INKUBIS: Jurnal Ekonomi dan Bisnis
Volume 8, Issue 3, 1-17
e_ISSN: 2775-3913
https://inkubis.polteksci.ac.id/index.php/ink/index
DOI: doi.org/10.59261/inkubis.v8i3.285

The Influence of Green Finance on Reducing Emission Intensity in Electric Utility Companies in ASEAN

***Okky Aufarul Mawahib**
Universitas Airlangga, Indonesia

Wisnu Wibowo
Universitas Airlangga, Indonesia

***Corresponding author:**
Okky Aufarul Mawahib, Universitas Airlangga, Indonesia.
✉okky.aufarul.mawahib-2024@feb.unair.ac.id

Article Info:
***Article history*:**
Received: May 07, 2026
Revised: July 14, 2026
Accepted: August 13, 2026
Available Online: August 24, 2026

***Keywords*:**
ASEAN Utilities; Emission Intensity; Green Finance; Leverage; Return On Investment

This is an open access article under the CC BY-SA license.

Copyright © 2026 by Author. Published by Politeknik Siber Cerdika International

Abstract

Background: The decarbonization of electric utilities in ASEAN requires financing instruments that can reduce corporate carbon intensity without compromising energy security.
Objective: This study examines whether green finance reduces emission intensity and whether leverage and return on investment condition this effect.
Methods: The study uses secondary panel data from electric utility and energy companies in ASEAN during 2015–2024. Green finance is proxied by green loans and green bonds scaled by total assets and lagged by one year, while emission intensity is measured as emissions per unit of sales. The empirical model is estimated using panel regression, and model selection tests support the random-effects specification.
Results: The results show that green finance has a negative and statistically significant effect on emission intensity. The interaction between green finance and leverage is positive and significant, indicating that higher debt weakens the emission-reducing effect of green finance. Conversely, the interaction between green finance and return on investment is negative and significant, indicating that stronger investment returns enhance the effectiveness of green finance. ESG scores are also associated with lower emission intensity, while state-owned enterprises tend to exhibit higher emission intensity.
Conclusion: The findings imply that green finance is more effective when supported by a sound capital structure, adequate investment returns, and effective sustainability governance.

To cite this article: Mawahib, O. A., & Wibowo, W. (2026). The influence of green finance on reducing emission intensity in electric utility companies in ASEAN. *INKUBIS: Jurnal Ekonomi dan Bisnis*, *8*(3), xx–xx. https://doi.org/10.59261/inkubis.v8i3.285

INTRODUCTION

Climate change has become an increasingly urgent economic development issue due to the increasing concentration of greenhouse gases, especially carbon dioxide, which generates social costs in the form of global warming, ecosystem disruption, sea-level rise, and increasing intensity of extreme climate events. From an environmental economics perspective, carbon emissions are a form of negative externality because the social costs of production activities are not fully borne by producers but are instead passed on to society and future generations (Pigou & Aslanbeigui, 2017). When environmental costs are not reflected in market prices, a market failure occurs, causing businesses to have insufficient incentives to reduce emissions voluntarily. Therefore, the decarbonization agenda requires corrective mechanisms that can direct companies' investment decisions to incorporate environmental impacts into economic calculations.

One of the indicators widely used to assess the success of a company's decarbonization efforts is emission intensity. This indicator measures emissions relative to a company's economic

output, making it more informative than total absolute emissions, which are greatly influenced by business scale. At the enterprise level, emission intensity allows comparisons of environmental performance between entities with different operating scales, especially when emissions are linked to sales as a proxy for economic output. The lower the emission intensity, the greater the company's ability to generate revenue with a smaller emissions burden. Thus, a decrease in emission intensity can be understood as an increase in emissions efficiency (Bhattacharyya, 2011). This measure is relevant to cross-country research because utility companies in ASEAN have heterogeneous asset scales, market structures, and production capacities.

The context of ASEAN is important because the region faces a dual dilemma between the need for economic growth and the imperative to reduce emissions. Electricity demand is increasing in line with industrialization, urbanization, digitalization, and rising household consumption, while the primary energy mix in many ASEAN countries remains dominated by fossil fuels (ASEAN Centre for Energy, 2023). Dependence on coal and natural gas makes the electricity sector one of the main sources of carbon emissions in the region. On the other hand, ASEAN countries have established Nationally Determined Contributions (NDCs) and net-zero emissions targets with different target years. Consequently, the electric utility sector must pursue the energy transition without disrupting supply reliability or tariff affordability (UNFCCC, 2024).

The electric utility sector has special characteristics that distinguish it from other sectors. The industry is capital-intensive, long-term-oriented, highly regulated, and, in many cases, performs a public service function. Investments in power plants, transmission networks, distribution systems, energy storage technologies, and digital systems require substantial funding and have long investment horizons. These characteristics create a risk of carbon lock-in because fossil-fuel-based generation assets can operate for decades and hinder the acceleration of the transition to renewable energy (Seto et al., 2016). Therefore, reducing emission intensity in the electric utility sector requires not only technological changes but also substantial and targeted financing support.

Within this framework, green finance has developed as a strategic instrument to bridge the investment needs of the energy transition. Green finance refers to financing flows directed toward projects that provide environmental benefits, such as renewable energy, energy efficiency, emissions reduction, clean transportation, and low-carbon infrastructure (Schoenmaker, 2019). Instruments such as green bonds and green loans require the use of proceeds for activities that meet specified green criteria, thereby potentially directing capital allocation away from high-carbon-intensity activities and toward low-carbon investments (ICMA, 2021). In Indonesia and the ASEAN region, the development of green taxonomies and sustainable finance frameworks also demonstrates institutional efforts to strengthen the credibility of green financing and reduce the risk of greenwashing.

Theoretically, green finance can reduce emission intensity through several mechanisms. First, green finance can reduce funding constraints for clean energy projects, which generally require large initial investments. Second, green financial instruments can improve market discipline because the issuance or receipt of green financing is usually accompanied by frameworks governing the use of proceeds, reporting, and environmental impact evaluation. Third, green finance can signal to investors that a company is committed to sustainability, thereby improving its reputation, access to funding, and cost of capital. Flammer (2021) show that the issuance of corporate green bonds is associated with improvements in companies' environmental performance. Wei et al. (2023) also found that green finance reduces emissions through technological innovation and industrial upgrading.

However, recent literature shows that the influence of green finance is not always linear. Yang et al. (2024) found a U-shaped relationship between ESG ratings and green innovation; companies with low ESG ratings tend to engage in less innovation, but green innovation increases as ESG ratings improve. These findings suggest that the impact of green financing may differ between the early and more advanced stages of development. In addition, Treepongkaruna et al. (2024) caution that a high ESG rating is not always synonymous with actual emissions reductions because of the potential for greenwashing. Therefore, empirical testing remains necessary.

In the context of companies, leverage is one of the internal factors that has the potential to determine the effectiveness of green finance. Leverage indicates the proportion of debt used in a company's financing structure. On the one hand, debt can expand investment capacity and

provide managerial discipline. On the other hand, high leverage can create financial constraints because the company's cash flow must be allocated to interest payments and principal repayments (Brigham et al., 2004). The debt overhang theory explains that companies with high debt burdens tend to delay or reduce new investments because some of the benefits of investment may accrue to creditors (Myers, 1977). This condition is particularly relevant to green projects that involve large start-up costs and long-term benefits.

Leverage is becoming increasingly important in the electric utility sector because many energy infrastructure projects are financed through long-term debt. Utility companies can obtain green loans or issue green bonds, but when their existing debt levels are already high, additional financing does not necessarily translate into reduced emissions. The effectiveness of green financing can be constrained by limited financial capacity, refinancing obligations, liquidity risks, and the priority of maintaining public services. Therefore, leverage in this study is treated as a moderating variable that can weaken the negative relationship between green finance and emission intensity. By including the interaction between green finance and leverage, this study examines whether green financing remains effective for companies facing different levels of debt pressure.

In addition to leverage, the return on investment (ROI) is also important because it reflects a company's ability to generate economic benefits from invested capital. Companies with high ROI generally have better operational efficiency, higher-quality investment decisions, and greater internal funding capacity. From a resource-based perspective, strong investment performance reflects internal capabilities that can support organizational innovation and transformation (Barney, 1991). In the context of the energy transition, stronger ROI allows companies to provide matching funds, bear implementation risks, and accelerate asset modernization. Companies with stronger financial conditions also tend to achieve higher carbon emissions efficiency through innovation and reduced financing constraints.

Thus, ROI has the potential to strengthen the influence of green finance on reducing emission intensity. Companies that can generate higher investment returns are not only more likely to gain investor confidence but are also better able to allocate green financing to productive projects that contribute to improvements in emissions efficiency. In contrast, companies with low ROI may face implementation limitations despite having access to green finance, as green-funded projects require adequate project management, technological capabilities, and operational capacity. Therefore, the interaction between green finance and ROI is an important component of the empirical model for explaining variation in the effectiveness of green finance across companies.

Sustainability governance factors also need to be considered. An ESG score represents the quality of a company's environmental, social, and corporate governance practices. In agency theory, ESG practices can reduce agency conflicts through greater transparency and oversight (Jenson & Meckling, 1976). In stakeholder theory, ESG reflects a company's ability to respond to the demands of stakeholders, including regulators, investors, consumers, and society (Freeman, 1984). In signaling theory, ESG can serve as a credible signal of a company's sustainability commitment amid information asymmetry (Spence, 1978). Previous research has also found that ESG is associated with emissions reductions, green innovation, and carbon efficiency (Yang et al., 2024). However, the findings of Treepongkaruna et al. (2024) caution that a high ESG rating is not always synonymous with actual emissions reductions due to the potential for greenwashing. Therefore, empirical testing remains necessary.

In addition to ESG, a company's ownership structure is also relevant in the ASEAN electric utility sector. Many major utility companies are state-owned enterprises (SOEs) or have strong ties to the state. SOEs often receive policy support, have access to funding, and are subject to strategic mandates to ensure the reliability of energy supply. However, SOEs can also face competing objectives involving economic efficiency, public service provision, tariff affordability, and the achievement of national development targets (OECD, 2023). State-owned enterprises can benefit differently from green finance policies because of differences in institutional support and risk perceptions (Su et al., 2023; Zhang, 2023). Thus, SOE status needs to be controlled for so that the influence of green finance on emission intensity can be estimated more accurately.

Based on the development of the literature, several research gaps remain. First, most studies on green finance and emissions focus on the country, provincial, or firm level in China,

while empirical evidence concerning electric utility companies in ASEAN remains relatively limited. In fact, ASEAN has institutional characteristics and energy structures that differ from those of developed economies and China, particularly because of its dependence on fossil energy, substantial infrastructure investment needs, and variations in policy capacity across countries. Second, previous research has often examined the direct influence of green finance on emissions, but relatively few studies have incorporated leverage and ROI as simultaneous interaction variables. Third, there are still limited studies that combine green finance, corporate financial conditions, ESG, and ownership status in a single model to explain emission intensity in the electric utility sector.

The research gap also arises in terms of measurement. Many studies use total emissions or regional-level emissions as the dependent variable, whereas a company's total emissions are greatly influenced by the size of its assets, generating capacity, and market share. In the utilities sector, companies with large asset bases can have high total emissions even when their emissions efficiency improves. Therefore, emission intensity is more suitable for assessing the effectiveness of green finance because it links emissions to the company's economic output. This approach is consistent with Bhattacharyya (2011) argument that intensity measures help distinguish changes in emissions resulting from changes in the scale of operations from changes resulting from production efficiency. By using emission intensity, this study seeks to capture whether green financing encourages improvements in emissions efficiency rather than merely changes in the level of company activity.

In addition, the time context of the research is relevant because the 2015–2024 period includes the period following the Paris Agreement and the acceleration of sustainable financial markets. As global climate commitments have strengthened, companies and financial institutions have increasingly incorporated climate risks into investment, financing, and risk governance decisions (World Bank, 2022). During the same period, ASEAN strengthened its energy transition frameworks, taxonomies, and green finance instruments, although the level of readiness varies across countries. This distinction is important because the effectiveness of green finance within a company is determined not only by internal decisions but also by the quality of financial markets, energy regulations, and institutional support in the countries in which the company operates.

Practically, this research is also important because green finance is often promoted as a primary solution for closing the financing gap associated with the energy transition. However, if green instruments merely increase the amount of debt without improving project quality and execution capabilities, their impact on reducing emission intensity may be limited. These risks are particularly relevant to utility companies that have substantial capital expenditure requirements and obligations to maintain a stable electricity supply. Therefore, the evaluation of green finance needs to be situated within the company's financial framework, not solely within an environmental framework. The combination of leverage, ROI, ESG, and SOE in this study is designed to conceptualize green finance as an instrument whose effectiveness depends on the company's financial capacity, managerial capabilities, and institutional context.

This study also emphasizes the importance of marginal effects analysis in interaction models. In a model that includes interactions between green finance and leverage as well as between green finance and ROI, the main coefficient of green finance represents the effect when the interacting variable equals zero or at its reference value, rather than the same effect across all companies. Without marginal effects analysis, interpretation may be inaccurate because the effect of green finance on emission intensity may differ among companies with low, average, or high levels of leverage. Therefore, this study evaluates the marginal effects at three levels (low, average, and high) to provide a clearer understanding of how companies' financial conditions alter the effectiveness of green financing.

In terms of academic contribution, this study brings together three groups of literature. First, the environmental economics literature emphasizes the internalization of carbon externalities through market-based instruments. Second, the corporate finance literature explains how capital structure and the ability to generate investment returns affect long-term investment decisions (Myers, 1977). Third, the sustainability governance literature identifies ESG and ownership structures as factors that shape companies' incentives to implement low-carbon strategies (Zhu, 2026). The integration of these three perspectives is expected to provide richer explanations than models that test only the direct influence of green finance on emissions.

On this basis, this article argues that green finance will be effective in reducing emission intensity when companies have sufficient financial capacity, strong investment capabilities, and supportive sustainability governance. In contrast, in companies with high leverage, the benefits of green financing may be reduced because of financial obligation pressures. In companies with higher ROI, the benefits of green finance are expected to be greater because such companies are better able to combine external funds with internal capabilities. These arguments provide the basis for hypothesis development and empirical testing in this study.

The contribution of this study lies primarily in its empirical scope and measurement design rather than in foundational theoretical innovation. Specifically, this study extends the green finance literature by empirically testing the conditional moderating roles of leverage and ROI (two financial condition variables that prior research has not simultaneously examined in the context of ASEAN electric utility companies) in the relationship between green finance and emission intensity during 2015–2024. These represent meaningful empirical extensions rather than paradigmatic theoretical breakthroughs and are framed accordingly. This study measures green finance using a one-year lag to capture the potential time-lag effect because the impact of green finance on emissions does not necessarily occur within the same period. In addition, ESG score and SOE status are included as control variables to capture sustainability governance quality and ownership characteristics. This approach is expected to provide a more comprehensive understanding of when and under what conditions green finance effectively reduces emission intensity.

The purpose of this study is to examine the influence of green finance on emission intensity in electric utility companies in the ASEAN region and to analyze whether leverage and ROI affect the strength of this relationship. This study also examines the influence of ESG score and company ownership characteristics on emission intensity. Thus, this article not only contributes to the green finance and environmental economics literature but also offers policy implications for regulators, investors, financial institutions, and utility companies in designing energy transition financing strategies that are more effective, measurable, and aligned with the decarbonization needs of the ASEAN region.

METHOD

This study used a quantitative approach with panel data. The unit of analysis was a company in the electricity and energy utility sector in the ASEAN region with available data on green financing, emissions, sales, leverage, ROI, ESG score, and ownership status. The observation period covered 2015–2024 to capture the development of green finance following the increasing global commitment to the low-carbon transition. The data were sourced from the Bloomberg Terminal and processed for the empirical models.

The sample comprised electric utility and energy companies from six ASEAN countries: Indonesia, Malaysia, Thailand, the Philippines, Singapore, and Vietnam. Companies were selected based on the following criteria: (1) classified under the electric utility or energy production sector (Bloomberg Industry Classification or equivalent SIC codes 4911, 4931, and 4941); (2) listed on a domestic stock exchange during the observation period; (3) reported Scope 1 and/or Scope 2 greenhouse gas emissions for at least five years during 2015–2024; and (4) had identifiable green financing activities (green bonds or green loans) recorded in Bloomberg or disclosed as zero. Companies with consecutive missing data exceeding two years for any key variable were excluded. After applying these filters, the final unbalanced panel dataset comprised N = 112 firm-year observations. Companies with no recorded green finance issuance in a given year were assigned GF = 0, consistent with the interpretation that the absence of formal green capital documentation reflected zero green capital allocation (Tolliver et al., 2020).

The dependent variable was emission intensity (EI), defined as the ratio of total emissions to sales. This indicator was used because it described the amount of emissions produced for each unit of a company's economic output. For the econometric analysis, EI was transformed using the natural logarithm to stabilize the distribution of the data. The main independent variable was green finance (GF), calculated as the value of the company's green loans and green bonds normalized by total assets. GF was measured using a one-year lag because the impact of green funding on emissions performance required time for implementation.

Green instruments were identified in Bloomberg using the Fixed Income Green Bond

Indicator field, which tags instruments that meet the ICMA Green Bond Principles' use-of-proceeds criteria (ICMA, 2021). For green loans, identification relied on Bloomberg's sustainability-linked loan annotations and loan-purpose fields. Instruments with ambiguous or unverified green classifications were excluded from the GF calculation. When a firm-year had no identifiable green instrument issuance, GF was coded as zero. This approach followed the convention adopted by Flammer (2021) and Tang & Zhang (2020), which treated the absence of green security issuance as a zero observation rather than as missing data, thereby preserving the full sample while avoiding attrition bias. Firms for which Bloomberg reported no emissions data were excluded, ensuring that the dependent variable was observable for all included observations.

The interaction variables were GF × LEV and GF × ROI. Leverage (LEV) was measured as the ratio of total debt to total assets, while ROI was measured as the net return on total investment. Before the interaction terms were formed, LEV and ROI were mean-centered so that a value of zero represented the average condition of the sample and facilitated the interpretation of marginal effects. The control variables included ESG score and SOE. The ESG score was obtained from Bloomberg, while SOE was specified as a dummy variable with a value of 1 for state-owned companies and 0 for non-SOE companies.

Table 1
Variable Operational Definition

Variable	Proxies/Measurements	Role	Source
Emission intensity	Total emissions divided by sales; Used in natural logarithms	Dependency	Bloomberg
Green finance	Green loans and green bonds are divided by total assets; One year lag	Independent major	Bloomberg
Leverage	Total debt divided by total assets; mean-centered for interaction	Interaction	Bloomberg
Return on Investment	Net income divided by total investment; mean-centered for interaction	Interaction	Bloomberg
ESG score	Company ESG score	Controls	Bloomberg
SOE	Dummy 1 for state-owned companies and 0 for non-SOEs	Controls	Company data

Source: processed from research design.

The empirical model was estimated using panel data regression. Model selection was conducted through the Chow test, Hausman test, and Lagrange Multiplier test to determine the most appropriate specification among the common effects, fixed effects, and random effects models. Based on the series of specification tests, the final model used was the random-effects model because it provided a more efficient estimator when the companies' individual effects were not significantly correlated with the independent variables.

The empirical equation used was:

$$EIit = \beta0 + \beta1GFi,t-1 + \beta2(GFi,t-1 \times LEVit) + \beta3(GFi,t-1 \times ROIit) + \beta4ESGit + \beta5SOEit + \mu i + \varepsilon it$$

Hypothesis testing was conducted through tests of the partial significance of the coefficients, overall model significance, coefficient of determination, and marginal effects analysis at three levels of LEV and ROI: low (−1 SD), mean (0), and high (+1 SD).

A potential endogeneity concern existed because firms with lower emission intensity might have been more attractive to green capital markets, creating the possibility of reverse causality from emissions performance to access to green finance. The primary mitigation strategy was the one-year lag applied to GF (GFi,t−1), which established the temporal precedence of the financing variable relative to the observed outcome. This lag structure was consistent with evidence that the effects of green investment on emissions emerged with a delay because of project implementation lead times (Li et al., 2023). To assess sensitivity to the lag assumption, robustness checks were conducted using two-year (GFi,t−2) and three-year (GFi,t−3) lags. Although dynamic panel methods such as System GMM Blundell & Bond (2023) are standard tools

for addressing endogeneity in panel settings, the relatively small sample size (N = 112) limited the available degrees of freedom for instrument proliferation, making the random-effects model with lagged regressors the preferred specification. Future research using larger ASEAN panels should incorporate GMM-based estimators to strengthen causal inference.

RESULTS AND DISCUSSION

Results

Descriptive statistics and preliminary testing

Descriptive statistics show that the research sample has heterogeneous characteristics. Green finance has an average of 0.01 with a standard deviation of 0.04, indicating that the use of green finance is uneven and remains concentrated in certain companies. Leverage has an average of 44.50 with a standard deviation of 11.60, indicating that the funding structure of ASEAN electric utility companies is relatively debt-intensive. ROI has an average of 4.80, but its minimum value is negative, indicating differences in companies' ability to generate returns on investment.

Table 2
Descriptive Statistics of Research Variables

Variable	N	Red	Std. Dev.	Min	Median	Max
GF	112	0,01	0,04	0,00	0,00	0,27
LEV	112	44,50	11,60	13,80	44,70	68,40
ROI	112	4,80	3,10	-4,20	4,70	14,00
ESG	112	3,80	1,20	1,50	4,00	6,40
SOE	112	0,30	0,40	0,00	0,00	1,00
YES.	112	2386,10	2717,30	7,00	1298,90	15545,30

Source: Stata output, processed from research data.

The multicollinearity test showed a mean VIF of 1.45, with the highest VIF of 2.07 for the GF variable. This value is well below the commonly used threshold of 10, indicating no evidence of serious multicollinearity. White's test for heteroscedasticity yielded a chi-square statistic of 24.68 with a p-value of 0.1713. Since the p-value is greater than 0.05, the model showed no evidence of heteroscedasticity. These results further support the suitability of the data for panel regression estimation.

Additional diagnostic tests were performed to validate the assumptions underlying the panel-data model. Im et al. (2003) panel unit root test confirmed that all variables were stationary at levels ($p < 0.05$), thereby reducing concerns about spurious regression. Pesaran (2021) Cross-sectional dependence (CD) test produced CD statistics that were below the critical thresholds at the 5% significance level, indicating no statistically significant cross-sectional dependence that would materially affect the random-effects estimator. Wooldridge (2002) test for first-order serial correlation yielded $p > 0.05$, confirming the absence of serial correlation in the idiosyncratic error terms. Taken together, these diagnostic results support the use of the standard random-effects estimator for the final model.

Panel data regression model selection

The model selection process was conducted in stages. The Chow test yielded an F-statistic of 90.91 with a p-value of 0.0000, indicating that the fixed-effects model was preferred over the pooled ordinary least squares (common-effects) model. Furthermore, the Hausman test produced a chi-square statistic of 7.53 with a p-value of 0.1104, indicating that the random-effects model was preferred to the fixed-effects model. The Lagrange Multiplier test yielded a chibar-square statistic of 129.15 with a p-value of 0.0000, indicating that the random-effects model was preferred to the pooled ordinary least squares (common-effects) model. Thus, the main estimation model selected for the analysis was the random-effects model.

Table 3
Panel Data Model Selection Summary

Testing	Statistics	Probability	Selected Models
Chow Test	F(17.89) = 90.91	0,0000	Fixed Effect

Hausman Test	Chi2(4) = 7.53	0,1104	Random Effect
LM Test	chibar2(01) = 129.15	0,0000	Random Effect

Source: Stata output, processed from research data.

Random effects *estimation results*

The results of the estimation show that green finance has a negative and statistically significant effect on emission intensity. The GF coefficient of −0.1079, with a p-value of 0.0120, indicates that an increase in green financing is associated with a decrease in emission intensity. These findings support the hypothesis that green finance plays a role in internalizing externalities through the allocation of capital to low-carbon projects. Economically, green financing can support power plant modernization, energy efficiency improvements, and investments in clean energy, ultimately reducing emissions relative to sales.

Table 4

Random Effect Model Estimation Results

Variable	Coefficients	Std. Error	z-stat	Prob.	Directions
GF	-0,1079	0,0431	-2,50	0,0120	Negatives
GF x LEV	0,0143	0,0047	3,03	0,0020	Positive
GF x ROI	-0,0059	0,0035	-1,65	0,0980	Negatives
ESG	-0,1917	0,0860	-2,23	0,0260	Negatives
SOE	2,0892	0,8401	2,49	0,0130	Positive
_cons	6,5108	0,7630	8,53	0,0000	-

Source: Stata output, processed from research data

The GF × LEV interaction has a positive coefficient of 0.0143 and is significant at the 1% level. The positive coefficient indicates that higher leverage weakens the negative effect of green finance on emission intensity. These findings are consistent with the debt overhang and financial constraint theories. Companies with high levels of debt face interest and principal repayment obligations that can limit managerial flexibility in allocating green funds to long-term projects. As a result, the presence of a green financing label alone is not sufficient if the company's funding structure is not financially healthy.

The GF × ROI interaction has a negative coefficient of −0.0059 and is significant at the 10% level. This finding shows that a higher return on investment strengthens the effect of green finance in reducing emission intensity. Companies with higher ROI tend to have stronger internal resources and greater project execution capacity. Green funds can be complemented by internal funds, managerial expertise, and operational efficiency, making the effect on emissions reduction more substantial.

The ESG score has a negative and statistically significant effect on emission intensity, with a coefficient of −0.1917. This finding suggests that better environmental, social, and governance practices are associated with lower emission intensity. From the perspectives of stakeholder theory and signaling theory, ESG scores not only serve as indicators of corporate reputation but also demonstrate the quality of risk management, transparency, and commitment to long-term investment. Companies with strong ESG performance tend to be better equipped to meet the demands of regulators, investors, and society for a low-carbon transition.

However, the reliability of ESG scores as proxies for environmental quality warrants caution. Prior research has documented significant divergence in ESG ratings across major rating agencies, driven by differences in data scope, weighting methodologies, and aggregation approaches (Berg et al., 2022). In addition, selective disclosure bias may allow companies to report favorable environmental metrics without commensurate operational improvements, potentially inflating ESG scores relative to actual emission outcomes (Christensen et al., 2022). These concerns are particularly salient in ASEAN, where mandatory sustainability reporting standards are still developing and third-party verification of ESG disclosures remains limited. Future research should complement ESG score analysis with physically verified emissions data and granular, project-level disclosures to disentangle genuine sustainability governance from reputational signaling.

The SOE variable has a positive and statistically significant effect on emission intensity.

The coefficient of 2.0892 indicates that state-owned enterprises tend to have higher emission intensity than non-SOEs. This condition can be attributed to the large scale of their operations, greater ownership of fossil fuel assets, and public service mandates. In many ASEAN countries, state-owned utilities must maintain supply reliability and tariff affordability, causing the energy transition process to proceed more gradually. Thus, ownership status is an important institutional factor in explaining variations in emissions performance.

Overall, the model is statistically significant, with a Wald chi-square statistic of 29.49 and a p-value of 0.0000. The overall R-squared value of 0.2679 indicates that the variables in the model explain 26.79% of the variation in emission intensity. In cross-company and cross-country panel data, this explanatory power is still acceptable because emissions performance is also influenced by many external factors, such as the national energy mix, tariff regulations, energy prices, power generation technologies, and each country's energy transition policies.

Marginal effects analysis

Because the model includes interaction variables, the effect of green finance cannot be interpreted from the main coefficient alone. Therefore, marginal effects analysis was conducted at three evaluation points: low (−1 SD), average (0), and high (+1 SD) levels of leverage and ROI. In this analysis, a value of 0 represents the average condition because the interaction variables were constructed after mean-centering.

Table 5

Marginal Effect of Green Finance on Leverage Level

LEV Rate	dy/dx GF	Std. Err	Prob.	Remarks
Low (-1 SD)	-0,2811	0,1005	0,005	Significant negatives
Average	-0,1097	0,0440	0,013	Significant negatives
Height (+1 SD)	0,0616	0,0281	0,028	Significant positives

Source: Stata output, processed from research data.

At low leverage, green finance strongly reduces emission intensity, with a marginal effect of -0.2811. At average leverage, the impact remains negative but is smaller, at -0.1097. At high leverage, the influence becomes positive, at 0.0616. This pattern suggests that debt pressure not only weakens the effectiveness of green finance but, to some extent, can reverse the direction of its benefits. Substantively, highly leveraged companies may use green financing in an operational environment that is still dominated by fossil-fuel-based assets or constrained by limitations in completing low-carbon projects optimally.

Table 6

Marginal Effect of Green Finance at the ROI Level

ROI Rate	dy/dx GF	Std. Err	Prob.	Remarks
Low (-1 SD)	-0,0904	0,0405	0,025	Significant negatives
Average	-0,1097	0,0440	0,013	Significant negatives
Height (+1 SD)	-0,1290	0,0513	0,012	Significant negatives

Source: Stata output, processed from research data.

At all levels of ROI, green finance remains negative and statistically significant with respect to emission intensity. However, the magnitude of the effect becomes stronger as ROI increases. At low ROI, the marginal effect is −0.0904; at average ROI, it is −0.1097; and at high ROI, it increases to −0.1290. These findings confirm that the capacity to generate investment returns is an important prerequisite for green finance to translate into greater reductions in emission intensity.

As a robustness check addressing both endogeneity concerns and sensitivity to the lag structure, the main model was re-estimated using green finance with a two-year lag (GFi,t−2) and a three-year lag (GFi,t−3). In both alternative specifications, the coefficient of green finance remained negative and statistically significant ($p < 0.05$), while the interaction with leverage retained a positive sign and the interaction with ROI remained negative. The magnitude of the GF coefficient declined slightly with longer lags, consistent with the expectation that longer

implementation periods attenuate the annual effect before projects reach operational status. These results confirm that the main findings are not artifacts of the specific one-year lag assumption.

Discussion

The finding that green finance lowers emission intensity strengthens the argument that financial instruments can be part of the solution to environmental market failure. In Pigouvian theory, negative externalities need to be internalized so that companies have an incentive to reduce emissions. Green finance performs this function through the allocation of capital to projects that provide environmental benefits. In the electric utility sector, these benefits are especially important because low-carbon projects require substantial investment and long implementation periods.

The results of the study also confirm that the effectiveness of green finance is conditional. Green financing will be more effective if the company has a well-controlled leverage structure and the ability to generate an adequate return on investment. In other words, the energy transition is concerned not only with the availability of green funds but also with companies' ability to absorb, manage, and deploy those funds. This explains why companies with high debt can obtain green financing but do not necessarily achieve an optimal reduction in emission intensity.

The role of ESG scores shows that sustainability governance remains a key component of emissions performance. Strong ESG performance can improve the quality of decision-making, strengthen oversight, and increase a company's credibility in the eyes of investors. However, ESG is not a substitute for environmental outcomes. Therefore, ESG reporting needs to be complemented by more direct indicators, such as emission intensity, energy mix, carbon intensity of generation, and emission reductions resulting from green projects.

The findings related to SOE status have important implications for ASEAN. State-owned utility companies are often major actors in the development of electricity infrastructure, but they also inherit fossil-fuel assets and public service obligations. Governments need to design transitional policies that not only increase access to green finance for SOEs but also ensure asset portfolio restructuring, stronger project governance, and leverage control so that green funds truly result in emission reductions.

For investors and financial institutions, these results show that the assessment of green finance instruments should not focus solely on the project label. The evaluation needs to include the company's debt structure, the quality of its return on investment, project implementation track record, and ESG commitments. Green financing provided to high-leverage companies requires stricter monitoring, emissions-performance-based covenants, and reporting on the use of funds linked to environmental outcomes.

For regulators, the development of the green finance market needs to be accompanied by a clear green taxonomy, consistent reporting standards, and verified impact measurements. ASEAN is characterized by heterogeneity in regulations, energy structures, and institutional capacity. Therefore, regional policies need to allow for cross-border comparisons while acknowledging differences in the readiness of each market. This research shows that green financial instruments can be effective but must be supported by sound corporate financial governance.

Overall, this study shows that green finance is an important instrument for reducing emission intensity among electric utility companies in ASEAN. However, its influence does not operate in isolation. High leverage weakens and can even reverse the effectiveness of green financing, whereas high ROI reinforces a decrease in emission intensity. Thus, the effectiveness of green financing is determined by a combination of the availability of green capital, the soundness of the financial structure, investment performance, and sustainable governance.

These results demonstrate that the energy transition of utility companies in ASEAN must be viewed as both a financial and an environmental agenda. Emission reductions cannot be achieved simply by increasing the volume of green bonds or green loans. Companies need to maintain financial flexibility, improve investment productivity, and strengthen ESG practices so that green funds are genuinely directed toward technological and operational changes that contribute to reducing emissions.

The effectiveness of green finance is a central question in the recent literature. Research

has moved beyond asking whether green finance affects emissions to exploring which transmission mechanisms explain why it works for some firms but not others. Macro-level analyses typically highlight green financial market development, technological innovation, and regulatory quality as key determinants. At the firm level, however, success depends on managerial capacity, capital structure, and project execution quality. This study therefore shifts attention from the volume of green financing to the internal firm conditions that determine whether such financing translates into emission reductions.

Another novelty of this study is the use of emission intensity as a more precise indicator than total absolute emissions for comparing companies across countries and scales of operation. Total emissions are heavily influenced by the size of operations, so large companies may appear to perform worse despite having greater operational efficiency. In contrast, emission intensity measures emissions relative to an economic output measure, such as sales, making it more suitable for assessing emissions efficiency. In this study, a decrease in emission intensity is interpreted as an increase in emission efficiency because the company generates economic value with a lower carbon impact.

This research also combines green finance with two conceptually distinct internal conditions. Leverage reflects funding pressures and the risk of financial constraints, whereas ROI reflects the ability to generate returns on investment. The two variables are not interchangeable. Companies can have access to green financing, but if their debt levels are high, their financial flexibility to execute projects may be limited. In contrast, companies with high ROI have a greater ability to provide counterpart funding and absorb the risks associated with green project implementation.

By including ESG and SOE as control variables, the empirical model also recognizes that a company's emissions performance is not influenced solely by financing and financial conditions. ESG captures the quality of sustainability governance, whereas SOE captures the institutional dimension inherent in utility companies, especially in developing countries. This approach is important because the electric utility sector in ASEAN does not fully operate like a typical competitive market. Many companies operate in highly regulated environments, have public service mandates, and hold long-term assets that are difficult to change quickly.

The first mechanism that explains the negative influence of green finance on emission intensity is the capital allocation mechanism. Green finance normatively requires the use of funds for projects that provide environmental benefits, thereby directing companies toward projects with lower carbon emissions than those typically financed through conventional sources. In the electric utility sector, such projects can include renewable energy generation, grid modernization, digitalization of distribution systems, fuel efficiency improvements, or emissions-control technologies. Once these projects become operational, emissions per unit of economic output may decrease.

The second mechanism is the signaling mechanism and market discipline. The issuance of green bonds or the receipt of green loans usually requires a framework for the use of proceeds, project evaluation, fund management, and impact reporting. This process creates disciplinary pressure for companies to demonstrate that the funds received are actually supporting environmental objectives. Thus, green finance can increase corporate accountability, especially when investors and creditors demand periodic reporting on emissions indicators or other sustainability indicators.

The third mechanism is the time-lag effect. Green investments in the utility sector do not result in an immediate reduction in emissions because energy projects require planning, procurement, construction, commissioning, and integration into the electricity system. Therefore, the use of green finance with a one-year lag is more appropriate than measuring its effect within the same period. Significant results in this model indicate that green financing in the previous period begins to be associated with improvements in emissions performance in the following period.

However, these mechanisms can be disrupted by high leverage. In highly indebted companies, cash flow is more heavily directed toward meeting financial obligations. This condition creates short-term priorities that can reduce the quality of green project implementation. In addition, high leverage increases the risk that new financing will be used to maintain liquidity or refinance existing obligations rather than to expand low-carbon investment

capacity. This helps explain why the interaction between green finance and leverage has a positive direction.

Conversely, high ROI strengthens the green finance mechanism because companies with strong investment performance are better able to convert funds into productive assets. High ROI reflects management's efficiency in selecting projects, controlling costs, and generating economic benefits. When these capabilities are combined with green financing, companies have a greater chance of executing low-carbon projects in a timely manner and achieving measurable emission reductions.

The ASEAN context provides a unique backdrop, as the region faces increasing electricity demand as well as decarbonization pressures. Many ASEAN countries still rely on fossil fuels because of cost considerations, resource availability, system reliability, and the need to expand access to electricity. Therefore, the shift toward a low-carbon system requires substantial financing and cannot rely solely on government budgets. Green finance is a relevant instrument for filling this funding gap.

However, ASEAN's heterogeneity also means that the effectiveness of green finance will differ across companies and countries. Countries with deeper financial markets may have broader access to green instruments, whereas countries with fossil-fuel-based energy structures may face greater transition costs. State-owned enterprises are often the primary implementers of infrastructure projects but also bear responsibility for tariff management and supply reliability. This condition helps explain why the SOE variable in this study is positively related to emission intensity.

The results of this study do not mean that state-owned companies are failing in the energy transition. Instead, the results show that SOEs face a more challenging starting point because they manage large assets and electricity systems that form the backbone of national economies. Reducing emissions in SOEs requires gradual strategies, such as the early retirement of fossil-fuel assets, asset repowering, improvements in grid efficiency, and the expansion of renewable energy. Thus, green finance for SOEs must be linked to a clear transition roadmap and measurable performance indicators.

For ASEAN, these findings encourage a more selective policy approach. Governments and regulators should not only encourage the issuance of green instruments but also assess the financial readiness of issuers. Companies with high leverage can still obtain green finance, but this should be accompanied by strict supervision, debt restructuring, or blended finance schemes so that the financing burden does not reduce the effectiveness of green projects. Meanwhile, companies with high ROI can be priority candidates for accelerating projects that have a major impact on reducing emissions.

The main managerial implication for companies is the need to align green finance strategies with capital structure strategies. Companies should not treat green bonds or green loans simply as additions to ordinary debt. These instruments need to be incorporated into a long-term investment plan that contains project priorities, emission reduction estimates, implementation schedules, and impact reporting plans. Without such integration, green financing risks becoming symbolic financing that does not result in a meaningful reduction in emission intensity.

Management also needs to maintain leverage at a level that allows for investment flexibility. If leverage is already high, companies may consider restructuring their debt portfolios, rescheduling liabilities, increasing equity financing, or pursuing project-based financing arrangements. This strategy is important so that green funds are not absorbed by short-term liquidity pressures. With a healthier financial structure, companies have greater capacity to undertake energy transition projects that generally require longer payback periods.

In addition, increasing ROI is part of the sustainability strategy. Companies with low ROI may find it difficult to maximize green finance because their ability to execute projects and provide counterpart funding is limited. Therefore, operational efficiency programs, improved asset management, reduction of network losses, and the selection of projects with clear economic value can improve a company's ability to leverage green financing. In the context of utilities, energy efficiency projects often provide the dual benefits of reducing costs and emissions.

Management needs to strengthen ESG not merely as a reporting framework but as a decision-making system. Strong ESG performance means that investment projects are evaluated

not only in terms of cost and revenue but also in terms of environmental impact, social risk, procurement governance, and transparency in the use of funds. Integrating ESG into the investment process can increase a company's credibility in the eyes of investors and facilitate access to green financing at a more competitive cost of capital.

In terms of policy, the results of this study indicate that green taxonomy needs to be linked to outcome measurement. The categorization of green projects is important for preventing greenwashing, but it is not sufficient to assess effectiveness. Regulators need to encourage reporting that links the funds raised to indicators such as reduced emission intensity, absolute emission reductions, renewable energy capacity added, or energy efficiency improvements achieved. In this way, the market can distinguish green instruments that actually generate environmental impact from those that merely meet administrative criteria.

Policies also need to consider leverage risk. For highly leveraged utility companies, green finance support can be combined with de-risking instruments, government guarantees, blended financing, or performance-based schemes. This approach can lower the cost of capital while ensuring that funds are used for projects that have a measurable impact on emissions. On the other hand, regulators can establish stricter fund-use reporting standards for companies with high financial risk.

The development of the green finance market in ASEAN also requires harmonization of standards. Differences in definitions, reporting requirements, and verification procedures between countries can hinder comparisons and reduce investor confidence. A consistent regional framework will help investors assess the quality of cross-border green instruments. Harmonization does not have to eliminate national distinctiveness, but it needs to provide a common language regarding what qualifies as green, how impact is measured, and how accountability is maintained.

Finally, energy transition policies need to position utility companies as the main actors. As utility companies control generation and network assets, changes in emissions performance in this sector will have a major impact on national and regional targets. Green financing should be directed toward projects that directly transform the emissions structure of the electricity sector, rather than merely supporting projects with limited emissions impacts. Thus, green finance can serve as a meaningful instrument for supporting the region's net-zero and NDC targets.

Although the results of the study provide consistent empirical evidence, there are some conceptual limitations that need to be considered when interpreting the findings. First, green finance is measured using green loans and green bonds identified in the company's database. This measure captures the existence of formal green financing, but it does not fully describe the quality of project implementation, the level of environmental additionality, or the extent to which funds actually transform the company's operational technology. Thus, future research can differentiate green instruments based on project type and implementation stage.

Second, the emission intensity used in this study is based on emissions relative to sales. This measure is appropriate for comparisons between companies because it accounts for differences in scale, but it is still influenced by changes in electricity prices, exchange rates, and revenue structures. If data are available, further research can use several indicators simultaneously, such as emissions per MWh of electricity produced, emissions per unit of installed capacity, or absolute emissions. The use of multiple measures will provide a richer picture of a utility company's emissions performance.

Third, this study has not included all macroeconomic and policy factors that can affect emission intensity. In the electricity sector, fuel prices, tariff regulations, energy subsidies, energy-mix targets, fossil-fuel retirement policies, and renewable-energy incentives can influence a company's investment decisions. Further research can combine company-level variables with country-level variables so that the influence of green finance can be distinguished from national policy pressures and energy-market conditions.

Fourth, the SOE variables in this study use dummy variables that distinguish between state-owned and non-SOE companies. This approach is useful for capturing basic institutional characteristics, but it does not distinguish between ownership levels, forms of government control, the quality of SOE governance, or differences in policy mandates across countries. Subsequent research could use more detailed ownership measures, such as the percentage of state ownership, the level of policy intervention, or the classification of companies based on their

strategic functions within the national electricity system.

Fifth, the results of this study focus on the 2015–2024 period. This period is relevant for examining developments following the Paris Agreement, but the green finance market in ASEAN is still growing and can change rapidly. Therefore, it is necessary to continue research over a longer period when more recent data become available, especially following the implementation of green taxonomies and the strengthening of energy transition targets in different countries. Analysis over a longer period also allows researchers to test the long-term effects of green finance on emissions.

The next direction of research can be to test mediation mechanisms, for example, whether the influence of green finance on emission intensity occurs through green innovation, changes in the energy mix, increased low-carbon capital expenditure, or reduced capital costs. By testing mediation pathways, researchers can explain not only whether green finance works, but also how and through which channels its impact emerges. This approach will help regulators and investors design more targeted instruments.

Follow-up research can also compare the utility sector with other equally carbon-intensive sectors, such as transportation, basic industries, and heavy manufacturing. Comparisons between sectors can show whether the role of leverage and ROI is general or specific to electric utilities. If similar findings emerge across multiple sectors, the policy implications regarding capital structure and investment readiness will be stronger. However, if the results differ, green finance policies will need to be adjusted to reflect sectoral characteristics.

Finally, subsequent research can use a quasi-experimental approach if there is a clear change in green finance policies in a particular country. Methods such as difference-in-differences or event-study analysis can provide stronger causal evidence regarding the impact of green policies on emissions performance. Such an approach will complement the panel-data evidence in this article and strengthen the basis for green finance policymaking in ASEAN.

Methodologically, this article also emphasizes the importance of using marginal effects analysis in models that contain interaction terms. Without marginal effects analysis, the main coefficient of green finance can be mistakenly interpreted as a single effect that applies to the entire sample. In fact, the results of the study show that these effects change markedly at different levels of leverage and ROI. Therefore, the study of green finance at the company level should not stop at the statistical significance of the interaction coefficient, but should also present changes in the estimated effects under low, average, and high conditions so that their economic meaning can be understood more precisely.

In the practice of scientific publication, these findings show that sustainable finance studies require integration among environmental economics theory, corporate finance theory, and governance theory. Green finance is related to the internalization of externalities, leverage is related to capital structure and financial constraints, ROI is related to investment capacity, while ESG and SOE are related to governance and institutions. This integration makes the analysis more comprehensive than a model that only tests the direct relationship between green finance and emissions.

This article provides three empirical messages. First, green finance is indeed relevant as an instrument for reducing emission intensity, but its impact operates through an investment process that takes time. Second, the company's financial structure determines whether green funds can result in operational changes. Third, investment performance and sustainability governance increase the likelihood that the funds raised will generate environmental impact.

The first message emphasizes that green financing needs to be understood as a productive instrument, rather than merely an instrument of compliance or reputation. Companies that obtain green funds must be able to connect the source of the funds to projects that have a clear emissions-reduction rationale. In the electricity sector, this rationale can take the form of reducing generation emission factors, reducing grid losses, increasing thermal efficiency, or replacing fossil-fuel capacity with renewable energy.

The second message is related to the discipline of capital structure. When leverage is too high, companies run the risk that green financing will only add to the financial burden without accelerating technological transformation. Therefore, green finance must be designed alongside a strategy of deleveraging, refinancing, or risk sharing. This strategy is particularly important for utility companies, whose capital expenditure needs are substantial and whose asset cycles are

long.

The third message shows that ROI and ESG have complementary functions. ROI indicates a company's economic ability to execute investments productively, while ESG indicates the quality of sustainability governance that drives accountability in the use of funds. Companies that are strong in both aspects have a greater chance of gaining market confidence and achieving a sustainable reduction in emission intensity.

Thus, this article suggests that the evaluation of green finance in the utility sector should not be oriented solely toward the amount of funds issued, but also toward the quality of recipient companies and the environmental results achieved. This approach will help build credible green financial markets, reduce the risk of greenwashing, and ensure that green finance truly supports the energy transition agenda in ASEAN.

CONCLUSION

This study concludes that green finance has a negative and statistically significant effect on the emission intensity of electricity and energy utility companies in the ASEAN region. This means that increased green financing is associated with reduced emission intensity, reflecting improved emissions performance. These findings support externality theory and the sustainable finance literature, which position green finance as an instrument for encouraging low-carbon investment.

Leverage has been shown to weaken the influence of green finance on emission intensity. In companies with low and moderate debt levels, green finance reduces emission intensity, but at high levels of leverage, the effect is reversed. This finding shows that an unhealthy funding structure can hinder the effective use of green funds. In contrast, ROI strengthens the influence of green finance, as companies with higher returns on investment have greater internal capacity to execute green projects.

ESG score has a negative effect on emission intensity, while SOE has a positive effect. Thus, sustainability governance and ownership characteristics also contribute to variations in emissions performance. The main implication of this study is that the success of green finance requires not only an increase in the volume of financing, but also improvements in capital structure and investment performance, as well as stronger governance. Further research can expand the cross-sector sample, include macroeconomic variables and energy policies, and distinguish the impacts of green bonds and green loans in greater detail.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Universitas Airlangga, Indonesia, for providing academic support and research facilities throughout this study. The authors also appreciate Bloomberg Terminal for providing access to the financial and sustainability data used in this research. Finally, the authors thank the anonymous reviewers and the editorial team of *INKUBIS: Jurnal Ekonomi dan Bisnis* for their valuable comments and constructive suggestions, which significantly improved the quality of this manuscript.

AUTHOR CONTRIBUTION STATEMENT

Okky Aufarul Mawahib conceived the research idea, designed the study, collected and analyzed the data, interpreted the results, and prepared the original manuscript draft. Wisnu Wibowo supervised the research process, contributed to the development of the research methodology, validated the findings, provided critical intellectual input, and reviewed and edited the manuscript. Both authors discussed the results, approved the final version of the manuscript, and agreed to be accountable for all aspects of the work.

REFERENCES

ASEAN Centre for Energy. (2023). ASEAN energy database system and outlook report. Jakarta: ACE.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108.

Berg, F., Kölbel, J. F., & Rigobon, R. (2022). Aggregate confusion: The divergence of ESG ratings. *Review of Finance*, *26*(6), 1315–1344. https://doi.org/10.1093/rof/rfac033

Bhattacharyya, S. C. (2011). Energy economics: Concepts, issues, markets and governance. In *Energy Economics: Concepts, Issues, Markets and Governance*. https://doi.org/10.1007/978-0-85729-268-1

Blundell, R., & Bond, S. (2023). Reprint of: Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, *234*. https://doi.org/10.1016/j.jeconom.2023.03.001

Brigham, E. F., Houston, J. F., & Clark, D. A. (2004). *Fundamentals of financial management*.

Christensen, D. M., Serafeim, G., & Sikochi, A. (2022). Why is Corporate Virtue in the Eye of The Beholder? The Case of ESG Ratings. *Accounting Review*, *97*(1). https://doi.org/10.2308/TAR-2019-0506

Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, *142*(2). https://doi.org/10.1016/j.jfineco.2021.01.010

Freeman, R. E. (1984). *Strategic management: A stokcholder approach*. Pitman Boston, MA.

ICMA. (2021). Green bond principles. Zurich: International Capital Market Association.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, *115*(1). https://doi.org/10.1016/S0304-4076(03)00092-7

Jenson, M. C., & Meckling, W. H. (1976). Theory of the firm: Managerial behaviour. *Agency Cost*.

Li, B., Zhang, J., Shen, Y., & Du, Q. (2023). Can green credit policy promote green total factor productivity? Evidence from China. *Environmental Science and Pollution Research*, *30*(3). https://doi.org/10.1007/s11356-022-22695-5

Myers, S. C. (1977). Determinants of corporate borrowing. *Journal of Financial Economics*, *5*(2). https://doi.org/10.1016/0304-405X(77)90015-0

OECD. (2023). Ownership and governance of state-owned enterprises. Paris: OECD Publishing.

Pesaran, M. H. (2021). General Diagnostic Tests for Cross Section Dependence in Panels. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.572504

Pigou, A. C., & Aslanbeigui, N. (2017). *The Economics of Welfare*. Routledge. https://doi.org/10.4324/9781351304368

Schoenmaker, D. and W. S. (2019). *Principles of sustainable finance*.

Seto, K. C., Davis, S. J., Mitchell, R. B., Stokes, E. C., Unruh, G., & Ürge-Vorsatz, D. (2016). Carbon Lock-In: Types, Causes, and Policy Implications. *Annual Review of Environment and Resources*, *41*. https://doi.org/10.1146/annurev-environ-110615-085934

Spence, M. (1978). Job market signaling. In *Uncertainty in economics* (pp. 281–306). Elsevier.

Su, R., Shui, X., & Du, J. (2023). Institutional Pressures and Corporate Green Innovation: Evidence From Chinese Public Enterprises. *Organization and Environment*, *36*(3). https://doi.org/10.1177/10860266231174039

Tang, D. Y., & Zhang, Y. (2020). Do shareholders benefit from green bonds? *Journal of Corporate Finance*, *61*. https://doi.org/10.1016/j.jcorpfin.2018.12.001

Tolliver, C., Keeley, A. R., & Managi, S. (2020). Drivers of green bond market growth: The importance of Nationally Determined Contributions to the Paris Agreement and implications for sustainability. *Journal of Cleaner Production*, *244*. https://doi.org/10.1016/j.jclepro.2019.118643

Treepongkaruna, S., Au Yong, H. H., Thomsen, S., & Kyaw, K. (2024). Greenwashing, carbon emission, and ESG. *Business Strategy and the Environment*, *33*(8). https://doi.org/10.1002/bse.3929

UNFCCC. (2024). Nationally determined contributions synthesis report. Bonn: United Nations Framework Convention on Climate Change.

Wei, P., Li, Y., & Zhang, Y. (2023). Corporate green bonds and carbon performance: An economic input–output life cycle assessment model-based analysis. *Business Strategy and the Environment*, *32*(6). https://doi.org/10.1002/bse.3267

Wooldridge, J. M. (2002). Econometric Analysis of Cross Section and Panel Data. *Booksgooglecom*, *58*(2). https://doi.org/10.1515/humr.2003.021

World Bank. (2022). Financing climate transition in developing economies. Washington, DC: World Bank.

Yang, C., Zhu, C., & Albitar, K. (2024). ESG ratings and green innovation: A U-shaped journey towards sustainable development. *Business Strategy and the Environment*, *33*(5). https://doi.org/10.1002/bse.3692

Zhang, T. (2023). Can green finance policies affect corporate financing? Evidence from China's green finance innovation and reform pilot zones. *Journal of Cleaner Production*, *419*. https://doi.org/10.1016/j.jclepro.2023.138289

Zhu, N. (2026). Strategic Pathways to Decarbonization Through ESG Innovation in High-Pollution Industries: Synergizing Digital Transformation and Sustainable Governance for Net-Zero Goal. *Business Strategy and the Environment*.