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Carbon Emissions and Economic Drivers in Kalimantan: New Evidence from ARDL Bounds Testing

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ABSTRACT

This study investigates how deforestation, economic growth, and trade openness affect carbon emissions in Kalimantan, Indonesian by using the Environmental Kuznets Curve (EKC) framework. The present study applies the ARDL bounds testing approach with quarterly data spanning from 2015Q1 to 2024Q4. The results show that all three selected parameters are significantly influence carbon emissions in Kalimantan. Deforestation increases emissions, while higher income and greater trade openness reduce carbon emissions. The findings show an inverted U-shaped relationship between income, trade openness, and carbon emissions, confirming the EKC hypothesis is valid in the present study. Environmental degradation rises in the early growth phase but declines once income reached a certain threshold level. The study also finds that cleaner energy and foreign direct investment (FDI) are crucial for improving environmental quality. Trade openness attracts FDI, boosts productivity, and supports advanced technology shared by the importing countries. The empirical outcomes suggest that the government can promote adoption of green technology, sustainable land use, and international trade cooperation between the countries. Strengthening global collaboration helps accelerate technology transfer and reduce environmental harm to the nation. These efforts align with the Sustainable Development Goals (SDGs) to combat the climate change for the long-term sustainability growth. This paper contributes to the limited literature on how deforestation, income and trade openness in reducing carbon emissions in Kalimantan.

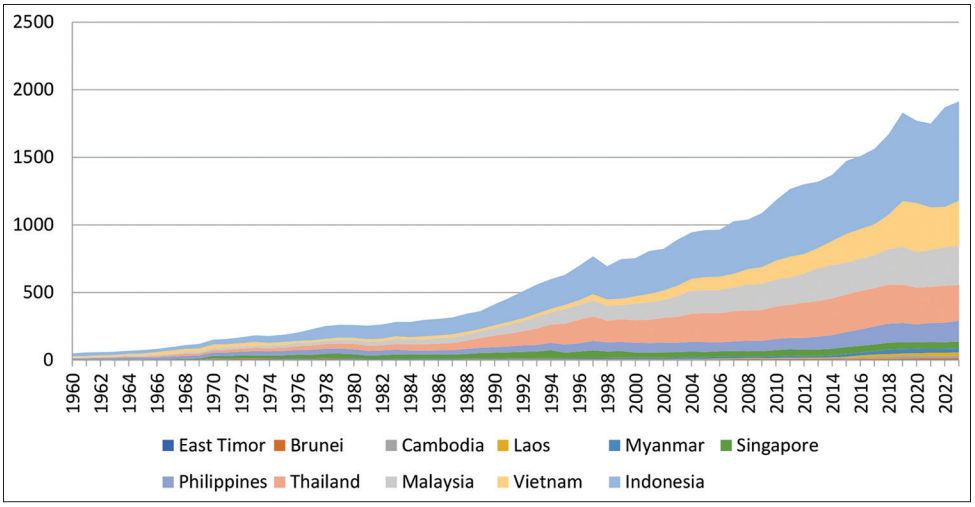
Keywords: ARDL, Carbon emissions, Deforestation, EKC, Green energy, Kalimantan
JEL Classifications: C32, F41, Q43

1. INTRODUCTION

Climate change has become one of the most pressing global challenges, with carbon emissions recognized as the primary driver of global warming and environmental degradation. Addressing this challenge is essential for advancing the United Nations Sustainable Development Goals (SDGs), which emphasize fostering sustainable economic growth, safeguarding the environment, and enhancing the welfare of both current and future generations. Developing countries, particularly those with rich natural resources, face the dual challenge of sustaining economic growth while minimizing environmental damage.

Figure 1 shows that prior to the Industrial Revolution, carbon emissions were minimal, below 9.3 million tonnes (Our World in Data by Ritchie and Roser, 2020). Their growth remained relatively modest until the mid-20th century. In 1950, global CO2 emissions stood at around 5.9 billion tonnes. By 1990, however, they had nearly quadrupled to over 20 billion tonnes and they have since risen sharply, reaching 37.8 billion tonnes in 2023. Among greenhouse gas emission contributors, the Asia region has been the largest emitter, contributing nearly 60% of world carbon emissions in 2023. Among the subregions, Southeast Asia generated 1.9 billion tonnes of carbon emissions in 2023. The largest carbon emission producer in this subregion was Indonesia (733.2 million tonnes, 38.3%), followed by Vietnam

Figure 1: Carbon Emissions in East Asian Countries (Million Tonnes), 1960-2023



Source: Our World in Data by Ritchie and Roser (2020)

(334.7 million tonnes, 17.5%), Malaysia (288.8 million tonnes, 15.1%), Thailand (264.4 million tonnes, 13.8%), the Philippines (154.6 million tonnes, 8.1%), Singapore (49.3 million tonnes, 2.6%), and other remaining countries (Our World in Data by Ritchie and Roser, 2020).

Unlike in most countries, where energy use is the largest contributor to carbon emissions, land-use change and forestry (LUCF), especially deforestation, peatland degradation, and forest fires, play a dominant role in greenhouse gas emissions in Indonesia (Saputro, 2025). In the 1960s, Indonesia emitted around 20 million tonnes of carbon emissions annually. This figure started to increase rapidly in the 1980s to hundreds of million tonnes of CO_2 and reached 700 million tonnes in recent years (Our World in Data by Ritchie and Roser, 2020). Without intervention, by 2030, Indonesia's emissions could be nearly double the levels recorded in 2010 (445.8 million tonnes of carbon emissions). This significant upward trend in carbon emissions in Indonesia is mainly due to growing population, industrialization, and urbanization.

Consequently, pursuing climate action is not merely an obligation for developed countries but also a strategic necessity for developing nations to ensure the protection of their natural resources, food security, and societal welfare. Within the Global South, Indonesia holds a critical strategic position in the global climate architecture. Endowed with abundant natural resources, including the most extensive tropical peatlands in the Asia-Pacific region, vast forest cover, and considerable renewable energy capacity, Indonesia is instrumental in guiding the world toward sustainability and climate resilience.

In 2019, the President of Indonesia announced that the nation's capital would be relocated from Jakarta to the eastern part of the Kalimantan region. The decision is rooted in a combination of environmental (land subsidence, frequent flooding, and air pollution in Jakarta), economic, demographic (overpopulation in Jakarta and the need to stimulate economic growth in other regions), and geographic considerations (a safer location with lower risks of natural disasters in Kalimantan) that have long challenged Indonesia's sustainable development agenda. In 2024, Jakarta's population reached approximately 11.4 million, with a population density of about 17,233 people per square kilometre (World Population Review, 2025). The combination of severe land subsidence and extremely high population density has created an urgent need for the relocation of the national capital to Kalimantan, where the government envisions a more balanced, resilient, and sustainable model of urban development.

According to McEwan and Skinner (2024), construction activities in the new capital are expected to grow by an average of 8%/year over the 4 years to 2028. Rapid industrial and infrastructural development is expected to reshape economic growth patterns, population distribution, and industrial activities in the region. However, it also poses serious environmental risks, particularly large-scale deforestation and rising carbon emissions. In between 2018 and 2021, Forest Watch Indonesia (2023) stated that approximately 18,000 hectares of the forest were cleared to build the new capital of Indonesia. Additionally, another 1,663 hectares of the forest had been destroyed by mid of 2023. It is estimated that 10 to 12 million tonnes of CO_2 released into the atmosphere due to this deforestation. Therefore, assessing the impact of deforestation on carbon emissions in Kalimantan is essential to ensure the region's long-term sustainable development.

Kalimantan is located on the land of Borneo, one of the world's most biodiverse regions. It is also one of the most regions vulnerable to rapid environmental degradation in the world. Over the past two decades, extensive forest conversion for agriculture, mining, and infrastructure development has driven significant land loss across the five provinces of Kalimantan. Deforestation and rapid development of the economic activities directly and indirectly leading to climate change and rise in carbon emissions.

In 2024, nearly half of the deforestation in Indonesia were contributed by Kalimantan region. Mongabay (2025) forecasted that about 129,896 hectares of forest were cleared in 2024, an increase of 4% compared to the previous year. Agriculture is one of the key sectors in Indonesia, and palm oil plantations are among

the main factors contributing to deforestation. The report showed that Kalimantan alone represented 72% of Indonesia's industrial palm oil-driven deforestation between 2018 and 2022 (Stockholm Environment Institute, 2023).

Meantime, Kalimantan serves as a key region for economic growth in Indonesia. The gross domestic product (GDP) of Indonesia has grown progressively mainly fuelled by resource-based industries and international trade. Trade openness, commonly assessed through the proportion of exports and imports to GDP, has been a major catalyst for economic growth. However, this openness also introduces potential risks to long-term environmental sustainability. These dynamics underscore the difficulty of reconciling economic expansion with environmental sustainability, especially in the context of Indonesia's pledge to lower greenhouse gas emissions through its Nationally Determined Contributions (NDCs).

This study examines how land loss, GDP, and trade openness influence carbon emissions in Kalimantan using the Autoregressive Distributed Lag (ARDL) model within the Environmental Kuznets Curve (EKC) framework. The findings aim to show whether Kalimantan follows the expected EKC pattern or diverges because of its land-use-driven emissions, as well as whether trade acts more as a driver of ecological damage or a pathway toward sustainability.

The remainder of this paper is structured as follows. Section 2 reviews the theoretical framework and relevant literature. Section 3 describes the data and research methodology employed in this study. Section 4 presents and discusses the empirical results. Finally, Section 5 concludes with policy implications and suggestions for future research.

2. LITERATURE REVIEW

The EKC framework commonly serves to analyze the link between economic growth and environmental degradation, suggesting that income and pollution follow an inverted U-shaped trajectory (Grossman & Krueger, 1991). It suggests that at low levels of development, economic expansion tends to increase emissions due to reliance on resource extraction and polluting industries (scale effect). However, as income rises, societies often adopt cleaner technologies, enforce stricter environmental regulations, and shift toward less carbon-intensive production (technique and composition effects), thereby reducing emissions (Dinda, 2004).

Malahayati (2023) employed the EKC framework together with the ARDL model to examine the case of Indonesia. She examined the causal relationship between forest management and economic growth and identified an inverted U-shaped relationship between GDP per capita and deforestation in Indonesia during the period 1970-2018. Other studies that have utilized EKC theory include Effendi et al. (2024), Zafar et al. (2019), Culas (2007) and Panayotou (1993). Both Culas (2007) and Panayotou (1993) determined that forest cover often declines during the early stages of development, but that it has the potential to recover as governance strengthens, and economies reach higher levels of maturity.

Zafar et al. (2019) found evidence supporting the EKC in several emerging economies, whereas Stern (2004) argued that many countries are unable to reach the turning point because of a persistent reliance on fossil fuels. Al-Mulali et al. (2015) partially support the EKC hypothesis because deforestation adds complexity to the relationship between economic growth and environmental sustainability. Therefore, this complexity makes it more challenging to achieve a balance between development and ecological preservation in Indonesia. Furthermore, Effendi et al. (2024) stated that EKC hypothesis may not be valid, as the economic growth remains carbon intensive unless the industries adopt green energy and implement sustainable land-use policies.

Globally, deforestation is one of the key contributors to carbon emissions, particularly in tropical areas (Harris et al., 2021). According to the Forest Transition Theory introduced by Mather (1992), the environmental impacts vary across different stages of economic development with inverted U-shaped pattern. The initial stage of economic growth poses a huge scale of deforestation due to extensive industrial expansion and urbanization. The environmental quality begins to improve once the income reaches a certain threshold level that driven by technological advancements, stricter environmental regulations, and greater demand of cleaner environment. Kumaran et al. (2024) mentioned that technological innovation can help to mitigate adverse environmental impacts. They also suggested that the environmental quality in Indonesia can be improved through the effective forest management and the implementation of advanced technologies.

In terms of trade openness, Wang et al. (2024) found that it can have positive or negative influence on country's carbon emissions. They used panel data from 30 OECD and G20 countries and figured out that the rise in carbon emissions is generally linked with higher levels of trade openness. Consistently, Barkat et al. (2025) and Wang et al. (2023) figured out that trade openness positively associated with carbon emissions because it tends to promote large scale of industrialization. In contrast, Wang et al. (2024) found that trade openness can reduce the carbon emissions with the support of advance technologies and thus increased the productivity of the industries.

The impact of income levels on carbon emissions can be mixed.

Li et al. (2025) found that income levels influence the carbon emissions differently across different provinces in China. They detected that Beijing, Chongqing and Shanghai successfully reduced carbon emissions while maintaining economic output. However, Xinjiang and Shanxi produced higher carbon emissions when producing same level of output compared with other provinces, as these provinces rely heavily on carbon intensive industries. An adverse relationship between income levels and trade openness has been detected in the study of Barkat et al. (2025). They pointed out that rising income levels can help to reduce carbon emissions, which in line with the EKC hypothesis. Similarly, Barkat et al. (2025) validated the inverted U-shaped relationship of EKC hypothesis and found that higher income levels significantly reduce carbon emissions in the long term among OECD countries.

Pata et al. (2025) proposed the Renewable Kuznets Curve (RKC) hypothesis to examine whether income level is the prerequisite for the validity of the EKC. Their finding confirmed that the RKC is indeed a necessary condition for the validity of EKC hypothesis. They imply that higher income levels encourage the adoption of renewable and green energy, thereby contributing to lower carbon emissions. In sum, income level is an important factor influence the carbon emissions of a country.

3. RESEARCH METHODOLOGY

This study utilizes time series econometric framework using quarterly data covering the period from 2015Q1 to 2024Q4. This paper examines the long-run dynamic relationships between deforestation, economic growth (GDP), trade openness, and carbon emissions in Kalimantan using the EViews software. This ARDL model proposed by Pesaran et al. (2001) is employed to analyze the causal relationships between the selected variables and carbon emissions in Kalimantan.

Due to its numerous advantages, the ARDL technique has been widely applied across various fields of study. One of the key advancements of this approach is its ability to accommodate variables integrated at *I*(0), *I*(1), or a mixture of both. However, any *I*(2) variable is not permitted in the model. Other methods such as Engle-Granger or Johansen approaches required all variables to be cointegrated at the same order. Therefore, the ARDL technique has been widely employed by the researchers including Al-Kasasbeh et al. (2025), Hu and Puah (2025), Kumaran et al. (2024) and Jong et al. (2022) in their studies.

Additionally, unlike other estimation methods that require a large sample size, the ARDL technique is applicable for studies with relatively small sample sizes. The present study utilized quarterly data spanning from 2015Q1 to 2024Q4, comprising a total of 40 observations which makes it suitable for the application of ARDL technique. In addition, ARDL does not require pre-testing for unit roots to determine the stationarity levels of the variables (Pesaran et al., 2001). For these reasons, this study adopts the ARDL approach.

Based on the EKC theory, the model functions as follows:

$$CO_2 = f(TL + GDP + TO) \quad (1)$$

Table 1 presents a description of the variables used in this study.

Prior conducting the long-run estimation, we transform all variables into logarithm form for estimation purposes, as seen in Equation 2:

$$\Delta LCO_2 = \beta_0 + \beta_1 LTL + \beta_2 LGDP + \beta_4 LTO + \varepsilon_t \quad (2)$$

Although testing for stationarity is not mandatory in the ARDL model, this study still employs unit root tests to examine the stationarity of the variables. This consideration is essential because ARDL technique is not suitable to be applied if any variable is integrated at the *I*(2) level. Thus, we applied the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to verify that none of the variables are integrated at the *I*(2) level before proceeding with the long-run analysis using the ARDL approach.

The following equation shows the ARDL model for the purpose of estimation for the present study:

$$\Delta LCO_2 = \beta_1 + \beta_2 \sum_{i=1}^{p} \Delta LCO_{2t} + \beta_3 \sum_{i=0}^{q_1} \Delta LTL_t + \beta_4 \sum_{i=0}^{q2} \Delta LGDP_t + \beta_5 \sum_{i=0}^{q3} \Delta LTO_t + \lambda_1 \Delta LCO_{2t-1} + \lambda_2 \Delta LTL_{t-1} + \lambda_3 \Delta LGDP_{t-1} + \lambda_4 \Delta LTO_{t-1} + \varnothing ECT_{t-1} + \varepsilon_t \quad (3)$$

The coefficient of the Error Correction Term (ECT) should lie between −1 and 0, be negative, and be statistically significant, indicating that any shocks will eventually return to the long-run equilibrium within a certain period. Furthermore, diagnostic tests such as the Breusch-Godfrey Lagrange Multiplier (LM) test, Breusch-Pagan-Godfrey (BPG) test, heteroskedasticity test, Ramsey RESET test, and the CUSUM and CUSUM of Squares tests are essential to validate the model's goodness of fit.

4. RESULTS AND DISCUSSION

To confirm that none of the variables in the model are integrated at the *I*(2) level, this study applies the ADF and PP unit root tests to determine the stationarity of the series. Table 2 tabulates the ADF and PP unit root tests results and shows that all variables are stationary at the *I*(0) or *I*(1) levels, while none is stationary at *I*(2) level, signifying that the ARDL technique is applicable to this

Table 1: Variables description

Variable	Description	Source
CO_2	Carbon emissions (Million tonnes)	GFW Kalimantan Dashboard
TL	Deforestation (Million hectares of tree loss)	GFW Kalimantan Dashboard
GDP	Gross domestic product (Millions of USD)	World Bank
TO	Trade openness (Export+Import/GDP)	Statistics Indonesia and World Bank

Table 2: Unit root tests results

Variable	Level		First different	
	Constant	Trend	Constant	Trend
Augmented Dickey-Fuller				
LCO_2	−1.89 (1)	−2.33 (1)	−3.28 (0)**	−3.30 (0)*
LTL	−1.98 (1)	−2.29 (1)	−3.28 (0)**	−3.31 (0)*
LGDP	−0.58 (5)	−3.46 (5)*	−2.65 (4)*	−4.43 (3)***
LTO	−2.48 (0)	−3.08 (0)	−6.49 (0)***	−6.60 (0)***
Phillips-Perron				
LCO_2	−1.44 (3)	−1.53 (3)	−3.34 (1)**	−3.36 (1)*
LTL	−1.48 (3)	−1.49 (3)	−3.36 (1)**	−3.38 (1)*
LGDP	−0.52 (3)	−2.40 (3)	−3.67 (3)***	−3.59 (3)**
LTO	−2.54 (1)	−3.08 (0)	−6.50 (2)***	−6.62 (3)***

Asterisks (***), (**) and (*) indicate statistical significance at the 1%, 5%, and 10% levels, respectively

study. After identifying the levels of stationarity of the variables, we proceed to the long-run estimation using the ARDL technique. Table 4 reports the long-run estimation results, indicating that all selected variables have a significant impact on carbon emissions in Kalimantan.

The deforestation (LTL) of Kalimantan is identified as positively impacting carbon emissions in this region. The finding reveals that 1% deforestation will increase carbon emissions by 1.03% in Kalimantan, reflecting the strong carbon sensitivity of land-use change in Kalimantan. Sugiarto et al. (2024) conducted a study to examine the impact of deforestation on CO_2 emissions in Kubu Raya District, West Kalimantan Province. They also found that the positive relationship between deforestation and carbon emissions in West Kalimantan of Indonesia.

In general, GDP is positively associated with carbon emissions. However, this study finds an inverse relationship between GDP and carbon emissions in the case of Kalimantan. The result shows that GDP is a significant variable in reducing carbon emissions in Kalimantan. A 1% increase in GDP of Kalimantan will reduce carbon emissions by 0.39%. This suggests that as income level rises, it will improve the environmental quality in Kalimantan. This supports the inverted U-shaped relationship between economic growth and carbon emissions in Kalimantan. This outcome is in line with the findings of Zou et al. (2025), Ali et al. (2024) and Le et al. (2020) that higher income contribute to lower carbon emissions. The rise in income also indicates that the government can allocate more resources for environmental protection such as subsidies for renewable energy, conservation of forest, carbon taxes, and other clean energy policy in order to mitigate the adverse impact of carbon emissions. Low carbon emissions is one of the main principles in the relocation of the new capital in Indonesia. According to the Nusantara Capital Authority (2023), the new capital of Indonesia located at the Kalimantan region will install a 50-megawatt solar power plant capable of generating approximately 92.8 gigawatt-hours of renewable energy annually, thereby reducing carbon dioxide emissions by about 194.8 thousand tonnes each year. Therefore, GDP growth in Kalimantan can help reduce carbon emissions through the implementation of cleaner energy technologies

Additionally, LTO significantly reduces carbon emissions in Kalimantan. The finding implies that a 1% increase in trade openness lessens carbon emissions by 0.15%. The result aligns with the evidence provided by Wang et al. (2024) and Wang and Zhang (2021), indicating that trade openness plays a mitigating role in carbon emissions, particularly in upper-middle-income countries. Kumaran et al. (2024) stated that stronger forest management and advanced technologies can accelerate Indonesia's path toward net-zero emissions. Similarly, Bakri et al. (2025) found that the technology effect implies that trade openness can enhance environmental quality by promoting advanced production techniques, technological innovation, and greater energy efficiency. These mechanisms are highly relevant to Kalimantan's transition, where the relocation of the new capital is expected to expand trade liberalization and attract foreign investment to support sustainable industrial upgrading while reducing dependence on carbon-intensive production systems. The ECT is significant, less than one, and negative with a value of −0.58, indicating that the model adjusts by 58% each quarter following an economic shock. This result suggests that the model will return to its long-run equilibrium within approximately two quarters after experiencing a shock.

Table 3: ARDL Bound Test Results

F-statistics Value=3.56		
Significance Level	***I* (0)**	***I* (1)**
10%	2.60	3.45
5%	3.10	4.09
1%	4.31	5.54

Table 4: ARDL long-run results and diagnostic test results

Variable	Coefficient	Std. Error	*t*-statistic	Prob.
C	11.30	0.46	24.45	0.00
LTL	1.03	0.02	60.02	0.00
LGDP	−0.39	0.04	−10.61	0.07
LTO	−0.15	0.08	−1.84	0.00
ECT	−0.58	0.12	−4.69	0.00
Diagnostic tests				
Jarque-Bera Test	3.77 (0.15)			
BG-LM Test [2]	0.29 (0.75)			
ARCH [1]	0.55 (0.46)			
Ramsey RESET [1]	2.36 (0.14)			

Figure 2: CUSUM Test Result

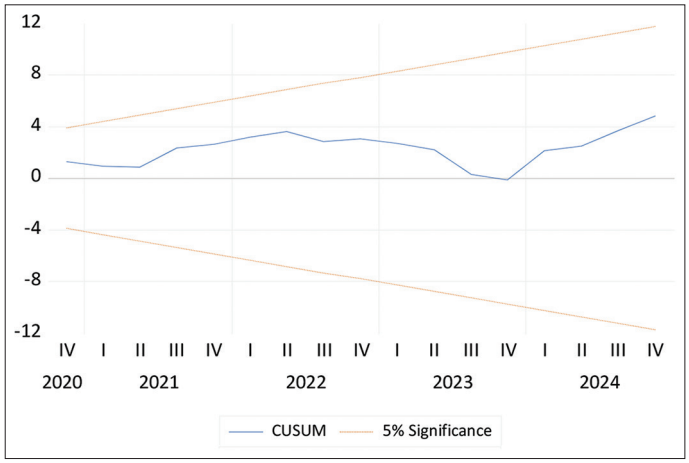
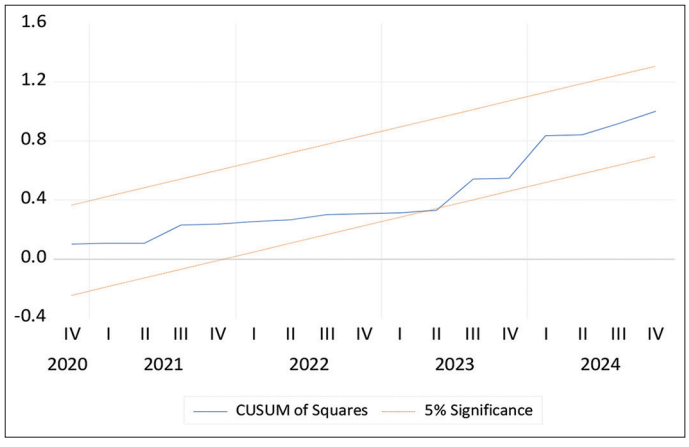


Figure 3: CUSUM of Square Test Result



To ensure the validity of the model, this study has carried out diagnostic tests (Table 4). The results show that the model is normally distributed based on the Jarque-Bera Normality test, indicating that the model does not violate the assumption of Gaussian errors. Furthermore, the Breusch-Godfrey Serial Correlation LM test is used to test whether there is any existence of serial correlation issue in the model. The finding implies that the P-value is not significant and thus there is no serial correlation problem in the model. In addition, the Heteroskedasticity and Ramsey RESET tests also reveal that the model does not suffer from variance instability and misspecification problems. Lastly, Figures 2 and 3 illustrate the CUSUM and CUSUM of Square test results, respectively, showing the curve falls within the 5% critical regions and suggesting that the model is stable within the period of the study.

5. CONCLUSION

Indonesia is the largest carbon emissions emitter in East Asia and deforestation is one of the key contributors to its carbon emissions. The subregion of Kalimantan is one of the major contributors to deforestation in the country due to agricultural activities such as oil palm tree plantation. This critical issue has motivated us to investigate the impact of deforestation, economic growth (GDP), and trade openness on carbon emissions in Kalimantan. This study utilized quarterly time-series data spanning from 2015Q1 to 2024Q4 to scrutinize the dynamic relationship between carbon emissions and its economics drivers in Kalimantan. Due to the small sample size of the study, and because the ADF and PP unit root tests found a mixture of $I(0)$ and $I(1)$ variables, we employed the ARDL approach to capture the long-run relationships among the variables.

In the present study, deforestation is one of the key variables in our estimation model. The empirical outcomes revealed that deforestation can foster carbon emissions in Kalimantan. Deforestation in Kalimantan, for example, large-scale land clearing for such as ends as oil palm tree plantation, is a key driver of rising carbon emissions. The results showed that a 1% rise in deforestation will increase carbon emissions in Kalimantan by 1.03%. Therefore, stricter forest protection laws and the promotion of sustainable land use practices, in line with the SDGs, are important to combat climate change. In addition, economic incentives and community participation are essential to balance conservation goals with local development needs.

The findings signify that economic growth is a significant factor in reducing carbon emissions in Kalimantan. A 1% rise in economic growth will reduce carbon emissions by 0.39%. This outcome validated the inverted U-shaped curve of the EKC theory that suggests that economic improvement will lead to better environmental quality through technological advancements and shifts to cleaner technologies, thus minimizing carbon emissions from economic activities. Furthermore, increasing public awareness and societal demand for improved environmental quality, reflected in preferences for cleaner air, the adoption of advanced technologies, and the enforcement of stricter regulations, are expected to continuously play a significant role in mitigating carbon emissions in Kalimantan.

The present study found that trade openness plays an important role in reducing carbon emissions in Kalimantan. The results of this study indicate that the relationship between trade openness and carbon emissions is statistically significant and negative, suggesting that greater integration into international markets may facilitate the adoption of cleaner technologies, promote efficiency in production processes, and encourage foreign direct investment in environmentally friendly industries. The ARDL estimation shows that a 1% increase in trade openness will decrease carbon emissions by 0.15% in Kalimantan. Trade integration between countries can improve productivity by providing access to cleaner technologies and energy efficient machinery to reduce carbon emissions. The government can also diversify their economic structure to promote higher value and less carbon-intensive industries such as eco-tourism and the agro-processing of agricultural products.

In sum, all the selected variables which are deforestation, economic growth, and trade openness significantly affect carbon emissions in Kalimantan. Deforestation promotes carbon emissions whereas both economic growth and trade openness reduce the carbon emissions in Kalimantan. Therefore, the continuing efforts of the government are crucial to ensure existing policies such as the Long-Term Strategy for Low Carbon and Climate Resilience (LTS-LCCR) and the peatland restoration programs by the Peatland Restoration Agency (BRG) can be carried out continuously for carbon sequestration, biodiversity protection, and long-term sustainability growth.

Additionally, the government can further enhance forest protection by strengthening enforcement mechanisms through satellite monitoring. Besides that, by imposing stricter penalties for illegal clearing, and promoting transparent land-use governance also can help to reduce the carbon emissions. Furthermore, large scale reforestation and peatland restoration can as complementarily measure to reduce carbon emissions by strengthening the natural carbon sequestration capacity of Kalimantan's ecosystems. Besides that, the government can lower trade tariffs between the countries to enhance the import of green technologies and goods such as solar panels.

Economic growth generally leads to higher carbon emissions. Interestingly, this study figured out that economic growth can play a vital role in reducing carbon emissions in Kalimantan. Thus, the government can provide incentives such as tax reductions for companies that minimize carbon emissions during production. Moreover, mechanisms like monetary schemes for small enterprises can motivate them to utilize green technologies.

In summary, Kalimantan needs to adopt a dual strategy to reduce carbon emissions. First, the government must halt deforestation which directly contributes to rising emissions. Second, it should harness the positive potential of economic growth and trade openness to promote technology transfer, attract foreign direct investment, and encourage sustainable production practices. Future studies could further explore additional factors influencing carbon emissions in Kalimantan. Moreover, extending the timeframe of analysis would provide a more detailed and comprehensive understanding of long-term emission trends in the region.

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