, 2023). According to Indrati and Azizah (2022), companies with low leverage tend not to face financial problems. Conversely, companies with high leverage face financial pressures that encourage them to pursue green innovation to meet stakeholder needs and encourage sustainable development (Li et al., 2018). This result is in line with the research by Yang and Chen (2023), which shows a positive relationship between leverage as a control variable and green innovation. Thus, the formula used is as follows:

$$LEV = \frac{Total\ Debt}{Total\ Equity}$$

Firm size is a control variable that represents the capacity of resources owned by a company, whether in the construct of financial resources, personnel, or infrastructure (Martínez-Ros & Kunapatarawong, 2019). This capacity plays an important role in supporting environmentally friendly innovation action. Larger companies have more mature organizational structures and established environmental management systems. In addition, they also have broader access to technology and capital resources compared to smaller companies. This condition allows large companies to be more active in developing and implementing green innovation initiatives (Mansour et al., 2024). Firm size is formulated as follows:

$$FZ = ln\ (Total\ Assets)$$

Gross Domestic Product (GDP) per capita is used as a control variable representing a region's economic development level (Kogan et al., 2017; Rizki & Hartanti, 2021). GDP per capita is considered a key indicator in describing economic capacity and dynamics. GDP also directly influences the ability of companies to produce green innovation (Li et al., 2022). The higher the GDP per capita of a region, the greater the green innovation created by companies operating in that region (Du et al., 2019). Researchers use the natural logarithm of GDP per capita to measure a country's economic development level (Levate et al., 2021). The data was taken from a third source, World Bank Indicators.

$$GDP = ln(GDP\ per\ capita\ (Current\ US\$))$$

Data Analysis Techniques

A linear regression approach is used to analyze the influence of independent variables on dependent variables. Two stages of regression modeling can be used to obtain more accurate estimation results. The first model tested the direct effect of independent variables on dependent variables without considering control variables. Next, the second model included control variables: Firm Size, Leverage, and GDP per capita. The following are the regression equations used:

First, the researcher constructed a model for the influence of corporate ESG performance on green innovation. Second, the researcher constructed a model with leverage, firm size, and GDP as control variables:

Model 1:

$$Y_{it} = \beta 0 + \beta 1 X_{it} + \epsilon$$

Model 2:

$$Y_{it} = \beta 0 + \beta 1 X_{it} + \beta 2 LEV_{it} + \beta 3 FZ_{it} + \beta 4 GDP_{it} + \epsilon$$

Classical assumption tests must be conducted to ensure that the regression model used is unbiased and the testing process is reliable (Hair et al., 2019). The results of the classical assumption test in Appendix (1) show that the Kolmogorov-Smirnov normality test in this study shows a value of Asymp. Sig. s (2-Tailed) of 0.00 < 0.05 (Hair et al., 2019), meaning that the data has a non-normal distribution and does not meet the requirements. The multicollinearity test result shows no multicollinearity, as can be seen from the

tolerance value > 0.10 and VIF < 10, indicating no multicollinearity problem in the data in this study. Then, the heteroscedasticity test using the Glejser test stated that there was a symptom of heteroscedasticity because the p-value was < 0.05 (Ghozali, 2018). The final classical assumption test, namely the autocorrelation test using the Run test, shows autocorrelation with a p-value < 0.05, which means there are autocorrelation symptoms (Hair et al., 2019).

Classical assumption tests indicate that the data are not normally distributed, there is autocorrelation, and there are signs of heteroscedasticity. Therefore, this study uses the Generalized Least Square (GLS) regression method. This method was chosen because GLS can correct violations of classical assumptions and produce efficient and unbiased parameter estimates. In addition, GLS is known to explicitly show information and produce BLUE (Best Linear Unbiased Estimator) estimators **(**Gujarati & Porter, 2009). This GLS model is used to estimate the two regression models constructed previously, the model without controls and the model with control variables. The results of the GLS regression test can be seen in Appendix (4).

RESULTS AND DISCUSSION

Table 2 shows average score of ESG is 44.37, indicating that companies' involvement in ESG aspects is still moderate. This result reflects that although some companies have shown concern for sustainability, many have not optimally integrated ESG principles into their company strategies. The minimum ESG score of 20.26 and the maximum of 80.21 indicate a considerable gap in ESG performance between companies. This result suggests that not all companies have the same awareness and capacity to implement sustainability principles. Meanwhile, the average green innovation score of 2.19 shows that companies' degree of green innovation is still relatively low. It shows that most companies have not yet actively developed environmentally friendly technologies or business processes. In fact, green innovation is essential in creating energy efficiency, reducing emissions, and creating sustainable added value. The wide variation in GI scores, ranging from 0.69 to 7.50, indicates that only a few companies are developing green innovation.

Table 2. Descriptive Statistics

Variabel	N	Minimum	Maksimum	Mean	Std. Deviation
ESG (X)	3837	20.26	80.21	44.37	12.17
GI (Y)	3837	0.69	7.50	2.19	1.35
LEV (K1)	3837	0.01	3.00	1.74	0.34
FZ (K2)	3837	2.56	32.25	25.21	2.04
GDP (K3)	3837	32.75	35.12	34.22	0.78

In Table 2, control variables such as the average leverage (LEV) value of companies at 1.74 indicate that most companies in the sample do not rely heavily on debt in their capital structure. An optimal level of leverage can provide greater financial flexibility for companies. This flexibility allows for more effective resource allocation for long-term investment activities, including developing green innovation. In addition, firm size has an average of 25.21, indicating that most of the sample consists of large companies. Large companies generally have more supportive resources, infrastructure, and managerial capacity to adopt and develop green innovation.

On the other hand, the average GDP value of 34.22 with a relatively small deviation indicates that the companies in the sample operate in a stable macroeconomy. This stability provides a strong foundation for companies to design long-term strategic policies. One of these is the development of green innovation in response to regulations and increasing consumer awareness of environmental issues.

In general, descriptive statistics show that the company has performed quite well in terms of ESG. However, this performance is not yet fully reflected in the high level of green innovation implementation. On the other hand, support from a healthy capital structure, large company size, and economic stability provides significant opportunities for future improvements in green innovation. Therefore, the integration

of ESG into business strategy needs to be continuously strengthened to drive transformation towards more sustainable business practices through green innovation.

Pearson Correlations

According to Table 3, the results of the Pearson correlation test show the correlation value between the ESG performance variable (X) and green innovation (Y) is 0.404 with a p-value of < 0.05, representing a positive relationship between the two. The higher a company's ESG performance, the higher the tendency for the company to implement green innovation. In addition, the leverage control variable (K1) expresses a weak positive relationship with green innovation, with a correlation value of 0.125 (p < 0.05). This shows that the company's financing structure (debt level) plays a role, albeit not a dominant one, in the company's decision to implement green innovation. Firm size (K2) shows a positive correlation with green innovation of 0.250 (p < 0.05), indicating that larger companies have greater capacity and resources to develop green innovation. Meanwhile, the correlation between GDP (K3) and green innovation is very low (0.015), indicating that macroeconomic conditions represented by GDP do not have a strong direct relationship with the level of green innovation at the company level in this research sample. Overall, there is a reasonably high correlation between the GDP control variable and FZ (-0.705). However the multicollinearity test shows that all variables have a VIF value < 10. This result indicates that there is no multicollinearity problem in the regression model used (Hair et al., 2019).

Table 3. Pearson Correlations

	GI (Y)	ESG (X)	LEV (K1)	FZ (K2)	GDP (K3)
GI (Y)	1.000				
ESG (X)	0.404**	1.000			
LEV (K1)	0.125**	0.048**	1.000		
FZ (K2)	0.250**	0.436**	0.027	1.000	
GDP (K3)	0.015	-0.068**	0.017	-0.705**	1.000

Note: Significant correlation at **p<0,05

Table 4 show a positive relationship between ESG and green innovation (GI) in Model 1 and Model 2. Model 1 uses ESG as a single predictor, while Model 2 adds three control variables: leverage (LEV), firm size (FZ), and GDP. In Model 1, the ESG coefficient value is recorded at 0.0450 with a p-value of 0.000, indicating that ESG positively affects green innovation. This result means that every one-unit increase in the ESG score will increase the GI score by 0.0450 units. The very low p-value indicates that this effect is very strong. The constant (intercept) value of 0.1889 with a p-value of 0.012 indicates that even without independent variables, companies have a fundamental tendency to engage in green innovation.

Table 4. Regression Test Results

Variable	Model 1		Model 2	
	Coefficient	**p-value**	**Coefficient**	**p-value**
(Constant)	0.1889	0.012**	-19.204	0.000***
ESG (X)	0.0450	0,000***	0.0318	0.000***
LV (K1)			0.1719	0.000***
FZ (K2)			0.2011	0.000***
GDP (K3)			0.4266	0.000***
Wald chi^2	**751.49**		**997.41**	
F	**0.000*** **		**0.000*** **	

Note: *p-value* is significant at **p<0.05, ***p<0.01

Model 2 shows the result after adding control variables; the ESG coefficient still shows a positive effect of 0.0318 (p-value = 0.000). This finding demonstrates that the influence of ESG on green innovation remains consistent even after controlling for other variables. This confirms that sustainability practices reflected in ESG performance continue contributing independently to the increase in green innovation. The leverage control variable (K1) has a coefficient of 0.1719 (p-value = 0.000), indicating that the higher the

proportion of a company's debt financing, the greater the incentive to pursue green innovation. This can be explained as a form of corporate efficiency strategy or compliance with sustainability regulations. The firm size variable (K2) shows a positive coefficient of 0.2011 with the same p-value, indicating that large-scale companies tend to be better able to allocate resources for research and development of green innovation. Meanwhile, the GDP variable (K3) shows the highest coefficient of 0.4266 (p-value = 0.000), indicating that stable or improving macroeconomic conditions also encourage increased environmentally friendly innovation at the corporate level.

The Wald chi² value in Model 1 was 751.49, increasing to 997.41 in Model 2. This increase indicates that the model became stronger after the control variables were added. The p-value of the Wald chi² test in both models was 0.000, indicating that the combination of all variables in the model was able to explain the dependent variable as a whole.

The effect of ESG performance on green innovation

The results of this analysis show that ESG performance positively affects increasing green innovation in manufacturing companies in East Asia. These findings indicate that the more attention companies pay to ESG aspects, the greater their tendency to develop innovations that support environmental sustainability. One company that represents this relationship is Contemporary Amperex Technology Co. Limited (CATL). This Chinese company obtained the highest green innovation score of 7.50 or 1,800 green patents with an above-average ESG score. This achievement is inseparable from the company's active role in promoting research and development of low-carbon battery technology and its involvement in sustainable development initiatives in China (Lesmana, 2023). Furthermore, CATL is listed as one of the top 50 entities holding patents for environmentally friendly and low-carbon technology inventions globally (Panagiotopoulou et al., 2022). The company has demonstrated its innovative capacity in supporting the sustainable energy transition agenda at the international level (WIPO, 2023).

In addition to Chinese companies such as CATL, Japanese companies such as Toto Ltd have demonstrated consistently high ESG performance. Based on data from 2021 to 2023, Toto Ltd recorded ESG scores of 77.49 in 2021, 79.82 in 2022, and 80.21 in 2023. This consistency makes Toto Ltd one of the companies with the highest ESG scores for three consecutive years. This achievement is in line with the company's green innovation score, which is above the average green innovation score, ranging from 3.09 to 3.74. This result shows that the company's high commitment to ESG aspects also encourages the creation of sustainable innovation.

Toto Ltd's commitment to sustainability is reflected in various technological policies that support resource efficiency and carbon emission reduction. According to a report published by Property and the City (2023), Toto implements sustainability principles through a technological approach, including the development of water- and energy-efficient sanitation products and the use of environmentally friendly production systems. The company has also achieved water consumption efficiency of up to 50% and recycles wastewater from the production process (Toyosada & Xu, 2022). These initiatives not only demonstrate the tangible implementation of ESG, but also reflect the alignment between the company's values and the expectations of its stakeholders.

The control variables such as leverage, firm size, and the GDP of the company's country of origin. These three variables are used to ensure that other structural factors do not influence ESG on green innovation. The results show that corporations with stable leverage tend to be more flexible in allocating resources for green innovation. High financial obligations do not overly burden these companies. Meanwhile, larger companies (firm size) can better access resources, technology, and capital to develop sustainable innovation. Finally, Gross Domestic Product (GDP) as a macroeconomic indicator reflects a country's level of economic progress. GDP also influences a country's ability to support the development of sustainable innovation through national policies, the provision of technology incentives, and the creation of a stable economic climate.

The stakeholder theory proposed by Freeman (1984) states that corporate obligation is not limited to shareholders alone. Companies are also obligated to examine the interests of all parties involved or affected by their activities, such as consumers, the government, investors, environmental non-governmental

organizations (NGOs), employees, and the wider community. In this case, green innovation is a form of strategic adaptation to the demands and pressures from stakeholders increasingly concerned about sustainability issues.

External stakeholders, such as the government, can encourage companies to pursue green innovation through regulations, incentive policies, and environmental standards. Consumers also play a role as drivers of change with their increasing preference for environmentally friendly products. Meanwhile, institutional investors are beginning to exert pressure through ESG-based investments that encourage companies to innovate sustainably. Meanwhile, internal stakeholders such as management and employees contribute to shaping an organizational culture that supports innovative and sustainability-oriented practices. Thus, green innovation emerges as a result of dynamic interactions between companies and all their stakeholders. This innovation reflects responsibility for social and governance aspects, while also serving as a strategy to maintain business sustainability in the long term.

The results of this research have the same findings with Xu et al. (2021) that companies with high ESG performance impact green innovation. These findings indicate that stakeholders pay close attention to companies' efforts to integrate ESG principles into their firm operations to establish long-run value (Tang, 2022; Pane & Neinggolan, 2024). Effective ESG implementation provides certainty to investors in assessing a company's readiness to face environmental and sustainability challenges. This certainty encourages investors to further support the development of green innovation, both financially and technologically (Fadilah & Rosdiana, 2024). The increase in green innovation scores that occurs in companies with high ESG can be explained through the role of ESG as a catalyst in encouraging investment in environmentally friendly technology research and development, adopting low-emission production systems, and transforming business processes that support energy efficiency. This is in line with the findings of Tang (2022), which states that the application of ESG directly impacts a company's ability to create green innovation.

Thus, this study supports the investigation by Rauf et al. (2024) that good ESG practices not only impact a company's social and governance aspects but also contribute to improving green innovation. This finding aligns with stakeholder theory, which places companies as entities responsible to all parties affected by their business activities. In a worldwide situation that demands environmental responsibility and resource efficiency, East Asian companies are under pressure to transform. They are required not only to pursue profitability, but also to ensure business sustainability through comprehensive ESG implementation and consistent implementation of green innovation.

CONCLUSION

The influence of ESG performance on green innovation in China, Japan, and South Korea public manufacturing companies during 2021–2023. The results of the analysis show that ESG performance positively impacts green innovation. This finding supports stakeholder theory, which states that companies that effectively integrate ESG can gain support from investors, regulators, employees, and consumers in promoting green innovation. This research contributes to the development of ESG literature by showing that improved ESG performance strengthens investor appeal and encourages companies to develop sustainability-oriented processes and technologies. This finding reinforces the relevance of stakeholder theory, which states that ESG performance reflects corporate responsibility towards stakeholder expectations that increasingly demand sustainable business practices. The implication is that ESG performance can be used as a decision-making indicator in assessing a company's innovative capacity and long-term sustainability.

This research still has limitations regarding geographical coverage and the availability of green patent data in Asian countries. As the availability of green patent data increases, future studies should expand their focus to developing Asian countries, such as Indonesia, which has not yet developed or classified a green patent system in its national policy. It is important to interpret the relationship between ESG performance and green innovation in depth. In addition, the limited availability of data related to green patents uses WIPO's *green innovation* measurement, which is international and globally standardized. Although the use of WIPO data provides consistency between countries, there are limitations because not all companies

register their patents internationally through WIPO. Many developing companies only register their patents with national patent offices in their respective countries, such as CNIPA in China, KIPO in South Korea, and JPO in Japan.

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