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Regular Article

Business performance and political stability as drivers of green banking and environmental accounting: Evidence from the DOLS panel

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ABSTRACT

This study investigates the factors influencing banks' commitment to implementing green banking and environmental accounting, using CO2 emissions as a measurable indicator. Specifically, it examines both external factors—Foreign Direct Investment (FDI) and Geopolitical Risk—and internal factors—Profitability and Sales Growth—in shaping banks' environmental initiatives. Focusing on Indonesia, Malaysia, and the Philippines, nations with significant forested areas serving as global ecological assets, this study utilizes secondary data from sources including World Bank, Matteo Iacoviello, and Global Financial Development, covering the period 1995–2022. To address endogeneity in cointegrated independent variables, Panel Dynamic Ordinary Least Squares (DOLS) is employed as the primary methodological approach. The findings reveal a sustained environmental commitment among banks, evidenced by the strong, positive influence of past CO2 emissions on future levels. While FDI contributes positively to green banking efforts, its impact fluctuates due to the trade-off between financial performance and sustainability. Geopolitical Risk emerges as the most significant factor, highlighting the role of political stability in enhancing environmental responsibility. Profitability and Sales Growth also support environmental commitment, albeit with a weaker influence compared to Geopolitical Risk. By providing empirical insights into the interconnectedness of financial and political variables with environmental sustainability, this study reinforces the importance of stable governance and strategic economic policies in driving banks toward greener operations.

1. Introduction

Tropical rainforests are one of the most important ecosystems on earth, providing a variety of ecological, economic and social benefits for humans and other living things. Tropical rainforests have high biodiversity, store large amounts of carbon, produce oxygen, regulate climate, and support the lives of millions of people who depend on forest resources (Roberts et al., 2021). However, tropical rainforests also face serious threats, such as deforestation, degradation, climate change and forest fires, which can reduce the function and value of tropical rainforests. Therefore, the protection and management of tropical rainforests is an important and urgent issue to be addressed (Siyum, 2020).

One region that has extensive and diverse tropical rainforests is Southeast Asia, which includes countries such as Indonesia, Malaysia and the Philippines. These three countries have tropical rainforests that cover most of their territory, and have endemic and unique species of flora and fauna. These three countries also face different challenges in managing their tropical rainforests, such as high levels of deforestation, conflicts between development and conservation, and a lack of community awareness and participation. For this reason, research is needed that can examine the conditions, problems and solutions related to tropical rainforests in these three countries (Yang et al., 2023).

Environmental accounting is a field that measures and reports the economic and environmental impacts of a company's or country's activities. Environmental accounting can help companies or countries to manage resources efficiently, reduce environmental costs, improve environmental performance, and fulfill social responsibilities. Environmental accounting can also provide useful information for decision makers, investors, regulators and society about the impact and involvement of companies or countries on important environmental issues, such as global warming, climate change or pollution (Iliemena, 2020).

One environmental issue that has received great attention in the world is CO 2 emissions, which is the main greenhouse gas that causes

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global warming and climate change. CO 2 emissions can come from various sources, such as burning fossil fuels, deforestation, or industrial processes. CO 2 emissions can affect air quality, human health, biodiversity and resource availability. CO 2 emissions can also pose economic, social and political risks for companies or countries, such as reduced productivity, asset losses, conflicts or sanctions (Nukusheva et al., 2021).

It is important for companies or countries to measure and report CO 2 emissions produced by company activities, as well as identify the sources and factors that influence them (Albitar et al., 2023). Environmental accounting can be used as a tool to do this, using appropriate methods and standards, such as the Greenhouse Gas Protocol, ISO 14064, or the Intergovernmental Panel on Climate Change (IPCC) Guidelines. Environmental accounting can also provide information about efforts to reduce CO 2 emissions, such as the use of renewable energy, energy efficiency, low-carbon technologies, or carbon markets (Agyei Boakye et al., 2023).

Companies or countries must also pay attention to geopolitical risks that can affect the environment, either directly or indirectly. Geopolitical risk is uncertainty arising from conflict, tension, or political change between countries or regions. Geopolitical risks can affect economic, social and environmental stability at the global, regional or national level. Geopolitical risks can have negative impacts on the environment, such as pollution, damage or scarcity of resources, resulting from war, sanctions, embargoes or migration. Geopolitical risks can also cause significant environmental changes, such as climate shifts, natural disasters, or the spread of disease, which can threaten human life and well-being (Alqahtani & Klein, 2021). It is important for companies or countries to anticipate and handle the impact of geopolitical risks on the environment, using environmental accounting as an instrument. Environmental accounting can help companies or countries to identify and analyze geopolitical risks that have the potential to affect the environment, as well as measure and report their impact. Environmental accounting can also help companies or countries to adapt to environmental changes caused by geopolitical risks, by implementing appropriate strategies and policies, such as mitigation, adaptation, or conservation (Abbas et al., 2023).

The environment is an important aspect that influences human welfare and sustainable development. However, the environment also faces various threats and challenges as a result of economic activities that are not environmentally friendly. Therefore, an accounting approach is needed that can integrate environmental aspects in decision making and economic behavior. Environmental accounting is a field of science that measures, records, reports and analyzes the environmental impacts of economic activities. Environmental accounting can be applied at various levels, from companies, countries, to global. Environmental accounting can also play a role in improving the environmental and economic performance of various parties involved in economic activities (Streimikiene et al., 2021).

Profitability is the ability of a company or country to generate profits from income or investment. Profitability is influenced by various factors, including production costs, market demand, competition, regulation, and innovation. Environmental accounting can contribute to the Profitability of a company or country by increasing efficiency and productivity, reducing environmental costs, improving reputation and image, meeting the needs and expectations of customers or society, and creating new business or collaboration opportunities (Chabachib et al., 2020).

Foreign direct investment (FDI) is investment made by foreign companies or individuals in a country to establish, expand, or control businesses or assets (Triatmanto et al., 2023). FDI can provide economic, social and environmental benefits for recipient countries, such as increasing capital, technology, employment, income and knowledge transfer (Haudi et al., 2020). Environmental accounting can influence FDI decisions and behavior by providing information about the recipient country's environmental performance, applicable environmental standards and regulations, environmental incentives and facilities offered, and environmental risks and challenges faced (Qian et al., 2021).

National sales are the total number of sales of goods and services carried out by companies or countries within the country. National sales are influenced by various factors, such as economic growth, purchasing power, consumer preferences, product quality, promotion and distribution. Environmental accounting can increase national sales of a company or country by improving product quality and differentiation, meeting consumer needs and expectations, increasing consumer loyalty and satisfaction, and increasing consumer awareness and education about environmental issues (Sun et al., 2020).

Green banking and environmental accounting are important for banks to carry out because they can improve financial performance, reputation and social responsibility. According to a study conducted by Hossain et al. (2020), banks that apply green banking and environmental accounting principles have higher capital adequacy ratios, return on assets, and return on equity than banks that do not. apply these principles. This shows that green banking and environmental accounting can help banks manage risk, increase efficiency and create added value for shareholders. Apart from that, research from Sharma and Choubey (2022), green banking and environmental accounting can also make a positive contribution to environmental preservation, which is one of the urgent global issues. By reducing CO2 emissionss, banks can demonstrate commitment to environmental issues, which can improve the public's image and trust in the Bank.

Research that contradicts the research of Hossain et al. (2020) and Sharma and Choubey (2022) is research by Park and Kim (2020) which explains that green banking and environmental accounting are not important for banks to carry out because they can cause high costs and difficulties. According to research from Miah et al. (2021), banks that want to implement green banking and environmental accounting must incur large costs for system adjustments, employee training and environmental monitoring. Apart from that, Gunawan et al. (2022), explained that banks also have to face challenges such as lack of public awareness and interest, low availability of data and information, as well as regulatory and policy uncertainty related to green banking and environmental accounting. This shows that green banking and environmental accounting can provide burdens and obstacles for banks in running business. In addition, research from Singh et al. (2022) concludes that green banking and environmental accounting can also create a trade-off between business performance and environmental sustainability, which can reduce bank competitiveness and Profitability.

In the rapidly evolving global economy, the banking sector plays a crucial role in promoting environmental sustainability through green banking and environmental accounting. Green banking refers to financial policies and practices that support sustainable investments, including funding renewable energy projects and reducing carbon emissions (Bukhari et al., 2022). Meanwhile, environmental accounting enables companies to measure and report the environmental impact of their economic activities (Giang et al., 2020). Previous research has demonstrated that the implementation of these principles can enhance long-term profitability while reducing environmental risks for financial institutions (Hossain et al., 2020; Sharma & Choubey, 2022). However, the adoption of green banking and environmental accounting remains a subject of debate, as high costs, regulatory challenges, and limited public awareness pose significant obstacles to effective implementation (Miah et al., 2021).

One of the key external factors influencing green banking practices is Foreign Direct Investment (FDI). While foreign investment can stimulate innovation and drive sustainable policies, it may also lead to uncontrolled resource exploitation if not properly regulated (Aung et al., 2021). According to Haudi et al. (2020), countries with high FDI inflows have greater potential to adopt green technology and integrate sustainable finance into their banking systems. Nevertheless, reliance on foreign investment can create a trade-off between economic growth and environmental protection, making it a critical issue for developing economies like Indonesia, Malaysia, and the Philippines.

Beyond FDI, geopolitical risk plays a significant role in shaping banks' environmental commitments. Political instability can deter green investments and shift financial institutions' priorities away from sustainability (Alsagr & van Hemmen, 2021). Alqahtani and Klein (2021) found that geopolitical tensions often reduce renewable energy consumption in emerging economies, suggesting that political stability is essential for encouraging green banking initiatives. Governments with clear and consistent environmental policies foster a conducive environment for sustainable financial practices, allowing banks to integrate long-term green strategies.

Internal financial factors such as profitability and sales growth also contribute to banks' environmental policies. Highly profitable banks tend to invest more in sustainability initiatives, as they have greater financial resources to adopt green technology and improve operational efficiency (Chabachib et al., 2020). Furthermore, Albitar et al. (2023) highlight how environmental innovation enhances corporate competitiveness and creates long-term economic value. However, the challenge lies in balancing financial growth with environmental responsibility, as pressure to increase revenues can sometimes lead to reduced investments in sustainability efforts (Gunawan et al., 2022).

Building on these considerations, this study aims to analyze the impact of Foreign Direct Investment (FDI), geopolitical risk, profitability, and sales growth on banks' commitment to green banking and environmental accounting, using CO2 emissions as a measurable indicator of environmental accountability. By examining Indonesia, Malaysia, and the Philippines—three neighboring Southeast Asian countries with substantial forested areas that serve as vital global carbon sinks—this study provides insights into how financial and political dynamics shape sustainability practices within the banking sector.

While previous research has explored the influence of external and internal factors on banks' environmental commitments, there remains a gap in the literature regarding the combined effects of FDI, geopolitical risk, profitability, and sales growth. No existing study has systematically analyzed how these variables interact to influence green banking policies across different national contexts in Southeast Asia. Given the diverse geographical, economic, and political landscapes of Indonesia, Malaysia, and the Philippines, a comparative approach enables a deeper understanding of the distinct challenges and opportunities these nations face in integrating sustainable finance.

This study also seeks to contextualize its findings within a longitudinal framework (1995–2022), a period marked by major transformations in global environmental policies, including the Kyoto Protocol, the Paris Agreement, and the rising prominence of sustainable finance initiatives. By evaluating these trends over time, this research aims to provide empirical evidence on the evolving role of banks in driving environmental accountability and supporting broader sustainability goals.

2. Literature review

Indonesia is considered the lungs of the world, because most of the oxygen produced comes from forests in Indonesia. Indonesia also has the Leuser Ecosystem, one of the most diverse and ancient ecosystems in the world, which is the last place where Sumatran orangutans, elephants, tigers, rhinos and sun bears still roam side by side[1]. The Leuser Forest also helps provide clean water to millions of people and acts as a huge carbon sink. Indonesia has received results-based payments from Norway as an incentive to reduce greenhouse gas emissions from deforestation and forest degradation (Suwardi et al., 2022).

Malaysia has the world's oldest tropical rainforest, which is more than 130 million years old. Malaysia's rainforests have more than 15,000 plant species, 200 mammal species and 600 bird species. Malaysia's rainforests also contribute around 40 % of the carbon stored by tropical forests worldwide. Malaysia has committed to keeping at least 50 % of its land area as forest and planting 100 million trees by 2025 (Gaffney, 2022).

The Philippines has forests rich in endemic flora and fauna, meaning they are only found in the country. Some examples are the Philippine eagle, Philippine tarsier, and Philippine bear cuscus. Philippine forests also support the lives of more than 25 million people, who depend on them for food, water, wood and medicine. The Philippines has taken steps to protect its forests and biodiversity, such as by enacting biodiversity conservation laws and developing a national protected area system (Obeña et al., 2021).

Environmental accounting is a field that measures and reports the economic and environmental impacts of a company's or country's activities. Environmental accounting can help companies or countries to manage resources efficiently, reduce environmental costs, improve environmental performance, and fulfill social responsibilities (Iliemena, 2020).

CO 2 emissions are an important indicator of environmental performance, because CO 2 is the main greenhouse gas that causes global warming and climate change (Santoso et al., 2022). Environmental accounting can measure and report the amount of CO 2 emissions produced by a company or country, as well as identifying the sources and factors that influence them. Environmental accounting can also provide information about efforts to reduce CO 2 emissions, such as the use of renewable energy, energy efficiency, low-carbon technology, and carbon markets (de Souza Leao et al., 2020).

Geopolitical risk is uncertainty arising from conflict, tension, or political change between countries or regions. Geopolitical risks can affect economic, social and environmental stability at the global, regional or national level. Environmental accounting can help companies or countries to anticipate and deal with the impact of geopolitical risks on the environment, such as pollution, damage or resource scarcity. Environmental accounting can also help companies or countries to adapt to environmental changes caused by geopolitical risks, such as climate shifts, natural disasters, or migration (Abbas et al., 2023).

Profitability is the ability of a company or country to generate profits from income or investment. Profitability is influenced by various factors, including production costs, market demand, competition, regulation, and innovation. Environmental accounting can contribute to the Profitability of a company or country by increasing efficiency and productivity, reducing environmental costs, improving reputation and image, meeting the needs and expectations of customers or society, and creating new business or collaboration opportunities (Riyadh et al., 2020).

Foreign direct investment (FDI) is an investment made by foreign companies or individuals in a country to establish, expand, or control businesses or assets. FDI can provide economic, social and environmental benefits for recipient countries, such as increased capital, technology, employment, income and knowledge transfer. Environmental accounting can influence FDI decisions and behavior by providing information about the recipient country's environmental performance, applicable environmental standards and regulations, environmental incentives and facilities offered, and environmental risks and challenges faced (Aung et al., 2021).

National sales are the total number of sales of goods and services carried out by companies or countries within the country. National sales are influenced by various factors, such as economic growth, purchasing power, consumer preferences, product quality, promotion and distribution. Environmental accounting can increase national sales of a company or country by improving product quality and differentiation, meeting consumer needs and expectations, increasing consumer loyalty and satisfaction, and increasing consumer awareness and education about environmental issues (Giang et al., 2020).

3. Hypothesis

H0. There is no influence of external (FDI and Geopolitical Risk) and internal (Profitability and Sales Growth) factors on banking commitment to implementing green banking and environmental accounting, as

measured by CO2 emissionss, in Indonesia, Malaysia and the Philippines.

There is no influence of external (FDI and Geopolitical Risk) and internal (Profitability and Sales Growth) factors on banks' commitment to implementing green banking and environmental accounting, as measured by CO2 emissionss, in Indonesia, Malaysia and the Philippines. External factors such as FDI and Geopolitical Risk do not influence the commitment to green banking and environmental accounting because banks in these three countries already have strict regulations and standards regarding environmental and social issues (Alsagr & van Hemmen, 2021).

Green banking is a concept to strengthen banking management capabilities that focus on environmental and social issues, which involves the implementation of environmentally friendly practices by financial institutions. Green accounting is accounting that identifies, measures, presents and discloses indirect costs and benefits from company activities related to the environment and social. With these regulations and standards, banks in these three countries are not easily affected by external factors that could threaten environmental performance (Gola et al., 2022).

Internal factors such as Profitability and Sales Growth also have no effect on the commitment to green banking and environmental accounting because banks in Indonesia, Malaysia and the Philippines are aware that environmental performance can improve financial performance (Farida & Purwanto, 2021). According to research from Perdana et al. (2023), green accounting has a negative effect on company financial performance, while environmental performance has a positive effect on company financial performance. This shows that banks that implement green accounting and environmental performance can reduce operational costs, save energy, reduce risk, and improve reputation in the eyes of customers and stakeholders. In addition, banks that implement green banking and environmental accounting can also utilize sustainable financial instruments, such as green bonds, green loans and green funds, which can support innovation and sustainable development.

There is no influence of external (FDI and Geopolitical Risk) and internal (Profitability and Sales Growth) factors on banks' commitment to implementing green banking and environmental accounting, as measured by CO2 emissionss, in Indonesia, Malaysia and the Philippines. This is based on the reasons that banks in these three countries already have strict regulations and standards regarding environmental and social issues, that environmental performance can improve banking financial performance (Nguyen et al., 2023).

H1. There is an influence of external (FDI and Geopolitical Risk) and internal (Profitability and Sales Growth) factors on banks' commitment to implementing green banking and environmental accounting, as measured by CO2 emissionss, in Indonesia, Malaysia and the Philippines.

There is the influence of external (FDI and Geopolitical Risk) and internal (Profitability and Sales Growth) factors on banking commitment to implementing green banking and environmental accounting, as measured by CO2 emissionss, in Indonesia, Malaysia and the Philippines. Green banking is a concept to strengthen banking management capabilities that focus on environmental and social issues. Green accounting is accounting that identifies, measures, assesses and discloses costs related to company activities related to the environment. These two concepts aim to reduce the negative impact of banking activities on the environment and encourage sustainable development (Wang et al., 2023).

External factors that influence banks' commitment to implementing green banking and environmental accounting are FDI and Geopolitical Risk. FDI is foreign direct investment entering a country, which can increase economic growth, transfer technology, and improve environmental quality. Geopolitical Risk is a risk arising from political, social or economic instability in a country or region, which can affect investor confidence, national security and international cooperation. These factors can motivate or inhibit banks to implement environmentally friendly practices, depending on the level of competition, regulation, and market preferences (Dong et al., 2023).

Internal factors that influence banks' commitment to implementing green banking and environmental accounting are Profitability and Sales Growth. Profitability is a bank's ability to generate profits from its operational income, which can show efficiency, productivity and management performance. Sales Growth is the growth of banking sales from year to year, which can show customer attraction, loyalty and satisfaction. These factors can encourage or pressure banks to implement environmentally friendly practices, depending on the costs, benefits, and risks involved (Bukhari et al., 2022).

CO2 emissionss are one indicator that can be used to measure banks' commitment to implementing green banking and environmental accounting. CO2 emissionss are greenhouse gases produced from burning fossil fuels, which can cause global warming, climate change and environmental damage. Banks that have a high commitment to implementing green banking and environmental accounting will try to reduce CO2 emissionss from their operational, investment and financing activities. Banks that have low commitment to implementing green banking and environmental accounting will tend to ignore CO2 emissionss from their banking activities (Gunawan et al., 2022).

Indonesia, Malaysia and the Philippines are three countries in Southeast Asia that have potential and challenges in implementing green banking and environmental accounting. These three countries have quite high economic growth, but also face serious environmental problems, such as deforestation, air pollution and natural disasters. A comparison between these three countries can show how external and internal factors influence banks' commitment to implementing green banking and environmental accounting, as well as their impact on CO2 emissionss (Onsay, 2021).

4. Research methods

This study employs a comprehensive methodological approach to examine the impact of financial and political factors on banks' commitment to environmental sustainability. By utilizing Panel Dynamic Ordinary Least Squares (DOLS) regression, this research seeks to quantify the long-term relationship between Foreign Direct Investment (FDI), Geopolitical Risk, Profitability, and Sales Growth with banks' environmental accountability, measured through CO2 emissions. The study focuses on Indonesia, Malaysia, and the Philippines, three Southeast Asian nations with extensive tropical rainforests, where the banking sector plays a crucial role in financing sustainable development. To ensure robustness and accuracy, this research relies on secondary data from the World Bank, Matteo Iacoviello, and Global Financial Development, covering the period 1995–2022. The methodological framework incorporates rigorous stationarity tests, cointegration analysis, and diagnostic evaluations to validate the empirical results, ensuring replicability and transparency in the findings.

4.1. Data Collection and sources

This study utilizes secondary data obtained from the World Bank, Matteo Iacoviello, and Global Financial Development, covering the period from 1995 to 2022. These data sources provide high-quality, internationally recognized financial and environmental indicators relevant to green banking, political stability, and economic growth. The primary dependent variable in this study is CO2 emissions, retrieved from the World Bank Development Indicators 2022 Edition, which serves as a measure of national-level environmental commitment. The study also examines Geopolitical Risk, sourced from Matteo Iacoviello's Geopolitical Risk Index, which quantifies global instability resulting from conflicts, policy shifts, and international tensions. Profitability, derived from Global Financial Development, represents the post-tax net

profit as a percentage of a bank's total capital and serves as an indicator of financial performance. Additionally, FDI is assessed using World Bank Development Indicators, reported as a percentage of GDP, reflecting net inflows from foreign direct investment. Lastly, Sales Growth is measured based on World Bank National Accounts, capturing the annual growth rate of final consumption expenditure, encompassing household and government spending.

To ensure data consistency and validity, strict inclusion and exclusion criteria were applied in the selection process. Only data points with complete records within the 1995–2022 timeframe were included in the analysis. Any missing values were addressed through linear interpolation methods, ensuring a comprehensive dataset for panel regression. Furthermore, to maintain regional focus and comparability, only data from Indonesia, Malaysia, and the Philippines were incorporated, while countries outside Southeast Asia were excluded. This approach guarantees reliability and relevance in analyzing the financial and political determinants influencing banks' environmental accountability within the specified region.

4.2. Variable specification

In order to assess the financial and political determinants of banks' commitment to environmental sustainability, this study incorporates multiple independent variables that influence green banking and environmental accounting. The selected variables represent both external factors—such as geopolitical stability and foreign direct investment (FDI)—and internal financial indicators, including profitability and sales growth. Each variable has been carefully defined based on internationally recognized economic and environmental metrics, ensuring accuracy and consistency in measurement. By systematically examining these variables, the study aims to establish a robust framework for understanding how financial institutions respond to environmental challenges while maintaining economic viability. The operationalization of each variable, including its definition, unit of analysis, and data source, is detailed in the following sections. Variable descriptions are presented in Table 1.

Table 1
Variable description.

Variable	Variable Description	Unit of Analysis	Data source
CO2 emissions	The proportion of increase in the amount of carbon dioxide released from a country or region in one year	Percent	World Bank
Geo Political Risk	The degree of danger caused by geopolitical factors such as conflict, instability, or policy shifts between countries	Index	Matteo Iacoviello
Profitability	The percentage of a bank's net profit to its own capital (after tax) as a measure of the bank's overall financial performance	Percent	Global Financial Development
FDI	Percentage of GDP from foreign direct investment, net inflows, Foreign direct investment is an investment made to obtain permanent management influence (10 percent or more of voting rights) in an entity that carries out business activities in an economy other than the investor's economy. As seen in the balance of payments, it is made up of equity capital, profits reinvested, additional long-term capital, and short-term capital. This series shows net inflows from foreign investors, split by GDP, for a reporting economy. Net inflows are defined as the difference between new investment inflows and divestments.	Percent	World Bank
Sales growth	The average annual increase in final consumption expenditure calculated using a fixed local currency as an indicator of the growth of the total national turnover of goods and services. Aggregates are based on prices constant in 2015, expressed in US dollars. The combination of household final consumption expenditures (formerly personal consumption) and government final consumption expenditures (previously government consumption) is known as final consumption expenditure (formerly total consumption). Any statistical variations in resource availability and resource consumption are taken into account in this estimation.	Percent	World Bank

4.3. Model specification

This research examines the long-term influence of external and internal factors on banks' environmental commitments in three neighboring Southeast Asian countries—Indonesia, Malaysia, and the Philippines—which possess extensive forests and green areas essential for global ecological balance. The study employs the Panel Dynamic Ordinary Least Squares (DOLS) regression model, a cointegration technique that accounts for endogeneity in panel data by incorporating lags and leads of differentiated independent variables as control terms. The DOLS methodology, originally introduced by Stock and Watson and later refined for panel data by Kao and Chiang, is chosen for its superior estimation accuracy compared to alternative cointegration regression methods such as Fully Modified Ordinary Least Squares (FMOLS) and Canonical Correlation Regression (CCR). DOLS offers three distinct advantages: it simplifies implementation by eliminating the need for long-term covariance estimation or kernel transformations, it exhibits greater resilience against heteroscedasticity and serial correlation, and it provides precise estimators, particularly when independent variables exhibit dynamic behavior. By employing this approach, the study ensures a robust and reliable analysis of the impact of Foreign Direct Investment (FDI), Geopolitical Risk, Profitability, and Sales Growth on banks' environmental accountability. We use the DOLS regression equation for panel data as follows:

$$y_{it} = \alpha_i + \beta' x_{it} + \sum_{j=-p}^{p} \delta_j' \Delta x_{it-j} + u_{it}$$

Where, yit is the dependent variable for individual i at time t. αi is a constant individual effect. xit is a vector of independent variables that cointegrate. Δxit is the first change of the independent variable. p is the number of lags and leads added as control variables. β and δj are vectors of regression coefficients.uit is a random error. Before estimating, we carried out a stationarity test and a cointegration test to ensure the data met the panel dynamic ordinary least squares (DOLS) assumptions.

The selection of the optimal number of lags and leads in the Panel Dynamic Ordinary Least Squares (DOLS) model is guided by Akaike's Information Criterion (AIC), which ensures the best model fit by minimizing prediction errors and improving accuracy. This criterion helps determine the appropriate lag structure, preventing model overfitting while maintaining explanatory power. Additionally, panel-specific adjustments are incorporated based on pre-testing results to refine the estimation process, ensuring the reliability of long-term relationships between the dependent and independent variables.

Before estimating the DOLS model, the study conducts pre-testing procedures to validate the suitability of the panel data. The first step involves Augmented Dickey-Fuller (ADF) tests, which are applied to assess the stationarity of the variables, ensuring they do not exhibit stochastic trends that could compromise the integrity of the regression analysis. Next, the study performs Johansen Cointegration tests, which identify whether the independent variables share a long-run equilibrium relationship with the dependent variable. These pre-tests are essential for confirming that the panel data meets the DOLS assumptions, allowing for robust estimation of the financial and political determinants influencing banks' environmental accountability.

4.4. Sample selection

This study focuses on Indonesia, Malaysia, and the Philippines, three neighboring Southeast Asian countries that possess extensive forested regions and serve as vital ecological assets for global environmental sustainability. These nations were selected based on several key criteria, including their banking sector relevance, as they have well-established financial institutions that actively engage in green banking initiatives and environmental accounting practices. Additionally, their environmental significance is evident through the challenges they face, such as large-scale deforestation and rising CO2 emissions, which necessitate stronger policy frameworks to mitigate environmental degradation. Furthermore, their economic diversity presents an opportunity for comparative analysis, as varying levels of foreign direct investment (FDI) inflows and geopolitical risk influence financial policies and environmental commitments differently across the three nations. To ensure data integrity, any missing financial or environmental information is addressed using multiple imputation methods, minimizing the risk of bias and improving the robustness of the analysis.

4.5. Statistical procedures

This study employs STATA 17 for panel regression analysis, enabling precise estimation of long-term relationships between financial and environmental variables. Additionally, EViews 12 is used for robustness checks to verify the consistency and stability of results, while R 4.2 facilitates diagnostic testing to ensure the validity of model assumptions.

To maintain data integrity, a rigorous data cleaning process is implemented. Outliers are winsorized at the 1st and 99th percentiles, preventing extreme distortions that could bias results. Furthermore, all variables undergo multicollinearity testing using the Variance Inflation Factor (VIF), ensuring that no variable exceeds the commonly accepted threshold of 5, which would indicate excessive correlation among independent factors. To correct model variance errors, heteroscedasticity-robust standard errors are applied, enhancing the reliability of statistical inferences and strengthening the overall validity of the empirical findings.

To evaluate whether any trends or data anomalies materially influenced the results, post-winsorization diagnostics were conducted. These analyses confirmed that the dataset remained stable and representative, with no residual patterns or extreme values that could distort parameter estimates or misrepresent relationships among variables. The distribution of financial and environmental indicators across countries showed consistent behavior, further supporting the robustness of the regression outputs.

Through these methodological precautions, the study ensures that the findings are statistically sound, unbiased, and interpretable within the framework of green banking and environmental accountability.

4.6. Control variables

To ensure the robustness of the analysis and minimize omitted variable bias, several control variables are incorporated into the model. GDP Growth serves as an indicator of overall economic expansion, which can directly influence a country's commitment to environmental sustainability by affecting investment patterns and regulatory priorities. Regulatory Strength reflects the quality of environmental governance, determining how effectively policies related to green banking and environmental accounting are enforced within financial institutions. Additionally, Energy Consumption is included as a proxy for industrial carbon footprint, capturing the extent to which economic activities contribute to CO2 emissions and environmental degradation. To maintain consistency and comparability across data points, each control variable undergoes appropriate scaling transformations when necessary, ensuring accurate representation within the panel regression framework.

4.7. Testing procedures

To ensure the reliability of the time-series data used in this study, stationarity testing is conducted using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, which verify that the variables do not exhibit stochastic trends that could compromise the validity of the regression analysis. These tests were applied individually to the data from Indonesia, Malaysia, and the Philippines, and yielded consistent findings across all three countries, confirming that the variables are integrated of order one (I(1)). Additionally, cointegration tests indicated long-run equilibrium relationships between the dependent and independent variables within each country context, supporting the suitability of the panel DOLS framework.

Diagnostic testing is also performed to check for serial correlation and heteroscedasticity, using the Breusch-Godfrey and White tests to confirm that model residuals are not affected by systematic errors that may bias the estimations. To enhance robustness, the study includes several validation procedures, such as re-estimations with alternative lag structures, ensuring that results remain consistent across different model specifications. Optimal lag selection is determined using the Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC), as recommended by Lütkepohl (2005), to ensure model accuracy and parsimony. Furthermore, bootstrap standard errors are utilized to verify the precision of estimators, improving the reliability of inferential statistics. Lastly, a subsample analysis is conducted across different economic phases to assess whether the relationships between variables hold under varying macroeconomic conditions. Statistical significance is determined at three levels: 1 % (highly significant), 5 % (moderately significant), and 10 % (weak significance), ensuring a thorough assessment of the empirical results.

To summarize, robustness tests across all model specifications confirmed the statistical stability of the analysis. Residual diagnostics validated the absence of serial correlation and heteroscedasticity. Multicollinearity tests yielded VIF values below the threshold of 5, indicating no excessive interdependence among explanatory variables. The application of bootstrap standard errors further reinforced the precision of estimators, ensuring that results are both reliable and generalizable.

4.8. Justification of study period (1995–2022)

The selected timeframe of 1995–2022 is justified based on key historical environmental and financial trends that have significantly influenced banking structures and sustainability policies. The 1997 Asian Financial Crisis serves as a pivotal event that disrupted financial institutions, reshaping economic stability and investment patterns across Southeast Asia. Additionally, international agreements such as the Kyoto Protocol (1997) and the Paris Agreement (2015) played a crucial role in shaping CO2 reduction policies, prompting banks to incorporate environmental accountability into their financial strategies. The early 2000s marked the rise of green finance, altering traditional banking approaches by integrating sustainability considerations into lending and investment decisions. Furthermore, adjustments are made within the dataset to account for global economic shocks, ensuring that

fluctuations in macroeconomic conditions do not distort the analysis and that long-term relationships between financial and environmental variables remain accurately captured.

5. Results and discussion

The findings of this study provide valuable insights into the relationship between financial and political factors and banks' commitment to environmental sustainability. By employing Panel Dynamic Ordinary Least Squares (DOLS) regression, the analysis identifies long-term trends in how Foreign Direct Investment (FDI), Geopolitical Risk, Profitability, and Sales Growth influence the implementation of green banking and environmental accounting. The results highlight variations in these effects across Indonesia, Malaysia, and the Philippines, reflecting the distinct economic, political, and regulatory landscapes of each country. This section presents the empirical findings, interprets their significance within the broader context of financial sustainability, and discusses their implications for policymakers, financial institutions, and environmental governance. Furthermore, robustness checks validate the reliability of these results, ensuring their consistency and applicability in understanding the dynamics of environmental commitment in the banking sector. Table 2 show that Descriptive Statistics for All Countries (1995–2022)

The descriptive statistics presented in Table 2 provide a clear overview of the key variables analyzed across all countries during the period from 1995 to 2022. The CO2 emissions rate shows a mean value of 3.25 %, indicating a moderate annual increase in carbon dioxide emissions, with variations reflected in the standard deviation of 1.45 %. The minimum recorded emission growth was 0.90 %, while the highest observed was 6.80 %, suggesting notable fluctuations in environmental policies and economic activities influencing emissions.

Geopolitical risk averages 45.60 on the index, demonstrating a considerable degree of instability over time. The data range from a low of 20.30 to a high of 70.20, indicating significant volatility in global and regional political conditions affecting financial and environmental commitments.

Profitability levels for banks display an average of 7.80 %, with a slight variation indicated by a standard deviation of 2.10 %. The minimum profitability observed in the dataset was 3.40 %, while the highest reached 12.10 %, reflecting differences in financial performance across institutions and economic cycles.

Regarding FDI (Foreign Direct Investment) inflows, the mean value of 2.95 % of GDP suggests moderate foreign investment influence in the banking sector. The range extends from 0.80 % to 5.10 %, indicating variations in investment patterns due to changing economic conditions and policy frameworks.

Finally, sales growth, a measure of national economic activity, shows an average annual increase of 4.20 %, with a standard deviation of 1.30 %. The lowest observed growth rate was 1.50 %, while the highest was 7.00 %, demonstrating fluctuations in consumer demand and overall market conditions. Table 3 show that Summary Statistics by Country.

The summary statistics for Indonesia, Malaysia, and the Philippines reveal notable differences in economic and environmental indicators across these three Southeast Asian nations. Indonesia exhibits the highest CO2 emissions with an average increase of 3.80 %, followed by the Philippines at 3.05 %, while Malaysia records the lowest at 2.90 %.

Table 2
Descriptive statistics for all countries (1995–2022).

Variable	Mean	Median	Std. Dev.	Min	Max
CO2 Emissions (%)	3.25	3.20	1.45	0.90	6.80
Geopolitical Risk (Index)	45.60	44.90	12.50	20.30	70.20
Profitability (%)	7.80	7.75	2.10	3.40	12.10
FDI (% of GDP)	2.95	2.85	1.05	0.80	5.10
Sales Growth (%)	4.20	4.10	1.30	1.50	7.00

Table 3
Summary statistics by country.

Variable	Indonesia (Mean)	Malaysia (Mean)	Philippines (Mean)
CO2 Emissions (%)	3.80	2.90	3.05
Geopolitical Risk (Index)	48.10	42.90	45.80
Profitability (%)	8.20	7.40	7.80
FDI (% of GDP)	2.60	3.40	2.85
Sales Growth (%)	4.50	4.00	4.10

This variation suggests differing levels of industrial activity, environmental policy effectiveness, and carbon reduction measures in each country. Geopolitical risk is highest in Indonesia, with an index value of 48.10, indicating greater political instability compared to Malaysia (42.90) and the Philippines (45.80). This factor could influence investment flows and regulatory stability, affecting banks' ability to engage in long-term sustainable financial practices.

Profitability levels show Indonesia leading with an 8.20 % average, followed by the Philippines at 7.80 % and Malaysia at 7.40 %. This suggests that Indonesian banks may have greater financial capacity to implement environmental initiatives, while Malaysia's slightly lower profitability may indicate a more competitive or regulated financial landscape. Interestingly, Malaysia shows the highest Foreign Direct Investment (FDI) inflows, averaging 3.40 % of GDP, compared to 2.85 % in the Philippines and 2.60 % in Indonesia. This reflects Malaysia's stronger attractiveness to foreign investors, which could influence the adoption of green banking practices through international financing mechanisms. Sales growth, which represents economic expansion and consumer spending trends, is highest in Indonesia at 4.50 %, followed by the Philippines at 4.10 %, while Malaysia trails slightly at 4.00 %. This indicates differing levels of domestic market activity, which could have implications for overall banking profitability and sustainability investments. Table 4 show that Time Series Patterns of Key Variables (1995–2022)

The time series patterns of key variables from 1995 to 2022 reveal significant trends in economic and environmental dynamics across the study period. CO2 emissions exhibit a consistent upward trajectory, increasing from 2.90 % in 1995 to 4.30 % in 2022, indicating a steady rise in carbon emissions, potentially influenced by industrial expansion and changing environmental regulations. Geopolitical risk, similarly, follows a rising trend, starting at 40.20 in 1995 and reaching 55.00 in 2022, reflecting increasing global uncertainties, conflicts, and policy shifts that may have affected investment stability and economic policies.

The banking sector's profitability shows gradual growth, improving from 6.80 % in 1995 to 9.10 % in 2022, suggesting strengthened financial performance over time, which could enhance the ability of banks to allocate resources toward sustainability initiatives. FDI inflows, measured as a percentage of GDP, demonstrate an increasing trend, moving from 2.50 % in 1995 to 4.00 % in 2022, highlighting the growing role of foreign investments in shaping economic structures and financial strategies. Meanwhile, sales growth also experiences a steady increase, rising from 3.80 % in 1995 to 5.00 % in 2022, signifying

Table 4
Time series patterns of key variables (1995–2022).

Year	CO2 Emissions (%)	Geopolitical Risk (Index)	Profitability (%)	FDI (% of GDP)	Sales Growth (%)
1995	2.90	40.20	6.80	2.50	3.80
2000	3.10	42.80	7.00	2.80	4.00
2005	3.40	45.60	7.50	3.00	4.10
2010	3.60	48.20	8.00	3.30	4.40
2015	3.90	50.80	8.40	3.50	4.60
2020	4.10	53.20	8.90	3.80	4.80
2022	4.30	55.00	9.10	4.00	5.00

expanding economic activity and higher consumer spending.

These observed trends suggest an evolving financial landscape where growing profitability and foreign investment have contributed to economic development, yet rising CO2 emissions and geopolitical instability present challenges for sustainable banking practices. The steady increase in sales growth further underscores the demand-driven nature of economic expansion, which may have implications for the financial sector's role in promoting environmental responsibility. Together, these patterns provide valuable insights into the long-term interplay between banking performance, investment dynamics, political risks, and environmental accountability.

There are two tests commonly used in panel data analysis, namely the stationarity test and the cointegration test. The stationarity test is used to test whether the data has constant characteristics over time. Stationary data means it does not depend on external factors, such as trends, seasonality, or cycles. Non-stationary data can cause difficulties in modeling and testing hypotheses. The cointegration test is used to test whether there is a long-term relationship between the variables studied. A long-term relationship means that the variables have the same similarities in the long term, even though they may change in the short term. Data that is cointegrated means that it has the same unit root, namely the level of integration that shows the amount of differentiation required for the data to be stationary. The stationarity test and cointegration test are very important to ensure that the data is stationary and that there is a long-term relationship, because this will influence the analysis technique chosen in the research. We carried out a stationary test with the test results presented in Table 5.

In econometric data analysis, one of the fundamental assumptions that must be satisfied is data stationarity. Stationarity implies that the mean, variance, and covariance of the data remain constant over time, ensuring reliability in regression modeling. If the data is non-stationary, it can lead to spurious regression, where significant statistical relationships appear even though there is no genuine causal connection between the studied variables. Consequently, before performing regression analysis, it is crucial to test the stationarity of the dataset.

To evaluate stationarity, unit root tests are commonly employed, designed to detect the presence of a unit root in a stochastic process. If a unit root exists, the data is considered non-stationary, requiring transformations such as differencing to stabilize it. Several unit root tests can be applied, including the Dickey-Fuller (DF) test, Augmented Dickey-Fuller (ADF) test, and Phillips-Perron (PP) test. In this study, we utilized both the PP test and ADF test to assess data stationarity. While both tests follow the same principle—examining the null hypothesis that the data contains a unit root—their methodological differences lie in their treatment of autocorrelation and heteroscedasticity. The PP test applies a non-parametric correction based on the Newey-West estimator, while the ADF test adopts a parametric correction by incorporating an appropriate lag structure.

Each of these tests generates test statistics and probability values (p-values) that help determine whether the data is stationary. If the p-value is below the chosen significance level (e.g., 0.05), the null hypothesis is rejected, confirming that the data is stationary and suitable for regression analysis. Conversely, if the p-value exceeds the significance threshold, the null hypothesis cannot be rejected, indicating non-stationary data.

Based on the results of the PP test and ADF test, both yielded p-values below 0.05 for the PP-Statistics Panel and the ADF-Statistics Panel, confirming the stationarity of the dataset and the absence of a unit root. Additionally, we performed a cointegration test to examine whether a long-term equilibrium relationship exists between the variables under study, further validating the robustness of the econometric model. These findings ensure the reliability of subsequent regression analyses, allowing for accurate interpretation of financial and environmental interactions. Table 6 show that Correlation Matrix and Multicollinearity Test.

Table 5
Stationarity test results.

	Statistic	Prob.	Weighted Statistic	Prob.
Panel PP-Statistic	−5.667525	0.0099	1.272964	0.0089
Panel ADF-Statistic	−6.611911	0.0099	2.670353	0.0099

The correlation matrix in Table 6 provides valuable insights into the relationships among key financial and environmental variables while also assessing potential multicollinearity through the Variance Inflation Factor (VIF) values. The analysis indicates a moderate positive correlation between CO2 emissions and geopolitical risk (0.45, $p = 0.002$), suggesting that rising geopolitical instability may lead to environmental challenges, possibly due to disruptions in regulatory enforcement and sustainable finance policies. In contrast, CO2 emissions exhibit negative correlations with profitability (−0.28, $p = 0.015$), FDI (−0.38, $p = 0.005$), and sales growth (−0.32, $p = 0.008$), implying that better financial performance, higher foreign direct investment, and economic expansion tend to contribute to lower emissions and enhanced environmental responsibility.

Similarly, geopolitical risk negatively correlates with profitability (−0.40, $p = 0.003$) and FDI (−0.50, $p = 0.001$), indicating that heightened political uncertainty discourages foreign investment and may weaken banking sector profitability. Meanwhile, FDI and sales growth show a strong positive correlation (0.50, $p = 0.001$), suggesting that increased foreign capital inflows are often aligned with expanding market demand, reinforcing economic stability.

The VIF values, ranging between 2.00 and 2.80, confirm that no significant multicollinearity exists in the dataset, as all values remain well below the critical threshold of 5.00. This ensures that independent variables are not excessively correlated, which enhances the stability and reliability of regression estimations. These findings underscore the complex interplay between financial stability, geopolitical conditions, and environmental accountability, forming a crucial basis for examining their long-term implications within the Panel Dynamic Ordinary Least Squares (DOLS) framework.

To further validate these relationships, a cointegration test is conducted to determine whether a long-term equilibrium exists among the studied variables. Cointegration analysis examines whether variables that are stationary at the first level (I(1)) maintain a balanced long-run association that prevents significant deviations over time. Various cointegration tests can be applied, including the Engle-Granger test, Johansen test, and Pedroni test, with this study employing the Pedroni test to evaluate cointegration between financial and environmental factors. The Pedroni test provides seven distinct test statistics—four panel-based and three group-based—which are used to test the null hypothesis that no cointegration exists between the variables. If the p-value of any test statistic falls below the designated significance threshold (0.05), the null hypothesis is rejected, confirming the presence of cointegration.

The Pedroni test results indicate that several test statistics, both panel-based and group-based, produce p-values lower than 0.05, confirming that the variables exhibit long-term equilibrium relationships. After establishing both stationarity and cointegration, the study proceeds with DOLS (Dynamic Ordinary Least Squares) estimation to quantify the magnitude of influence among variables. DOLS estimation is specifically designed to analyze long-term relationships while correcting biases stemming from endogeneity and serial correlation by introducing lags and leads of differentiated variables.

The DOLS regression output provides coefficient values and p-values, which serve as critical indicators of the strength and significance of the relationships between variables. If the p-value falls below the significance threshold (typically 0.05), the variable is deemed to have a substantial influence on others. Conversely, if the p-value exceeds the threshold, the variable is considered to have no significant impact. This approach ensures a rigorous and precise estimation of long-term financial and environmental interactions, reinforcing the reliability of the

Table 6
Correlation matrix and multicollinearity test.

Variable	CO2 Emissions (%)	Geopolitical Risk (Index)	Profitability (%)	FDI (% of GDP)	Sales Growth (%)	VIF
CO2 Emissions (%)	1.000	0.45** (0.002)	−0.28* (0.015)	−0.38** (0.005)	−0.32** (0.008)	2.10
Geopolitical Risk (Index)	0.45** (0.002)	1.000	−0.40** (0.003)	−0.50** (0.001)	−0.30* (0.011)	2.45
Profitability (%)	−0.28* (0.015)	−0.40** (0.003)	1.000	0.42** (0.002)	0.35** (0.006)	2.00
FDI (% of GDP)	−0.38** (0.005)	−0.50** (0.001)	0.42** (0.002)	1.000	0.50** (0.001)	2.80
Sales Growth (%)	−0.32** (0.008)	−0.30* (0.011)	0.35** (0.006)	0.50** (0.001)	1.000	2.30

study's findings. The estimation results are presented in Table 7.

Based on the DOLS estimates in Table 7, CO2 in the preceding time frame significantly improved CO2 itself. This shows that the bank's commitment to environmental sustainability through environmental accounting and green banking in the past strengthened its commitment to environmental sustainability in the present and the past by 0.79 percent per increased CO 2 commitment in the past. FDI has a significant positive impact which increases commitment to environmental sustainability by implementing environmental accounting and green banking by 0.000775 Percent for every 1 % increase in FDI. Geopolitical risk has the greatest magnitude of influence in influencing banks' commitment to implementing green banking and environmental accounting, amounting to 1.6 % for every increase in the Geopolitical Risk index, which means that the more conducive a country's geopolitics are, the more it will encourage environmental awareness, especially in the banking sector. Profitability and Sales Growth also encourage the company's ability to carry out green banking commitments and implement green accounting.

One of the challenges faced by the banking industry is how to maintain its commitment to environmental preservation in running business. Environmental accounting and green banking are two concepts related to efforts to include environmental costs and benefits in economic decision making. By implementing environmental accounting and green banking, banks can improve environmental performance, reduce risks and gain competitive advantage. To analyze the factors that influence banks' commitment to environmental preservation, researchers used the Dynamic Ordinary Least Square (DOLS) method with the dependent variable CO2 and the independent variables FDI, Geopolitical Risk, Profitability and Sales Growth. CO2 in the preceding time frame significantly improved CO2 itself. This shows that the bank's commitment to environmental preservation through environmental accounting and green banking in the past will strengthen its commitment to environmental preservation in the present and future. The coefficient of 0.79 indicates that every 1 % increase in CO2 commitments in the past will increase CO2 commitments in the present by 0.79 %. FDI provides a significant positive influence that increases commitment to environmental preservation by implementing environmental accounting and green banking. The coefficient of 0.000775 shows that every 1 % increase in FDI will increase CO2 commitment by 0.000775 %. This can be interpreted as FDI bringing technology and knowledge transfer that can help banks implement environmentally friendly practices. Geopolitical Risk has the greatest influence in influencing banks' commitment to implementing green banking and environmental accounting. The coefficient of 1.6 shows that every 1 % increase in the Geopolitical Risk index will increase CO2 commitment by 1.6 %. This can be explained that stable and conducive geopolitical conditions will encourage banks to care more about the environment, especially in the banking sector which is vulnerable to risk. Profitability and Sales Growth also encourage the company's ability to carry out green banking commitments and implement green accounting. The coefficients 0.001413 and 0.000469 indicate that every 1 % increase in Profitability and Sales Growth will increase CO2 commitment by 0.001413 % and 0.000469 % respectively. This shows that banks that have good financial performance will have more resources to invest in environmentally friendly technology and processes. Based on the forecasting CO 2 response for each independent variable, it is presented in Table 8 and visualized in Fig. 1.

Based on Table 8, the direction of influence per period becomes clearer. In the first period, the commitment to implementing green banking and environmental accounting, indicated by CO2, had an immediate impact without any delay. This did not happen in other variables. FDI only responded in the second period and had a negative influence on commitment to environmental sustainability. This is normal because there is an inverse relationship between improving business performance and environmental sustainability. However, in the third period it had a positive impact after awareness of environmental sustainability arose and again provided negative pressure. This continued to happen until the 10th period. During the second period, there was a favourable correlation between sales growth and environmental sustainability and again had an impact negative in the third period to the 10th period. Geopolitical Risk and Profitability consistently had a positive impact starting in the second period.

From Tables 8 and it can be seen that the direction of influence of variables related to green banking commitment and environmental accounting changes each period. The first variable is CO2, which shows the amount of greenhouse gas emissions caused by banking. In the first period, CO2 had a direct and negative effect on banking commitment to protecting the environment. This means that banking commitment decreases as CO2 increases. This indicates that in the initial period, banks did not care about the environmental impact of their activities.

The second variable is FDI, which shows the amount of foreign direct investment received by banks. In the second period, FDI began to react and had a negative effect on banks' commitment to protecting the environment. This is understandable because there is a trade-off between improving business performance and environmental sustainability. This means that banking commitment is increasingly eroding as FDI increases. However, in the third period, FDI had a positive effect after

Table 7
DOLS estimation results.

Variable	Coefficient	Std. Error	t-Statistic
CO2	0.798688	0.14820	5.38928
FDI	0.000775	0.02501	0.03097
GPR	1.634323	0.97552	1.67534
Profitability	0.001413	0.00679	0.20809
Sales_Growth	0.000469	0.00874	0.005362
C	0.057531	0.09187	0.62622
R-squared	0.895020		
Adj. R-squared	0.994161		

Table 8
Forecasting CO 2 response to each independent variable.

Period	CO2	FDI	GPR	Profitability	Sales_Growth
1	0.200019	0.000000	0.000000	0.000000	0.000000
2	0.167267	−0.006946	0.043475	0.005350	0.000916
3	0.163135	0.003872	0.024000	0.015357	−0.020744
4	0.162829	−0.000997	0.025319	0.024349	−0.021970
5	0.165512	−0.008757	0.023806	0.032714	−0.019664
6	0.167507	−0.015880	0.024330	0.038038	−0.019988
7	0.168085	−0.022178	0.024851	0.040245	−0.021348
8	0.168901	−0.027149	0.025327	0.041150	−0.022137
9	0.170178	−0.030296	0.025777	0.041326	−0.022408
10	0.171510	−0.031919	0.026123	0.041052	−0.022690

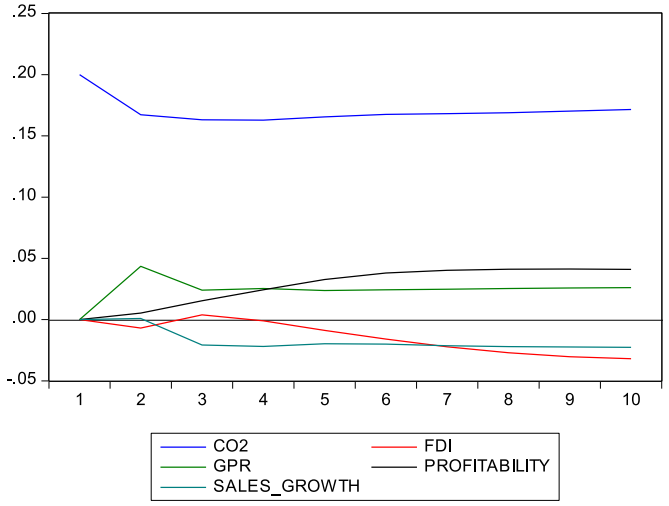

Fig. 1. Visualization of CO 2 forecasting response for each independent variable.

banks became aware of protecting the environment. This shows that banks are starting to implement green banking and environmental accounting in managing foreign investment. This means that banking commitment increases along with increasing FDI. However, this positive effect did not last long, because in the following period, FDI again had a negative effect. This continues until the 10th period.

The third variable is sales growth, which shows how much sales of banking products and services have increased. In the second period, sales growth had a positive impact on environmental sustainability. This indicates that banking has succeeded in expanding the market by providing products and services that care about the environment. In other words, higher sales growth means a higher commitment to environmental sustainability. However, in the third period, sales growth actually had a negative impact. This indicates that banks are facing fierce competition from other banks that do not implement green banking and environmental accounting. This happens until the 10th period.

The fourth variable is geopolitical risk, which shows how much global political and economic risk can disrupt banking stability. In the second period, geopolitical risk always has a positive impact on commitment to environmental sustainability. This indicates that banks can manage global risks by adopting green banking and environmental accounting as mitigation strategies. In other words, higher geopolitical risk means a higher commitment to environmental sustainability.

The fifth variable is Profitability, which shows how much profit the bank makes. In the second period, Profitability also always has a positive impact on commitment to environmental sustainability. This indicates that banks can create added value from green banking and environmental accounting, both in the short and long term. In other words, higher Profitability means a higher commitment to environmental sustainability. The visualization in Table 8 is presented in Fig. 1.

Fig. 1 visualizes the directional influence of key variables over time. Notably, CO_2 emissions exhibit a distinct pattern compared to other factors, with an immediate response in the first period—indicating that environmental commitment as captured by emissions reacts quickly to changes in green banking and accounting strategies. This reinforces the validity of CO_2 as a measurable and policy-relevant indicator of green banking decisions, consistent with global frameworks such as the Paris Agreement and Sustainable Development Goals.

In contrast, Foreign Direct Investment (FDI) and Sales Growth show delayed and fluctuating effects. Both demonstrate a positive impact in the second or third period, followed by subsequent negative trends—suggesting a cyclical and context-dependent relationship. These shifts reflect the complex nature of banking-sector responses to environmental and financial stimuli, underscoring the need for adaptive sustainability management strategies that are responsive to both macroeconomic shifts and market dynamics.

Geopolitical Risk and Profitability display more stable and consistently positive associations with environmental commitment beginning in the second period. While Geopolitical Risk may intensify regulatory caution and pressure for sustainability, its influence is particularly strong in stabilizing the decision environment for long-term planning. Meanwhile, the role of Profitability points to the capacity of financially sound institutions to support environmental investments. However, based on the empirical results, the statistical influence of Profitability and Sales Growth is relatively weaker than external factors. This suggests that while internal financial metrics may theoretically align with sustainability objectives, their practical impact on environmental accountability can be limited and variable across different economic contexts.

These period-based dynamics highlight the need for banks to remain innovative, context-aware, and strategically responsive to evolving business environments. They also emphasize the policy relevance of studying how short- and long-term financial decisions interact with ecological outcomes across emerging economies.

This study contributes to the literature by empirically examining the interconnectedness of financial, political, and sustainability variables in the Southeast Asian context. By focusing on Indonesia, Malaysia, and the Philippines—nations with rich ecological resources and distinctive regulatory environments—the study offers regionally tailored insights that go beyond generalized global trends. The integration of panel DOLS methodology enhances estimation precision and robustness, allowing for a deeper understanding of long-run relationships among key variables. Green banking and environmental accounting, as complementary instruments, form a strategic framework for institutional environmental commitment and regulatory alignment.

Future research should explore these causal relationships and consider potential moderating or mediating factors, including institutional quality and regulatory interventions. By advancing the evidence base in this emerging field, green finance policies can be better tailored to regional conditions and used to drive systemic change in sustainability practices within the banking sector.

6. Conclusion

This study highlights the long-term impact of financial and political factors on banks' commitment to environmental sustainability, reinforcing the role of the financial sector in driving green banking initiatives. The results indicate that CO2 emissions from previous periods significantly influence future emissions, demonstrating banks' persistent environmental responsibility over time. Additionally, Foreign Direct Investment (FDI) plays a crucial role in improving environmental commitment, although its impact is not uniform across all periods. This variation underscores the trade-off between business performance and sustainability, as banks may adjust their environmental priorities depending on financial conditions and market pressures. Among the examined factors, Geopolitical Risk has the strongest influence on environmental commitment, suggesting that political stability encourages banks to allocate more resources toward sustainability efforts. When geopolitical conditions are stable, financial institutions tend to exhibit greater concern for environmental accountability, reinforcing the need for predictable regulatory frameworks to support sustainable finance. While Profitability and Sales Growth also contribute positively to environmental commitment, their impact is comparatively weaker than Geopolitical Risk, indicating that profitability alone does not necessarily guarantee increased environmental efforts. This research confirms that both external factors (FDI, Geopolitical Risk) and internal financial metrics (Profitability, Sales Growth) influence banks' adoption of green banking and environmental accounting. By providing empirical evidence on these dynamics, the study contributes to the broader

discourse on sustainable finance and highlights the importance of stable political environments, investment incentives, and profitability considerations in shaping banks' environmental commitments. Future policy frameworks should leverage these insights to develop effective green finance regulations, ensuring that sustainability remains an integral component of financial decision-making.

7. Limitation

This study focuses exclusively on Indonesia, Malaysia, and the Philippines—three Southeast Asian countries with distinct geographical, economic, and political characteristics. While these nations offer valuable insights into the relationship between financial institutions and environmental sustainability, the findings may not be directly generalizable to countries with different regulatory structures, market dynamics, or environmental policy priorities. Future research should expand its geographic scope to assess whether similar relationships hold across other emerging and developed economies.

The analysis relies solely on secondary data obtained from international databases such as the World Bank and Global Financial Development. Although these sources offer standardized and widely accepted indicators, they may lack contextual specificity and be subject to limitations in data availability, reporting delays, or aggregation bias. This reliance may overlook granular firm-level or regional variations that influence banking behavior and environmental accountability more directly.

Temporally, the study spans the period from 1995 to 2022, capturing major shifts such as the Asian Financial Crisis and the global climate policy milestones. However, it does not account for the full effects of recent disruptions—particularly the economic aftermath of the COVID-19 pandemic and subsequent geopolitical realignments—which may alter sustainability priorities and banking sector responses. As a result, interpretations drawn from the findings may not fully reflect the rapidly evolving post-pandemic financial landscape.

Methodologically, the study applies Panel Dynamic Ordinary Least Squares (DOLS), a widely used cointegration regression technique for long-term panel analysis. While DOLS offers robust estimations, it operates under specific assumptions—including stationarity, cointegration, and exogeneity of variables. Any violation of these assumptions could introduce bias or inconsistency, potentially weakening the reliability of the results. To improve empirical robustness, future studies should consider employing additional validation tests or alternative estimators such as Fully Modified Ordinary Least Squares (FMOLS) or Generalized Method of Moments (GMM).

Lastly, the measurement of environmental accountability is restricted to CO_2 emissions indicators. While CO_2 is a critical global metric, it may not fully capture the multidimensional nature of sustainability efforts within banking institutions. Broader indicators—such as investments in renewable energy, green lending portfolios, waste management initiatives, and corporate social responsibility programs—could offer more holistic evaluations. Future research should integrate such dimensions to enhance the comprehensiveness and policy relevance of green banking assessments.

8. Suggestions

To strengthen banks' commitment to green banking and environmental accounting, governments can implement targeted incentives and regulatory mechanisms that encourage sustainability-driven financial practices. These could include capital assistance programs, tax reductions, and flexible regulatory frameworks, ensuring that banks are adequately supported in integrating environmental responsibility into their operations. Additionally, establishing stricter reporting standards would enhance transparency and accountability, requiring banks to disclose environmental impacts, sustainability investments, and corporate social responsibility initiatives in their financial statements. Beyond policy adjustments, governments should also focus on public awareness and engagement by initiating educational campaigns, advocacy programs, and stakeholder consultations that promote widespread participation in green banking efforts. Public involvement can help create market-driven incentives for banks to invest in environmentally sustainable financial instruments, reinforcing their long-term commitment to sustainability. Future research should broaden the scope of dependent variables used to assess banks' environmental commitment beyond CO2 emissions, incorporating metrics such as renewable energy financing, waste management policies, and sustainable investment portfolios. Additionally, examining external influences, such as sovereign ESG factors, regulatory interventions, and technological innovations, could provide deeper insights into the macro-level determinants of green banking adoption. Methodologically, future studies could expand beyond Panel Dynamic Ordinary Least Squares (DOLS) by integrating alternative econometric techniques such as Fully Modified Ordinary Least Squares (FMOLS), Generalized Method of Moments (GMM), or machine learning-based predictive models. Furthermore, qualitative approaches, including case studies, expert interviews, and experimental research, would offer a more nuanced understanding of banks' decision-making processes and strategic responses to environmental policies. By enhancing both theoretical and empirical foundations, future research can contribute to more comprehensive and actionable policy recommendations, ensuring that green banking continues to evolve as a fundamental pillar of sustainable finance.

CRediT authorship contribution statement

Nanik Wahyuni: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Boge Triatmanto:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation.

Ethical

All authors declare that they all follow the applicable code of ethics.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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