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THE IMPACT OF FINANCIAL DEVELOPMENT ON CARBON EMISSIONS: AN ASEAN PERSPECTIVE

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Abstract

The global discourse surrounding the climate crisis has intensified in recent years, leading to various international agendas of global and regional bodies. Notably, ASEAN, characterised by its rapid development, has emerged as a significant contributor to CO_2 emissions. Therefore, this study seeks to explore the relationship between financial development and CO_2 emissions using the data of nine ASEAN countries from 2000 to 2020. Recognizing the multidimensional nature of financial development, the analysis divides financial development to two distinct indices, FM and FI. This study uses panel data ARDL with the PMG estimation used after testing all the outcomes. The analysis found non-significant effects of financial development on carbon emissions using various estimation techniques. However, separating into FI and FM yields insightful results. While the effect in the short run is unclear, FI increases the carbon emission in the long run by 1.17 percent of each one percent increase, proving that financial institutions in the current state promote an unsustainable effect on the environment. This effect occurs because they drive demand towards energy consumption while also expanding more environmentally harmful sectors. The error correction term signifies that the adverse effect of financial institutions takes approximately six years. These findings underscore the importance of integrating sustainability into development of the financial sector and advancing its maturity by enhancing access to financial institutions and markets to reduce the adverse effect of the climate crisis.

Keywords: *ASEAN, carbon emission, financial development, financial institution, panel data ARDL*

I. INTRODUCTION

In recent years, the climate crisis has drawn significant attention from global institutions, environmental researchers, and policymakers, particularly since the United Nations introduced the 17 Sustainable Development Goals (SDGs) in 2016, several of which emphasise environmental concerns. The rapid surge in greenhouse gas emissions, notably carbon dioxide (CO_2), due to extensive use of environmentally detrimental energy sources, has been a major catalyst for environmental degradation. Research indicates that CO_2 emissions have risen annually by 1.9% due to this reliance on harmful energy sources.[1] [2] Consequently, scholars have focused on identifying the determinants influencing energy consumption and CO_2 emissions to formulate effective strategies for mitigating global warming. Economic expansion, industrialisation, energy utilisation, and trade openness have been pinpointed as key factors exacerbating CO_2 emissions.[3] [4]

In many studies, increased energy consumption has been closely linked to economic growth,[5] and thus, a connection between energy consumption and financial development is demonstrable.[6] Financial development (FD) typically refers to the growth in a country's financial activities, such as increased foreign direct investment (FDI), higher credit provision to the private sector, and increased stock market activities. This development enhances economic efficiency but also raises energy consumption levels.[7] Based on previous research, there are three main mechanisms linking financial development and energy consumption. First, Financial development attracts more FDI, boosting energy consumption and economic growth. Second, Financial development promotes financial sector development, leading to more efficient financial intermediation and increased consumer credit, which drives purchases of high-energy-consuming items. Third, the development of capital and financial markets increases economic reserves, further enhancing energy consumption. Additionally, financial development supports the expansion of businesses in the service and industrial sectors, thereby escalating energy demand and CO2 emissions through scale effect and composition effect.[8]

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1 Tusawar Iftikhar Ahmad et al., "Urban Population Growth, per Capita Energy Use, and CO2 Emissions: Evidence from the World's Fifth-Most Populous Country." *IRASD Journal of Energy & Environment* 3, no. 2 (November 30, 2022): 97–110. https://doi.org/10.52131/jee.2022.0302.0029.

2 Kais Saidi and Anis Omri, "The Impact of Renewable Energy on Carbon Emissions and Economic Growth in 15 Major Renewable Energy-Consuming Countries." *Environmental Research*. 186 (2020), https://doi.org/10.1016/j.envres.2020.109567

3 A. Sinha et al., "Renewable Energy Policies and Contradictions in Causality: A Case of Next 11 Countries," *Journal of Cleaner Production*, (2018) 197, 73-84. https://doi.org/10.1016/j.jclepro.2018.06.219

4 Ahsan Anwar et al., "Modelling the Macroeconomic Determinants of Carbon Dioxide Emissions in the G-7 Countries: The Roles of Technological Innovation and Institutional Quality Improvement," *Global Business Review*, (2021): https://doi.org/10.1177/09721509211039392.

5 Shah Saud et al., "An Empirical Analysis of Financial Development and Energy Demand: Establishing the Role of Globalization," *Environmental Science and Pollution Research*, 25 (24) (2018): 24326–24337

6 Serap Çoban and Mert Topcu, "The Nexus Between Financial Development and Energy Consumption in the EU: A Dynamic Panel Data Analysis," *Energy Economics*, 39, (2013): 81-88.

7 Perry Sadorsky, "Financial Development and Energy Consumption in Central and Eastern European Frontier Economies," *Energy Policy* 39, no. 2 (2011): 999–1006. https://doi.org/10.1016/j.enpol.2010.11.034.

8 Artur Tamazian et al., "Does Higher Economic and Financial Development Lead to Environmental Degradation: Evidence from BRIC Countries." *Energy Policy* 37, no. 1 (2009): 246–53. https://doi.org/10.1016/j.enpol.2008.08.025.

Conversely, some scholars argue that financial development can significantly reduce carbon emissions by enabling technological advancement as well as research and development (R&D).[9] [10] Financial development helps firms and governments adopt environmentally efficient technologies, thereby mitigating carbon emissions.[11] Moreover, financial development spawns good corporate governance, creating incentives for firms to undertake environmentally sustainable projects.[12] This aligns with the Paris Climate Agreement, which emphasises the importance of green investment for combating the climate crisis and creating a sustainable low-carbon future (UNFCC, n.d.). Significant investments are needed in sustainable sectors, which usually have high capital costs, including construction, industry, transportation, and energy.[13] To meet future climate targets, annual climate funding must increase to at least 10 trillion US dollars per year by 2050 (CPI, 2023). One path to this funding is through enhanced financial system development, which facilitates investment in environmentally friendly projects by providing cost-effective funding.[14]

Some economists suggest nonlinear relationships, such as an inverted U-shaped curve between financial development and environmental quality, using the Environmental Kuznets Curve (EKC).[15] [16] Financial development can influence energy use and environmental quality through multiple channels, including facilitating access to credit, promoting business expansion, and stimulating economic growth, all of which can lead to increased carbon

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[9] Alex O. Acheampong, "Modelling for Insight: Does Financial Development Improve Environmental Quality?" *Energy Econ* 83 (2019):156–179

[10] Tamazian, et al, "Does Higher Economic Development Lead to Environmental Degradation."

[11] Shushu Li et al., "Financial Development, Environmental Quality and Economic Growth." *Sustainability* 7, no. 7 (2015): 9395–9416. https://doi.org/10.3390/su7079395

[12] Nangjin Wang et al., "Can Financial Development Improve Environmental Quality? New Findings from Spatial Measures of Chinese Urban Panel Data," *Heliyon* 9, no. 7 (2023): e17954–54. https://doi.org/10.1016/j.heliyon.2023.e17954.

[13] Paolo D'Orazio and Lilit Popoyan, "Fostering Green Investments and Tackling Climate-Related Financial Risks: Which Role for Macroprudential Policies?" *Ecological Economics,* 160 (2019), 25-37.

[14] Xiongfeng Pan et al., "Dynamics of Financial Development, Trade Openness, Technological Innovation and Energy Intensity: Evidence from Bangladesh." Energy 171 (2019):456–464

[15] Lanouar Charfeddine and Karim Ben Khediri, "Financial Development and Environmental Quality in UAE: Cointegration with Structural Breaks," *Renewable and Sustainable Energy Reviews* 55 (2016): 1322–35. https://doi.org/10.1016/j.rser.2015.07.059.

[16] Cristina Ruza and Raquel Caro-Carretero, "The Non-Linear Impact of Financial Development on Environmental Quality and Sustainability: Evidence from G7 Countries," *International Journal of Environmental Research and Public Health* 19, no. 14 (2022): 8382. https://doi.org/10.3390/ijerph19148382.

emissions.[17] Conversely, financial development can support the adoption of cleaner technologies and renewable energy sources, reducing emissions.[18]

The International Monetary Fund (IMF) has developed comprehensive financial development indices, clustering them into Financial Market and Financial Institution, accounting for sub-indices in access, depth, and efficiency dimensions.[19] These indices capture the size, liquidity, access, and performance of financial institutions and markets, offering a detailed overview of a country's financial sector. Studies utilizing these indices have shown varying impacts of financial development on CO_2 emissions across different economic contexts.[20] [21] For instance, in South Asia, financial development positively correlates with environmental pollution, indicating that increasing levels of financial development do not reduce CO_2 emissions.

As one of the largest regional cooperative entities in the world, ASEAN plays a vital role in global economic activity and accordingly significantly contributes to carbon emissions. In 2023, ASEAN member states collectively contributed 7.3% to global GDP and 8.8% to global GDP growth over the

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[17] Maxwell Chukwudi Udeagha and Marthinus Christoffel Breitenbach, "Exploring the Moderating Role of Financial Development in Environmental Kuznets Curve for South Africa: Fresh Evidence from the Novel Dynamic ARDL Simulations Approach." Financial Innovation 9 (2013). https://doi.org/10.1186/s40854-022-00396-9.
Muhammad Mushafiq and Błażej Prusak. "Nexus between Stock Markets, Economic Strength, R&D and Environmental Deterioration: New Evidence from EU-27 Using PNARDL Approach." *Environmental Science and Pollution Research* (2022): https://doi.org/10.1007/s11356-022-24458-8.
Bassem Kahouli, "The Short and Long Run Causality Relationship among Economic Growth, Energy Consumption and Financial Development: Evidence from South Mediterranean Countries (SMCs)." *Energy Economics* 68 (2017): 19–30. https://doi.org/10.1016/j.eneco.2017.09.013.

[18] Ambe J. Njoh, "A Systematic Review of Environmental Determinants of Renewable Energy Performance in Ethiopia: A PESTECH Analysis." *Renewable and Sustainable Energy Reviews* 147 (2021): 111243. https://doi.org/10.1016/j.rser.2021.111243.
Najia Saqib. "Green Energy, Non-Renewable Energy, Financial Development and Economic Growth with Carbon Footprint: Heterogeneous Panel Evidence from Cross-Country." *Economic Research-Ekonomska Istraživanja* (2022): 1–20. https://doi.org/10.1080/1331677x.2022.2054454.
Muhammad Shahbaz et al., "The Effect of Financial Development on Renewable Energy Demand: The Case of Developing Countries." *Renewable Energy* 178 (2021): 1370–80. https://doi.org/10.1016/j.renene.2021.06.121.

[19] Katsiaryna Svirydzenka, "Introducing a New Broad-Based Index of Financial Development." *IMF* (2016). https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Introducing-a-New-Broad-based-Index-of-Financial-Development-43621.

[20] Umme Habiba and Cao Xinbang, "The Impact of Financial Development on CO2 Emissions: New Evidence from Developed and Emerging Countries," *Environmental Science and Pollution Research* (2022). https://doi.org/10.1007/s11356-022-18533-3.

[21] Acheampong, "Modelling for insight."

past decade.[22] The IMF anticipates continued robust economic growth for ASEAN, with a projected growth rate of 4.6% in 2024, driven by strong domestic demand and merchandise exports.[23] However, this economic growth comes with environmental repercussions. For example, Indonesia was the largest CO_2 emitter in ASEAN in 2021, releasing over 619 million metric tons of CO_2, ranking among the top emitters in the Asia-Pacific region. The energy sector, predominantly reliant on conventional fuel-based energy, contributes significantly to pollution in ASEAN, despite the rising adoption of renewable energy sources.[24]

Building upon these discussions, this study examines the impact of financial development, encompassing financial markets and financial institutions, on CO_2 emissions in ASEAN member states. This research also considers variables such as trade openness, renewable energy usage, and GDP per capita. This study offers two key contributions to the existing body of research. Firstly, while numerous time-series and panel studies have explored the relationship between financial development and carbon emissions (e.g., Shahbaz et al., 2013; Hu et al., 2020; Rehman et al., 2021), there is still no general consensus and in many respects, particularly in the context of ASEAN member states. These countries present a valuable panel for such an investigation due to their significant roles in global economic and environmental conditions. Moreover, to the best of the author's knowledge, no prior research has used the FD, Financial Institution, and Financial Market indices to study their impact on environmental quality in ASEAN. Domestic bank credit to the private sector has served as a proxy for financial development and resulted in positive long run effects to carbon emission.[25] This *proxy* is less effective to reflect more real conditions of financial development. Secondly, this study utilises panel data regression with the Autoregressive Distributed Lag (ARDL) method, addressing issues of cross-dependence, stationarity, and cointegration, providing insights into the short and long-run dynamics between financial development and carbon emissions. This approach will contribute to the existing body of literature and inform policy formulation for sustainable development in ASEAN.

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[22] Yan Carrière-Swallow and Krishna Srinivasan, "Asia Continues to Fuel Global Growth, but Economic Momentum Is Slowing," *IMF* (2023) https://www.imf.org/en/Blogs/Articles/2023/10/13/asia-continues-to-fuel-global-growth-but-economic-momentum-is-slowing.

[23] Rajiv Biswas, "ASEAN Economic Outlook in 2024," *IHS Markit* (2024). https://www.spglobal.com/marketintelligence/en/mi/research-analysis/asean-economic-outlook-in-2024-Jan24.html.

[24] International Energy Agency, "Global Energy Review: CO2 Emissions in 2021 – Analysis" *IEA* (March 2022). https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2.

[25] R.S. Hewage, N. Othman, J. J. Pyeman, and N.S.A., Samad, "Impact of Economic Growth, Financial Development and Technological Advancements on Carbon Emissions: Evidence from ASEAN Countries. In *IOP Conference Series: Earth and Environmental Science* 1102, no. 1, p. 012040 (2022).

II. LITERATURE REVIEW

II.A. Literature Review

Financial development refers to the growth and improvement of a country's financial system, including institutions, instruments, and markets that facilitate the efficient allocation of resources and promote economic growth. It encompasses the development of financial markets, institutions, and instruments that enable the efficient allocation of resources, promote economic growth, and reduce poverty.[26] This research also explains that carbon emissions refer to the release of greenhouse gasses, such as carbon dioxide, into the atmosphere primarily through human activities like energy consumption and industrial processes. It is known that financial development and carbon emissions are intertwined, with financial systems playing a crucial role in addressing climate change.[27] Since financial development is intricately linked to the effectiveness of investment distribution, its influence can be moderated through scale effects, technique effects, and composition effects.[28] From a scale effect viewpoint, financial development risks higher environmental consequences due to increased economic activity, which leads to higher energy consumption and carbon emissions.[29] It enhances risk diversification, facilitates low-cost financing, and promotes income and wealth generation by fostering business confidence, thereby driving economic growth. This growth increases energy demand and results in CO_2 emissions (Acheampong, 2019).[30] Under the scale effect, investments spurred by financial development generally elevate production levels and the utilization of input materials, including natural resources and fossil fuels, thus causing higher carbon emissions.[31]

Regarding the technique effect, research indicates that financial development can lower carbon emissions through enhanced economic efficiencies and the adoption of sustainable practices, such as renewable energy and energy

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[26] Tomiwa Sunday Adebayo et al., "A Time-Varying Analysis between Financial Development and Carbon Emissions: Evidence from the MINT countries," *Energy & Environment* (2022). 0958305X2210820. https://doi.org/10.1177/0958305x221082092

[27] F. Darweesh et al., "The Relationship Between Financial Development and Carbon Emissions: A Systematic Review," *International Journal of Professional Business Review* 8, no. 7 (2023), e02718–e02718. https://doi.org/10.26668/businessreview/2023.v8i7.2718

[28] Zhe Huang, "Does Green Investment Reduce Carbon Emissions? New Evidence from Partially Linear Functional-Coefficient Models," *Heliyon* 9, no. 9 (2023).

[29] Haichao Liu et al., "Linkage among Urbanization, Energy Consumption, Economic Growth and Carbon Emissions. Panel Data Analysis for China using ARDL model," *Fuel* 332 (2023), 126122.

[30] Acheampong, "Modelling for insight."

[31] Qui Shi Deng et al., "Asymmetric Impacts of Foreign Direct Investment Inflows, Financial Development, and Social Globalization on Environmental Pollution," *Economic Analysis and Policy* 76 (2022), 236-251.

efficiency via advanced technologies.[32] For example, studies in Asian countries have found that renewable energy and financial development, influenced by institutional quality and globalization, have long-term effects on reducing CO_2 emissions.[33] Similarly, in energy-intensive industries, financial development can reduce carbon emissions through increased investment in research and development and changes in the energy mix.[34] In 2022, it was argued that financial development can curb carbon emissions through a "technology effect" by enhancing the efficiency of production processes and equipment through technological advancements.[35] A robust financial system can attract more FDI, which can reduce carbon emissions through technology transfer and the adoption of low-carbon practices.[36] A well-developed financial system also encourages the adoption of advanced technologies through significant investments in research and development.[37]

From a composition effect perspective, financial development can have a dynamic impact on carbon emissions. Positively, a sophisticated financial system can steer industries toward more sustainable practices. It has been demonstrated that financial development via investment can lead to higher economic development and increased per capita income, which raises demand for sustainable environmental standards and green development, thereby reducing carbon emissions. Furthermore, a well-developed financial system invited greater FDI, enabling both private and public sectors to invest in cost-effective, environmentally friendly projects.[38] Empirical studies support this hypothesis, with Eskeland and Harrison (2003) finding that foreign companies in developing countries are more environmentally conscious than domestic firms. This is evident in U.S. investments in developing countries, which tend to be more energy-efficient and use greener energy sources compared to domestic investments in those countries.[39]

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[32] Yi-Bin Chiu and Wenwen Zhang, "Moderating Effect of Financial Development on the Relationship between Renewable Energy and Carbon Emissions." *Energies* 16, no. 3 (2023), 1467–1467. https://doi.org/10.3390/en16031467

[33] Xu Xu et al., "The Dynamic Relationship between Carbon Emissions, Financial Development, and Renewable Energy: A Study of the N-5 Asian Countries," *Sustainability* 15, no. 18 (2023), 13888. https://doi.org/10.3390/su151813888

[34] Yingying Zhou et al., "How Does Financial Development Affect Reductions in Carbon Emissions in High-Energy Industries?—A Perspective on Technological Progress." *International Journal of Environmental Research and Public Health* 16, no. 17 (2019): 3018. https://doi.org/10.3390/ijerph16173018

[35] Z. Yang et al., "Can Renewable Energy Investment Reduce Carbon Dioxide Emissions? Evidence from Scale and Structure," *Energy Economics* 112 (2022): 106181.

[36] Binyam Afewerk Demena and Sylvanus Afesorgbor, "The effect of FDI on environmental emissions: Evidence from a meta-analysis." *Energy Policy* 138 (2020): 111192.

[37] Tamazian et al, "Does Higher Economic Development Lead to Environmental Degradation."

[38] Pan et al., "Dynamics of Financial Development,

[39] Gunnar S. Eskeland and Ann E. Harrison, Ann E., "Moving to Greener Pastures? Multinationals and the Pollution Haven Hypothesis," *Journal of Development Economics* 70, no. 1 (2003), 1-23.

The impacts of financial development on carbon emissions take varying lengths of time to materialise across different countries. Research in China shows that private investment driven by financial development adversely affects the environment only in the long term.[40] This finding is consistent with a previously-identified significant positive relationship between financial development and carbon emissions in the long term for ASEAN countries.[41] Additionally, ARDL bounds testing and the VECM Granger causality test with quarterly time series data from 1971Q1-2011Q4 have been utlised to discover that financial development initially increases carbon emissions but ultimately enhances environmental quality as its value increases.[42] This nonlinear impact underscores the complex relationship between financial development and carbon emissions, which varies over different time horizons and economic contexts. The adjustment period for financial development means its effects are often felt only in the long term. Supporting this, autometrics have been used to demonstrate the long-term effects of financial development on altering carbon emissions.[43]

II.B. Hypothesis

Concerning global efforts to combat climate change, the impact of financial development on carbon emissions has garnered considerable attention. This is particularly pertinent in ASEAN countries, which are undergoing rapid economic expansion. Within this landscape, the role of financial development takes on heightened significance. Financial development, encompassing factors such as access to financial services, capital availability, and innovation in financial instruments, assumes a dual function. Financial development also facilitates economic growth and infrastructure advancement. On the other hand, it has the potential to shape policies and investments pertaining to clean energy and low-carbon technologies. Furthermore, the impact of financial development on carbon emissions has exhibited a dynamic nature, contingent upon the level of financial development attained. Thus, a nuanced understanding of the interplay between financial development and carbon emissions is imperative for the formulation of effective strategies aimed at mitigating climate change.

Against this backdrop, this research investigates the impact of financial development on carbon emissions in ASEAN countries. The hypotheses to be tested include:

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[40] Huang Jiemin and Wen Chen, "The Impact of Private Sector Energy Investment, Innovation and Energy Consumption on China's Carbon Emissions," *Renewable Energy* 195 (2022):1291–1299

[41] Hewage et al., "Impact of Economic Growth."

[42] Shahbaz et al., "Case of Developing Countries.".

[43] Shahriyar et al., "The Long-Run Effect of Financial Development on Carbon Emissions in Kazakhstan," *Energy Efficiency* 17, no. 3 (2024): 1-15.

1. Hypothesis 1 (H1). Financial development, financial institutions, and financial market have a crucial role to impact environmental quality.
2. Hypothesis 2 (H2). There is a long-run impact of financial development, financial institutions, and financial market to carbon emissions.

III. DATA AND MODEL

III.A. Variables and Data Description

This research utilises panel data from ASEAN member countries, focusing on national-level data spanning 2000 to 2020 to explore the impact of financial development on carbon emissions. The data sources include the Global Carbon Budget, International Monetary. This study uses panel data from ASEAN member countries, focusing on national-level data from 2000 to 2020, to investigate the role of financial development in influencing carbon emissions. The data was sourced from the Global Carbon Budget, the International Monetary Fund (IMF), and the World Development Indicators (WDI) from the World Bank. Panel data was chosen because it provides more information, greater variability, lower collinearity among variables, more degrees of freedom, and greater efficiency in parameter estimation. The selection of the study period and countries was determined by the availability of data, particularly for CO_2 emissions and financial development indicators. Due to missing values in Brunei Darussalam's data, which were difficult to interpolate, the study focuses on nine other ASEAN countries.

To represent environmental quality, annual (CO_2) emissions in tonnes were used as the proxy variable, with data sourced from the Global Carbon Budget. Given the diversification of the modern financial system, using a single index to indicate financial development is inadequate. Therefore, this study employs the financial development index developed by the IMF, which captures the multidimensional nature of financial development.[44] This index divides financial development into several indicators, with financial markets including bond and stock markets, and financial institutions encompassing banks, insurance companies, mutual funds, and pension funds.

Apart from the dependent and independent variables, this study also proposes other variables that determine the CO_2 emission. Based on existing research, this study selects GDP per capita, trade openness, and the proportion of renewable energy as control variables. GDP per capita and trade openness tend to have a positive correlation with increasing emissions, while the proportion of renewable energy has the opposite effect. The negative impact of trade openness on the environment occurs because open economies have

[44] Svirydzenka, "Introducing a New Broad-Based Index."

high trade volumes, leading to increased energy demand. The rise in energy demand also results from increased economic activity, reflected in higher GDP per capita. Conversely, the higher proportion of renewable energy use in meeting overall energy demand positively contributes to reducing carbon emissions. The specific variables and their sources are detailed in Table 1.

Table 1.
The list of variables used in the model

Variable Type	Variable Name	Variable Description	Source
Dependent Variable	CO2	Carbon Emission (tonnes)	Global Carbon Budget
Independent Variables	FD	Financial Development	IMF
	FM	Financial Markets	IMF
	FI	Financial Institutions	IMF
Control Variables	RE	Renewable Energy Consumption (% of total final energy consumption)	World Bank
	GDPC	Gross Domestic Product per capita (PPP, constant 2017 international $)	World Bank
	Trade	Sum of Export and Import to GDP (% of GDP)	World Bank

III.B. Econometrics Model and Estimation Procedures

The STIRPAT model is used as the framework to explain the role of economic activities on environmental pollution, including carbon emissions.[45] This model has been used frequently to analyze the impact of particular aspects or policies by using them as proxies for a component in STIRPAT or as the emission, e.g.: Industrial activity, energy efficiency, and Kyoto protocol ratification as the proxies for technological change (Aguir Bargaoui, Liouane, & Nouri, 2013), Industrial waste, SO2, soot, and domestic garbage as the proxies for carbon emission (Xu et al, 2020), carbon intensity and fixed assets investments (Wang et al, 2016), etc. The basic form of the model is as follows:

$$I_t = P^b{}_{it} \quad A^c{}_{it} T^d{}_{it} e_{it} \tag{1}$$

where I represents environmental pollution, P reflects the population size, A indicates economic prosperity, T stands to technology level, and e is the error term.

From that basic form, we use an extended STIRPAT model to accommodate our variable of interest and control variable that we want to analyze. The model also uses the natural logarithmic value of the variables to overcome

[45] Thomas Dietz and Eugene A. Rosa, "Effects of Population and Affluence on CO2 Emissions," *Proceedings of the National Academy of Sciences of the United States of America* 94, no. 1 (1997): 175–79.

the problem of nonlinearity and skewed distribution in the data (Wang et al., 2021).

$$lnCO2_{it} = \beta_{0i} + \beta_2 FD_{it} + \beta_3 lnRE_{it} + \beta_4 lnGDPC + \beta_5 lnTrade + e_{it} \quad (2)$$

Each variable corresponds to table 1 in the previous section. *i* represents the countries and *t* represents the periods specified before. The carbon emission per capita is used as the dependent variable. Instead of using a single financial development indicator, the indices and sub-indices for financial development indicators, following the IMF's method, are used interchangeably to obtain reliable results. Therefore, as much as three estimations will be run with this model. Lastly, e_{it} represents the stochastic errors for time and countries. The study aims to assess the significance of β_2 as the coefficient attributed to the financial development index, alongside other explanatory variables, on CO_2 emissions. It seeks to determine whether these variables have a significant impact on CO_2 emissions and whether this impact is positive or negative.

Given that the number of time periods (T=20) exceeds the number of cross-sectional units (N=9), the variables are likely to be non-stationary and dynamic, consistent with findings from Khan et al.[46] This characteristic causes the variables to have different orders of integration, such as I(0) and I(1). Consequently, the appropriate econometric method to employ is the ARDL panel model developed by Pesaran & Smith in 1995.[47] This model is adept at capturing both short- and long-term cointegration relationships among independent variables and provides an error correction mechanism to account for short-term dynamics in panel data. Unlike other dynamic panel methods such as fixed effects, instrumental variables, or the Generalised Method of Moments (GMM), which may produce inconsistent parameter estimates unless coefficients are identical across countries, the ARDL approach offers several advantages. The ARDL model can yield more accurate results and address autocorrelation issues by selecting the optimal number of lags based on the characteristics of the variables.

The estimation model from the ARDL panel data is structured to incorporate these dynamics, allowing for a comprehensive analysis of both short-term adjustments and long-term equilibrium relationships. This method is particularly useful when dealing with variables that have mixed integration

[46] Zeeshan Khan et al., "The Impact of Technological Innovation and Public-Private Partnership Investment on the Sustainable Environment in China: Consumption-Based Carbon Emissions Analysis," *Sustainable Development*, 28, no. 5 (2020): 1317–1330.

[47] M. Hashem Pesaran, and Ron Smith, "Estimating Long-Run Relationships from Dynamic Heterogeneous Panels," *Journal of Econometrics*, 68, no. 1 (1995).

orders and provides a robust framework for understanding the interplay between economic variables over time. The estimation model from the ARDL Data Panel is:

$$lnCO2_{it} = \varphi_i(lnCO2_{i,t-1} - \beta_1' X_{it} \sum_{j=1}^{p-1} \quad a_{ij}^* \, \Delta lnCO2_{i,t-j} + \sum_{j=0}^{q-1} \quad \vartheta_{ij}^*{}' \, \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (3)$$

In this context, β_i represents a vector that quantifies the long-term effects of independent variables, such as financial development (FD), which is the primary variable of interest, alongside other control variables, on the growth rate of per capita carbon dioxide emissions. Meanwhile, φ_i functions as an error correction mechanism. The remaining parameters capture short-term dynamics. The disturbances ε_{it} are independently distributed across time and units, with a mean of zero and a constant variance.

Based on Pesaran et al. (1995), he application of the ARDL method involves several essential stages,[48] including stationarity testing, selecting the optimal lag, conducting cointegration tests, performing the Hausman test, and choosing between Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effect (DFE) Panel ARDL estimation. The stationarity test is crucial as it determines the degree of integration of each variable, ensuring they meet the bound test assumptions of the ARDL model, which require variables to be either I(0) or I(1). To accomplish this, various stationarity test instruments are used, such as the Augmented Dickey Fuller (ADF), Kwiatkowski–Phillips–Schmidt–Shin (KPSS), Phillips–Perron (PP), Ng–Perron test, cross-sectional augmented IPS-CIPS, Breitung test, and the LS test.[49] Before selecting the most appropriate instrument, the Pesaran cross-sectional dependence (CD) test is conducted to confirm the independence of the variables, addressing the common issue of cross-sectional interdependence in panel data.

The next step involves determining the optimum lag by comparing various combinations of lagged independent variables to find the lowest Akaike Information Criterion (AIC) value. AIC serves as an indicator to evaluate the goodness of fit of a model while penalizing for the number of parameters to prevent overfitting. The model with the lowest AIC value indicates the best balance between appropriateness of fit and model complexity. Once the optimal lag for each model is identified, a cointegration test is conducted to examine

48 Pesaran, and Smith, "Estimating long-run relationships."

49 Jorg Breitung and M. Hashem Pesaran, "Unit Roots and Cointegration in Panels," in: L. Mátyás and P. Sevestre (eds), *The Econometrics of Panel Data. Advanced Studies in Theoretical and Applied Econometrics,* vol 46. (Springer: Berlin, Heidelberg, 2008) 279-322. https://doi.org/10.1007/978-3-540-75892-1_9.

the long-term relationship between per capita carbon dioxide emissions and the hypothesised influencing variables. The Pedroni ARDL test, developed by Pedroni, Kao, and Fisher, is used. If the p-value of the cointegration test results is less than 0.1, it indicates the presence of cointegration between the variables.

The Hausman Poolability Test is then conducted to ensure that pooling long-term coefficients is effective and accurate. The Hausman test results help determine the most appropriate model based on the assumption of parameter homogeneity in the long term, distinguishing between MG, PMG, or DFE models. The differences among these estimation methods lie in the treatment of short-term and long-term relationships between the dependent and independent variables across countries. PMG assumes common long-run relationships but allows short-run dynamics to vary across groups, MG allows both long-run relationships and short-run dynamics to vary across groups, and DFE assumes both long-run relationships and short-run dynamics are common across groups.[50]

IV. RESULT

IV.A. Descriptive Statistic

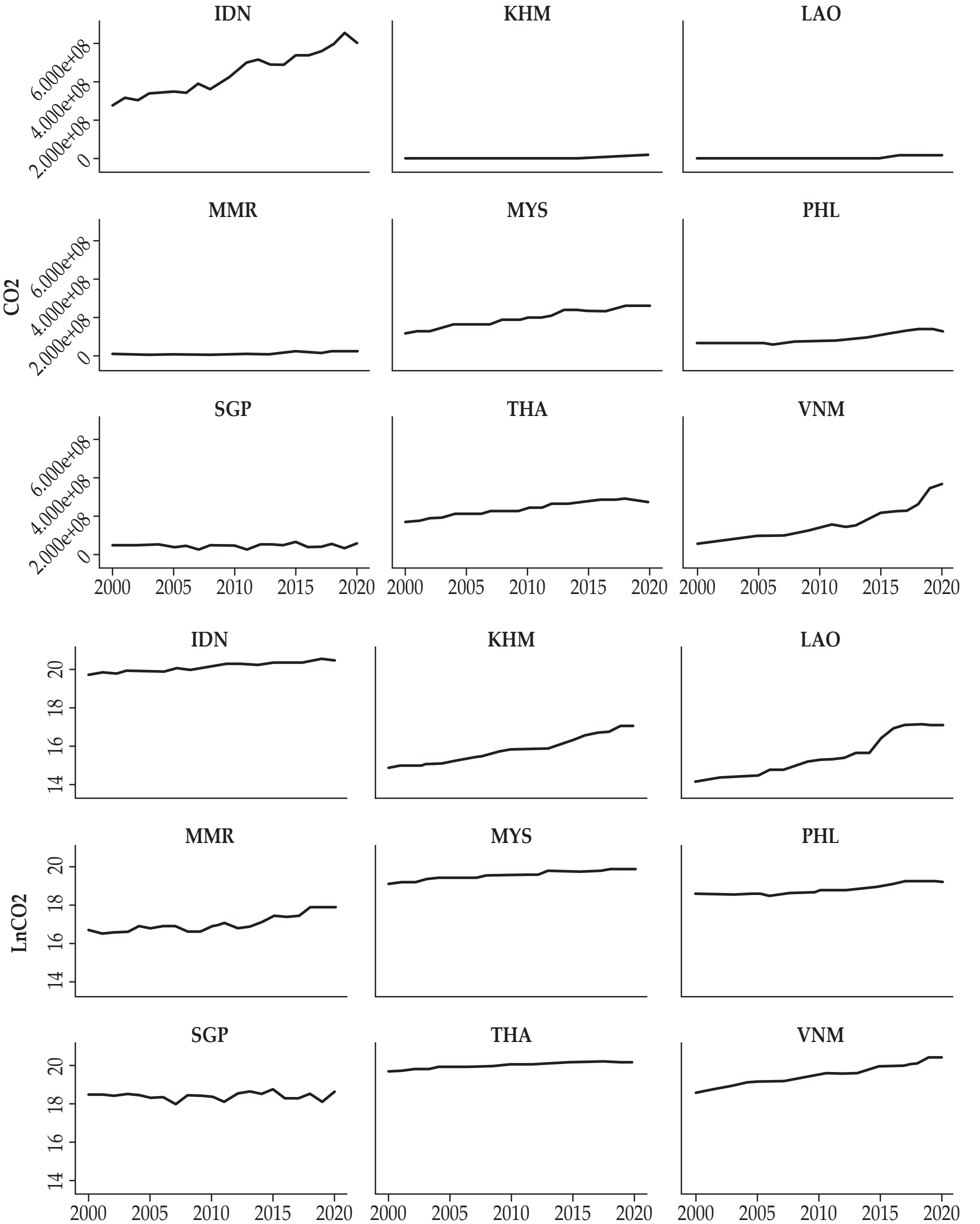
The analysis of carbon dioxide (CO_2) emissions and their natural logarithm ($LnCO_2$) trends for nine ASEAN countries from 2000 to 2020 reveals distinct patterns of emission growth and stability, seen in Figure 1. The CO_2 emissions graph shows actual emission levels, while the $LnCO_2$ graph provides a logarithmic scale to better understand the growth patterns across these countries. Indonesia, Laos, Malaysia, the Philippines, Thailand, and Vietnam exhibit significant increases in both CO_2 and $LnCO_2$ trends, indicating a consistent rise in carbon dioxide emissions over the period. Cambodia, despite a nearly flat CO_2 trend, shows a gradual increase in $LnCO_2$, suggesting a slow but steady rise in emissions. Myanmar presents relatively flat trends in both CO_2 and $LnCO_2$, indicating minimal changes in emission levels. Singapore stands out with stable trends in both CO_2 and $LnCO_2$, demonstrating no significant change in emissions throughout the observed period.

This comparative analysis highlights that while most ASEAN countries are experiencing increasing carbon dioxide emissions, Singapore maintains stable emission levels. This stability may reflect effective environmental policies and measures in place to control emissions, distinguishing Singapore from its regional counterparts. Overall, the varied emission trends underscore the

[50] Pesaran, and Smith, "Estimating long-run relationships."

differing environmental and economic trajectories of ASEAN countries over the past two decades (Fulton et al., 2017).[51]

Figure 1. Carbon Emission Trend in Nine ASEAN Countries, Annual CO_2 in Tonnes (left) and Natural Logarithmic CO_2 (right)



Source: Authors' documentation

[51] Lew Fulton et al., "Climate Change Mitigation Pathways for Southeast Asia: CO2 Emissions Reduction Policies for the Energy and Transport Sectors," *Sustainability* 9, no. 7 (2017): 1160.

The analysis of financial development trends for nine ASEAN countries from 2000 to 2020, represented by the Financial Development (FD), Financial Institutions (FI), and Financial Markets (FM) indices, reveals diverse patterns across the region in Figure 2. Indonesia shows relatively stable trends for FD, FI, and FM with some fluctuations around 2010, indicating consistent financial development with minor variations. Cambodia exhibits a gradual increase in FD and FI, while FM remains relatively flat, suggesting ongoing development in financial institutions but limited growth in financial markets.[52] Laos presents a similar pattern with a gradual increase in FD and FI, indicating a focus on developing financial institutions, while FM shows minimal growth. Myanmar displays stable trends across all indices with slight fluctuations, reflecting steady but slow financial development. Malaysia shows relatively stable trends with minor fluctuations in all indices, suggesting a mature and well-developed financial system. The Philippines also exhibits a stable trend with minor fluctuations across FD, FI, and FM, indicating steady financial development. Singapore stands out with stable trends in all indices, reflecting a highly developed and consistent financial system. Thailand shows gradual increases with fluctuations in all indices, indicating ongoing growth in financial development. Vietnam exhibits a gradual increase in FD and FI with more fluctuations in FM, suggesting dynamic growth in financial institutions and varying progress in financial markets.

A comparative analysis of the Financial Institutions (FI) and Financial Markets (FM) indices reveals that FI is generally higher than FM across most ASEAN countries. This indicates that financial institutions, such as banks and other lending entities, are more developed and stable compared to financial markets, which include stock exchanges and other trading platforms. For example, Indonesia's FI is higher than FM, showing stronger development in financial institutions compared to markets. Similarly, Cambodia, Laos, and Vietnam show higher FI trends, indicating more focus on institutional development. Myanmar, Malaysia, the Philippines, and Thailand also exhibit higher FI compared to FM, although the differences are less pronounced in these countries. Singapore's FI and FM indices are both highly developed, with FI slightly higher, reflecting a well-rounded and robust financial system. These findings highlight the emphasis on developing financial institutions across ASEAN countries, which is crucial for providing a stable foundation for economic growth and development. The relatively lower development of financial markets indicates the need for further reforms and enhancements to improve market infrastructure and efficiency.

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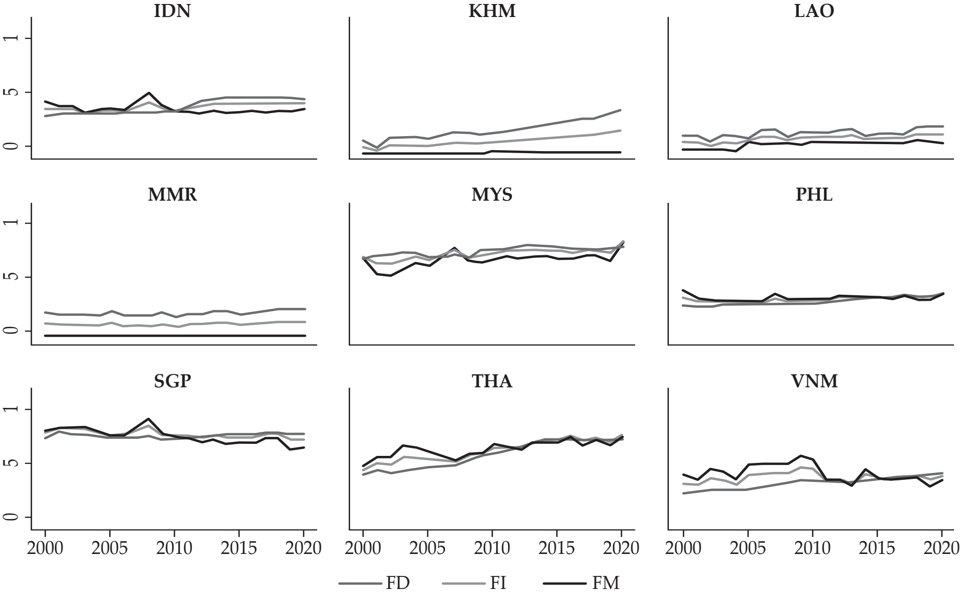
[52] Abrham Tezera Gessesse and Ge He, "Analysis of Carbon Dioxide Emissions, Energy Consumption, and Economic Growth in China," *Agricultural Economics* 66, no. 4 (2020): 183-92. https://doi.org/10.17221/258/2019-AGRICECON

Figure 2. Financial Development Index Trend in Nine ASEAN Countries



Source: Authors' documentation

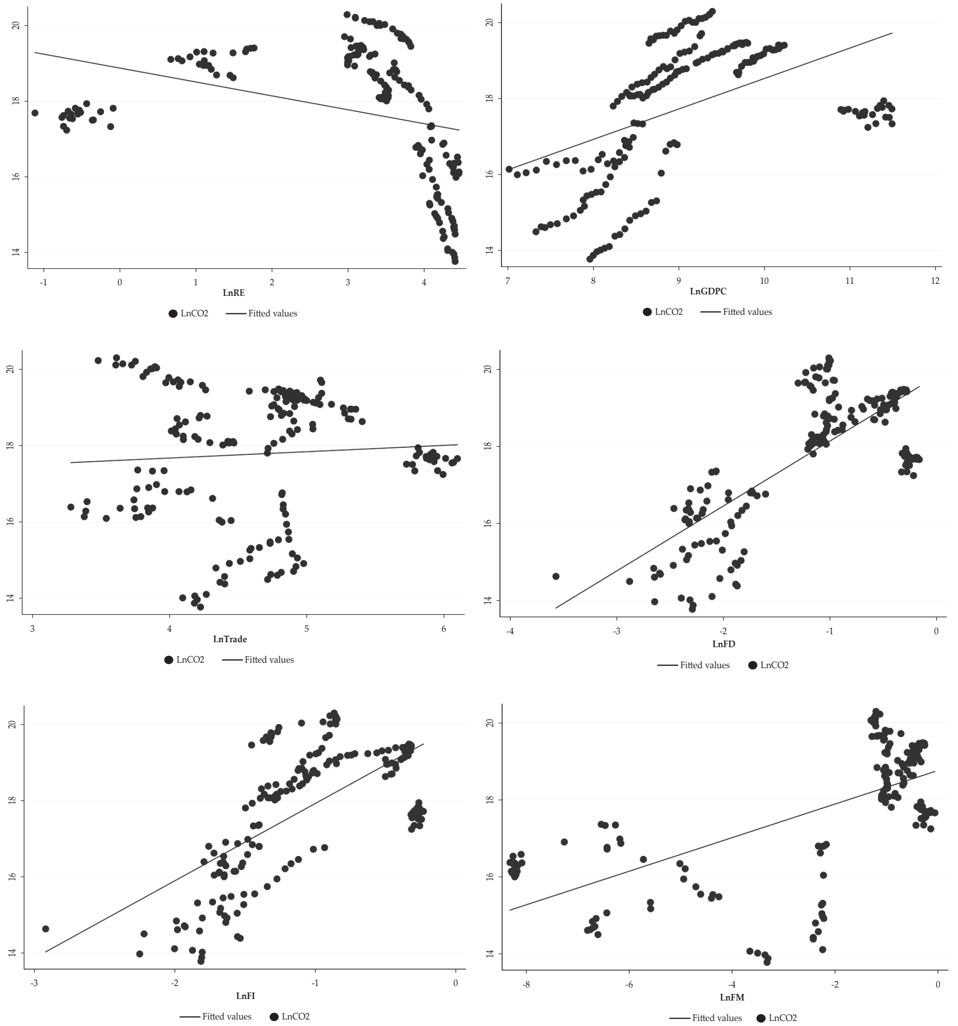
The scatter plots with fitted value lines in Figure 3 illustrate the relationships between carbon dioxide emissions (LnCO2) and various independent variables across ASEAN countries. The plot depicting the relationship between LnCO2 and GDP per capita (LnGDPC) demonstrates a strong positive correlation, indicating that higher GDP is associated with increased carbon dioxide emissions. This relationship underscores the environmental trade-offs inherent in economic growth, where industrial activities and increased energy consumption contribute significantly to carbon emissions.[53] Similarly, the positive correlation between LnCO2 and financial development (LnFD) suggests that financial sector growth supports economic activities that lead to higher emissions. Financial institutions (LnFI) and financial markets (LnFM) also show positive relationships with LnCO2, indicating that more developed financial sectors are associated with higher emissions.

In contrast, the relationship between $LnCO_2$ and renewable energy consumption (LnRE) is negative, suggesting that increased use of renewable energy sources can effectively reduce carbon dioxide emissions. This finding underscores the critical role of renewable energy in mitigating environmental impacts and promoting sustainable development. Additionally, trade openness (LnTrade) exhibits a slightly little positive correlation with LnCO2, indicating

[53] David I. Stern, "The Rise and Fall of the Environmental Kuznets Curve," *World development*, 32, no. 8 (2004): 1419-1439.

that higher trade openness may increase emission due to economic activity, but at the same time can facilitate the transfer of cleaner technologies and more efficient production methods, thereby reducing emissions.[54] Overall, these relationships highlight the complexity of managing economic growth and environmental sustainability in ASEAN countries. However, it is too soon to conclude based on the scatter plot alone and need further inferential approach to get better understanding.

Figure 3. Scatter Plots for independent and control variables toward dependent variables



Source: Authors' documentation

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54 Jeffrey A. Frankel and Andrew K. Rose, "Is Trade Good or Bad for the Environment? Sorting out the causality," *Review of economics and statistics*, 87, no. 1 (2005): 85-91.

IV.B. Unit Root and Cointegration Test

Before conducting a stationarity test, a Cross-Sectional Dependence (CD) test was performed to determine the appropriate method for the stationarity test. As shown in Table 2, all variables exhibit significant CD test results at the 1% significance level, except for LnRE, which is significant at the 5% level. This indicates the presence of cross-sectional dependence, suggesting that the Breitung method is more suitable for performing the unit root test to check data stationarity (Moon et al., 2006).[55]

The detailed results of the stationarity test are presented in Table 3. At the level without intercept and trend, all probabilities exceed 0.05, indicating that each variable in the study has a unit root or is non-stationary. Similar results were observed in the level unit root test with data trends, except for the FD variable. When the stationarity test was conducted again at the first lag level without intercept and trend, the probabilities still exceeded 0.05 for all variables except for the GDP per capita variable. Comparable results were found in the first lag level unit root test with data trends, except for the FD variable. However, to ensure consistent and accurate testing on time-series data panels, all variables must be stationary. To address this, the stationarity test was repeated using the first difference of each variable. As a result, all probabilities fell below 0.05, indicating that all variables in the study no longer have a unit root and are stationary.

To enhance the robustness of the stationarity test and validate the Breitung results, the Fisher ADF approach was also applied, as shown in Table 4. The Fisher ADF test results at all levels reached the same conclusions as the Breitung test. All variables had a probability value of less than 0.05 when the first difference was used. Consequently, the ARDL panel data method is applied by first differencing each variable. Since all variables are now stationary at the I(1) level, they may be cointegrated with each other, which necessitates further verification through a cointegration test.

Table 2.
Pesaran CD test

Variable	CD-test	p-value	corr	abs(corr)
LnCO2	19,77	0	0,719	0,725
LnFD	8,41	0	0,306	0,562
LnFI	17,11	0	0,622	0,624
LnFM	17,09	0	0,620	0,622
LnGDPC	27,14	0	0,987	0,987
LnTrade	4,16	0	0,151	0,382
LnRE	1,95	0,05	0,071	0,671

Source: Authors' calculation

[55] H.R. Moon et al., "On the Breitung Test for Panel Unit Roots and Local Asymptotic Power," *Econometric Theory* 22, no. 6 (2006): 1179-1190.

Table 3.
Breitung Unit Root Test

Variable	Lag zero		Lag zero with Intercept & Trend		Lag one		lag one with Intercept, & Trend		First Difference	
	Statistics	p-value	Statistics	p-value	Statistics	p-value	Statistics	p-value	Statistics	p-value
LnCO2	5,766	1,000	1,730	0,958	2,683	0,996	0,543	0,707	-4,034	0,000
LnFD	-0,309	0,379	-2,652	0,004	1,902	0,971	-1,903	0,029	-3,496	0,000
LnFI	3,139	0,999	-0,655	0,256	2,001	0,977	-0,650	0,258	-4,410	0,000
LnFM	-1,353	0,088	-0,352	0,362	-1,480	0,069	-1,407	0,080	-6,579	0,000
LnGDPC	7,635	1,000	7,248	1,000	-3,127	0,001	7,142	1,000	-2,963	0,002
LnTrade	1,258	0,896	-0,103	0,459	0,297	0,617	0,144	0,557	-5,363	0,000
LnRE	3,854	1,000	1,340	0,910	2,536	0,994	2,075	0,981	-3,738	0,000

Source: Authors' calculation

Table 4.
Fisher ADF Unit Root Test

Variable	Lag zero		Lag zero with Intercept & Trend		Lag one		lag one with Intercept, & Trend		First Difference	
	Statistics	p-value	Statistics	p-value	Statistics	p-value	Statistics	p-value	Statistics	p-value
LnCO2	24,919	0,127	20,980	0,280	15,625	0,619	19,155	0,382	133,865	0,000
LnFD	14,855	0,672	71,884	0,000	20,320	0,315	105,456	0,000	276,843	0,000
LnFI	14,428	0,701	38,266	0,004	12,900	0,798	85,078	0,000	247,392	0,000
LnFM	35,368	0,009	44,742	0,001	19,613	0,355	29,791	0,040	165,353	0,000
LnGDPC	23,854	0,160	6,792	0,992	23,232	0,182	7,307	0,987	103,302	0,000
LnTrade	9,597	0,944	11,480	0,873	17,269	0,505	31,267	0,027	117,086	0,000
LnRE	5,133	0,999	11,679	0,863	4,054	1,000	8,356	0,973	175,763	0,000

Source: Authors' calculation

The next step before conducting the cointegration test using the Pedroni ARDL Test is to determine the optimal number of lags for each model to be estimated. The selection of the optimal lag involves performing ARDL regression tests on each variable with a maximum lag set at 1, following the ARDL panel data method's flexibility, which allows variables to have mixed integration orders, as long as they do not exceed I(1). This setting is similar to the research by Gessese and He that also investigates carbon emission trends.[56]

In the ARDL test with a maximum lag of 1, using the AIC for each observation country, different optimal lag levels were identified. For instance, in the case of Indonesia, the optimal lags for the variables LnCO2, LnFD, LnGDPC, LnTrade, and LnRE are ARDL(1, 1, 0, 1, 0), whereas for Cambodia, the optimal lags are ARDL(1, 0, 1, 1, 1). Detailed results of the optimal lag estimates for each country are provided in Table 5. After selecting the

[56] Gessesse and He, "Analysis of carbon dioxide emissions."

ARDL model for each country individually, it was evident that the optimal lag structures varied significantly among the countries. However, a common observation was that all countries exhibited a lower AIC when using lagged LnCO2 as a variable. To ensure a consistent and robust analysis across all nine countries, we derived a generalised optimal lag structure by taking the essence of each country-specific model. This approach ensures that each variable includes at least the maximum required lag identified for any country. Thus, we conclude that the overall optimal lag structure for the variables LnCO2, LnFD, LnGDPC, LnTrade, and LnRE is ARDL (1, 1, 1, 1, 1). This conclusion holds true even when the variable of interest, FD, is replaced with its sub-indices, namely FI and FM.

Table 5.
Lag Optimum Test

Variable of Interest	Variable	Countries								
		Indonesia	Kamboja	Laos	Myanmar	Malaysia	Philippines	Singapore	Thailand	Vietnam
FD	LnCO2	1	1	1	1	1	1	1	1	1
	LnFD	1	0	0	0	0	1	0	1	0
	LnGDPC	0	1	0	0	0	0	0	0	0
	LnTrade	1	1	0	1	0	0	0	0	0
	LnRE	0	1	1	0	0	1	0	1	0
FI	LnCO2	1	1	1	1	1	1	1	1	1
	LnFI	1	0	1	0	1	0	0	1	0
	LnGDPC	1	1	0	0	1	0	0	0	0
	LnTrade	1	1	0	1	0	0	0	1	0
	LnRE	1	1	1	0	0	1	0	0	0
FM	LnCO2	1	1	1	1	1	1	1	1	1
	LnFM	0	0	0	0	0	1	0	1	0
	LnGDPC	0	1	0	0	0	0	0	0	0
	LnTrade	1	0	0	1	0	0	0	0	0
	LnRE	0	0	1	0	0	1	0	1	0

Source: Authors' calculation

After determining the optimal lag for each model, a cointegration test was performed to examine the long-term relationship between carbon dioxide emissions per capita and the hypothesised influencing variables. The Pedroni ARDL test, initiated by Pedroni, Kao, and Fisher, was utilised. In this test, a p-value less than 0.1 indicates cointegration among the variables. Table 6 presents the results of the cointegration test using the Pedroni method. The null hypothesis posits that there is no cointegration relationship among the variables, while the alternative hypothesis asserts that all panels are cointegrated with each other. The t-test values of the Phillips-Perron and Augmented Dickey-

Fuller parameters show p-values less than 0.01, indicating significant results, whereas the Modified Phillips-Perron parameter does not show significant results. Despite this, the two tests that produced highly significant values allow us to reject the null hypothesis, leading to the conclusion that there is a long-term cointegrated relationship among the variables. This conclusion holds true even when the variable of interest is alternated among FD, FI, and FM.

Table 6.
Pedroni Cointegration Test

Test	FD		FI		FM	
	Statistics	p-value	Statistics	p-value	Statistics	p-value
Modified Phillips-Perron t	1,268	0,103	1,679	0,047	1,373	0,085
Phillips-Perron t	-4,157	0,000	-3,344	0,000	-4,389	0,000
Augmented Dickey-Fuller t	-3,908	0,000	-3,324	0,000	-3,670	0,000

Source: Authors' calculation

IV.C. Econometric Result

Inferential

Table 7 reports the empirical results of the impact of financial development on carbon emission as a proxy of environmental quality for the ASEAN member states that represent nine countries sampled with the data from 2000 - 2019. This study employs Dynamic Fixed Effects (DFE), Pooled Mean Group (PMG), and Mean Group (MG) estimation techniques. The coefficients for FD shown in the table do not provide a clear indication of its effect on carbon emissions, as all coefficients are statistically insignificant. Additionally, the direction of the effect is ambiguous because different methods yield different results. In the PMG and MG models, FD increases carbon emissions in the short run but decreases them in the long run. Conversely, in the DFE model, FD decreases carbon emissions in the short run but increases them in the long run.

The analysis reveals that GDP per capita tends to increase carbon emissions, predominantly in the long run. However, in the short run, per capita GDP does not significantly affect carbon emissions. This suggests that economic growth initially does not contribute significantly to environmental degradation, but over time, increased economic activity leads to higher emissions. As hypothesised, renewable energy consumption generally decreases carbon emissions in both the long run and short run, particularly evident in the PMG results. This finding underscores the importance of renewable energy in mitigating environmental impacts and promoting sustainability. The impact of trade percentage to GDP on carbon emissions is mixed and statistically insignificant. This variability indicates that trade policies and practices have complex and context-specific effects on environmental outcomes. The error correction term shows a negative and significant value, indicating that any short-run deviations from the long-term equilibrium are corrected over time. The magnitude of the coefficient reflects the speed at which these adjustments occur, ensuring that the system returns to its long-term path after short-term fluctuations.

A set of Hausman tests is conducted to examine which result is better. The result of the test is shown in Table 8. Based on the result, it is shown that the PMG estimation is preferred in two of three cases, so further analysis will use this technique.

The analysis is divided into more specific metrics of financial development, specifically the development of financial institutions (FI) and financial markets (FM). The results, shown in Table 9, reveal distinct effects for FM and FI on carbon emissions. The development of FM tends to decrease carbon emissions both in the short run and the long run, though the coefficients are not statistically significant. Conversely, FI development significantly increases carbon emissions in the long run while having an insignificant effect in the short run. Specifically, a 1% increase in FI development is associated with a 1.178% increase in carbon emissions in the long run.

This significant long-term impact of FI on carbon emissions aligns with previous research. Udeagha and Breitenbach[57] explain that the development of the financial sector can lead to increased CO2 emissions through economic growth, which in turn raises energy demand. This phenomenon is particularly relevant in developing countries, where financial institutions often drive economic activities that are energy intensive. Habiba & Xinbang[58] also found that FI tends to impede environmental quality in these nations.

The coefficient for FM development is not significant, meaning it is not evident to affect carbon emission. This might be caused by the lack of financial market development overall in the sample, as have been shown in the descriptive statistics section.

Sadorsky[59] (2011) argues that financial development can increase CO2 emissions for several reasons. Firstly, improvements in FD mean expanding financing channels, allowing enterprises to access capital at lower costs. This can lead to an expansion in production scale, such as renting more equipment or building new production lines, both of which can increase carbon emissions. Furthermore, increased investment through these channels fosters economic

[57] Udeagha and Breitenbach, "Exploring the Moderating Role."

[58] Habiba and Xinbang, "The Impact of Financial Development on CO2 Emissions."

[59] Sadorsky, "Financial Development and Energy Consumption."

growth, which boosts income and capital formation, subsequently raising fossil fuel energy consumption and harming environmental efficiency.

Table 7.
Panel ARDL estimation result.

VARIABLES	DFE		PMG		MG	
	(1)	(2)	(3)	(4)	(5)	(6)
	LR	SR	LR	SR	LR	SR
ec		-0.119***		-0.179*		-0.750***
		(0.038)		(.105)		(0.125)
D.LnFD		-0.072		0.019		0.127
		(0.087)		(0.127)		(0.157)
D.LnGDPC		-0.005		0.152		-0.137
		(0.328)		(0.508)		(0.285)
D.LnRE		-0.103		-0.830**		0.222
		(0.132)		(0.418)		(0.370)
D.LnTrade		0.077		-0.036		-0.054
		(.101)		(0.199)		(0.165)
LnFD	0.409		-0.188		-0.629	
	(0.607)		(0.128)		(0.406)	
LnGDPC	1.864***		1.414***		0.295	
	(0.534)		(0.062)		(0.910)	
LnRE	-0.232		-0.193***		-5.127*	
	(0.499)		(0.043)		(2.771)	
Trade	1.047		0.043		0.868	
	(0.653)		(0.075)		(0.865)	
Constant		0.275		0.966**		18.436***
		0.916		(0.609)		4.636
Observations	180	180	180	180	180	180

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' calculation

Table 8.
Hausman test result

	Prob > chi2	Decision
PMG - MG	0.3318	PMG is preferred
DFE - PMG	0.4956	PMG is preferred
DFE - MG	0.0000	MG is preferred

Source: Authors' calculation

These results reflect the reality that most ASEAN member states have yet to achieve carbon peaks, either through natural processes or through stringent environmental policies. Their carbon emissions are closely linked to economic development, and they have not yet formed robust institutional guarantees for environmental governance. Instead, their focus often lies on political and economic performance rather than environmental protection.[60] For example, many major banks in Asia are still financing coal projects because of lack of regulations, making Indonesia a coal haven (O'Sullivan, 2024).[61]

The findings suggest that financial development through financial institutions has a detrimental impact on the environment. Financial institutions provide significant financial resources at low rates to customers, firms, and households, enabling large purchases that require substantial energy consumption. This observation is consistent with the findings of Çoban and Topcu, who reported that banking activities lead to higher energy consumption, thereby increasing CO2 emissions.[62] Additionally, many financial institutions in ASEAN member states, particularly in middle-income countries, still allocate their funds to environmentally harmful sectors such as mining and palm oil plantations. This exacerbates air pollution and deforestation, reducing carbon sink capacity and worsening environmental conditions.

Table 9.
Panel ARDL PMG method using FM and FI development

	LnFM		**LnFI**	
	LR	**SR**	**LR**	**SR**
ec		-0.061**		-0.163**
		(0.036)		(0.118)
D.Ln(FM/FI)		-0.042		0.170
		(0.058)		(0.374)
D.LnGDPC		0.290		0.130
		(0.506)		(0.551)
D.LnRE		-0.720**		-0.880**
		(0.327)		(0.411)
D.LnTrade		0.058		-0.017
		(0.001)		(0.197)
Ln(FM/FI)	-0.100		1.178***	
	(0.147)		(0.360)	

[60] Ya Wen et al., "Does Governance Impact on the Financial Development-Carbon Dioxide Emissions Nexus in G20 Countries," *PLOS ONE* 17, no. 8 (2022): e0273546. https://doi.org/10.1371/journal.pone.0273546.

[61] O'Sullivan, Will, "Coal Havens - Asia's Biggest Banks Still Open for Coal Business after COP28," *Bank Track News* (Jan 2024). Accessed in https://www.banktrack.org/article/coal_havens at 19/06/2024.

[62] Çoban and Topcu, "The Nexus."

Table 9.
Panel ARDL PMG method using FM and FI development (Continued)

	LnFM		LnFI	
	LR	**SR**	**LR**	**SR**
LnGDPC	2.314***		1.782***	
	(0.337)		(0.162)	
LnRE	-1.848***		-0.154***	
	(0.583)		(0.030)	
LnTrade	0.503		0.643***	
	(0.743)		(0.207)	
Constant		0.208		-0.500
		(0.724)		(0.787)

Source: Authors' calculation

This model also yields significant results for the control variables, predominantly in the long run. GDP per capita is found to have the highest contribution to the increase in carbon emissions, as indicated by the coefficient. This suggests that economic growth, while beneficial in many aspects, tends to exacerbate environmental degradation due to increased industrial activities and energy consumption associated with higher GDP.

Renewable energy usage, on the other hand, is found to reduce emissions both in the long run and the short run. Although the magnitude of this reduction is not as impactful as the increases caused by GDP per capita, it nonetheless highlights the importance of promoting renewable energy sources as a means to mitigate environmental damage. This is consistent with findings from several studies, which emphasise the role of renewable energy in improving environmental quality and reducing carbon footprints.[63]

Trade percentage to GDP also increases emissions, indicating that higher trade volumes, often associated with increased transportation and production activities, contribute to greater carbon emissions. This relationship underscores the environmental costs of globalization and trade expansion, necessitating policies that balance economic benefits with environmental sustainability (Çoban & Topcu, 2013).[64]

The error coefficient in the short run is -0.163, which implies that approximately 16.3% of any deviation from the long-term equilibrium is corrected each period, or it will take approximately six years to reach the long run equilibrium. This finding suggests that, despite short-term fluctuations in variables, the model will return to a stable long-term relationship. This stability

[63] Habiba and Xinbang, "The Impact of Financial Development on CO2 Emissions."
[64] Çoban and Topcu, "The Nexus,"

is crucial for policy implications, as it indicates that efforts to mitigate carbon emissions will have enduring effects even if short-term deviations occur.

V. CONCLUDING REMARKS

V.A. Conclusion

The issue of greenhouse gas emissions remains a critical topic across various contexts, including financial development and its implications. Numerous studies have found that the impact of financial development on greenhouse gas emissions varies significantly depending on the objects, variables, and countries studied. An in-depth analysis in ASEAN countries is essential to understand environmental sustainability within the financial landscape of this particular emerging market.

This paper investigates the impact of financial development on carbon emissions in selected ASEAN countries from 2000 to 2019 using panel data ARDL models. The financial development indicator is disaggregated into financial markets and financial institutions, providing a more nuanced understanding of its multidimensional nature. Several key findings emerge from the inferential analysis.

Firstly, there is no conclusive evidence that overall financial development affects carbon emissions in the sample, either in the short run and the long run. However, when disaggregating the financial development indicator, the analysis reveals that financial institutions significantly increase carbon emissions in the long run. The rationale behind this effect is that the development in the financial institution sector drives energy demand, business and industrial expansion, and unsustainable capital formations, which in turn harm the environment through emissions from such activities. These findings also reflect the underdevelopment of the financial sector in the sampled countries.

The findings underscore the importance of integrating sustainability principles into overall development strategies. Financial institutions must not only expand but also target their investment towards more sustainable projects. Emphasizing financing for renewable energy sources could also help alleviate emissions. Policymakers in developing countries should focus on strengthening financial markets and incorporating environmental considerations into financial development strategies to achieve sustainable growth. Prioritizing renewable energy investments and improving financial market maturity can help balance economic and environmental objectives, ensuring long-term sustainable development.

This study has some limitations, despite the generally satisfactory results. Data availability for all ASEAN countries is limited, resulting in a relatively small cross-sectional size and sample size, which may not capture the full spectrum of facts in ASEAN. Additionally, this paper only considers carbon dioxide (CO_2) emissions from fossil fuels and industries. Future research could benefit from disaggregating emissions by emitter (e.g., household, industry, land use change) and including other greenhouse gases (e.g., sulfur, methane, CFCs) to provide more comprehensive insights. Expanding the analysis to include more groups of countries and employing comparative estimations between developing and developed economies could enhance the understanding of these dynamics. Furthermore, considering the quality of institutions and governance could help to identify more specific policy recommendations from existing practices.

V.B. Policy Recommendations

In response to the result of this research, Bank Indonesia ("BI") stands at a crucial juncture where its policies can significantly impact both the financial landscape and environmental sustainability. With the advent of Bank Indonesia Regulation Number 11, Year 2023, regarding Macroprudential Liquidity Incentive Policies and the exploration of Central Bank Digital Currency (CBDC),[65] BI has a unique opportunity to integrate environmental concerns into its monetary policies and financial system. Recognizing the global imperative to address climate change, BI has an opportunity to align its monetary and financial strategies with sustainability goals. This involves adopting measures that not only promote financial sector development but also incentivise investments in environmentally sustainable projects. By integrating these dual objectives into its policies, BI can play a proactive role in steering Indonesia towards a low-carbon economy while ensuring long-term economic stability and resilience. Now, let's proceed with detailing the specific policy recommendations that BI could adopt to achieve these objectives:

- Promotion of Green Bonds: BI should actively promote the issuance of green bonds to fund sustainable projects, mirroring successful initiatives in Sweden[66] and Singapore.[67] This can be achieved through tax incentives and

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[65] Burhan, Fahmi Ahmad, "Bank Indonesia Jelaskan Perkembangkan Rupiah Digital, Ungkap 86% Bank Sentral Eksplorasi CBDC," Bisnis.com (December 6, 2023) https://finansial.bisnis.com/read/20231206/11/1721541/bank-indonesia-jelaskan-perkembangkan-rupiah-digital-ungkap-86-bank-sentral-eksplorasi-cbdc.

[66] Vikniswari Vija Kumaran et al., "Sustainability in ASEAN: The Roles of Financial Development towards Climate Change," *Asian Journal of Economics and Empirical Research* 8, no. 1 (2021): 1–9. https://doi.org/10.20448/journal.501.2021.81.1.9

[67] R.S. Hewage et al., "Impact of Economic Growth, Financial Development and Technological Advancements on Carbon Emissions: Evidence from ASEAN Countries. In *IOP Conference Series: Earth and Environmental Science* 1102, no. 1 (2022):012040.

regulatory support, fostering a robust market for investments in renewable energy and green infrastructure. By incentivizing their issuance, BI can channel investments into sectors crucial for reducing Indonesia's carbon footprint, such as renewable energy, energy efficiency, and sustainable infrastructure development. This not only supports economic growth but also aligns with global sustainability goals.

- Implementation of Carbon Pricing Mechanisms: BI should explore the implementation of a carbon pricing mechanism similar to the EU Emissions Trading System[68] or Malaysia's Carbon Pricing Mechanism.[69] This approach sets a price on carbon emissions, incentivizing industries to adopt cleaner technologies and reduce their environmental impact. By establishing a clear price signal, BI can drive investments towards sustainable practices and technologies, thereby fostering a more resilient and environmentally responsible economy in Indonesia.
- Establishment of a Green Finance Task Force: BI should establish a Green Finance Task Force, akin to China's Green Finance Committee, to promote green financial products and encourage banks to offer loans for environmentally friendly projects.[70] The recommendation to establish a Green Finance Task Force in Indonesia aligns with the objectives of the Financial Services Authority (OJK) (2022) in promoting green finance through its green taxonomy. The task force can provide guidance, standards, and incentives for green finance, similar to OJK's green taxonomy, which categorises and regulates green financial products to ensure they align with environmental goals and contribute to sustainable development. This initiative can facilitate capital flows towards projects that contribute positively to environmental goals, enhancing financial sector stability and supporting Indonesia's transition towards a low-carbon economy.
- Integration of SDGs into Monetary and Financial Policies: BI should integrate the Sustainable Development Goals (SDGs) into its monetary and financial policies, following the example of ASEAN and Indonesia.[71] (Hewag, Othman, Pyeman, and Samad, 2022). This involves aligning financial sector development strategies with SDG targets related to climate action, sustainable infrastructure, and clean energy. By embedding SDG principles into financial regulation and supervision, BI can guide financial institutions towards investments that support sustainable development, thus contributing to Indonesia's broader environmental and social objectives.

[68] Kumaran et al., "Sustainability in ASEAN."
[69] Hewage et al., "Impact of Economic Growth."
[70] Kumaran et al., "Sustainability in ASEAN."
[71] Hewage et al., "Impact of Economic Growth."

By implementing these recommendations, BI can play a pivotal role in promoting both financial stability and environmental sustainability, thus contributing to a more resilient and responsible economic future.

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