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Promoting Sustainable Banking: The Role of Private Credit in Reducing CO_2 Emissions in Indonesia

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ABSTRACT

The banking sector plays a pivotal role in Indonesia's economic growth, making a substantial contribution to GDP while also influencing environmental sustainability through CO_2 emissions. Despite numerous studies examining the relationship between banking development and environmental outcomes, there is a lack of research investigating the precise impact of banking activities, such as private credit distribution, on CO_2 emissions. This study aims to address this gap by examining the interactions between deposit money banks (DMB), private credit (PC), gross domestic product (GDP), renewable energy usage, and CO_2 emissions in Indonesia. The analysis employs an autoregressive distributed lag (ARDL) model to identify a significant negative relationship between GDP and CO_2 emissions, challenging the conventional assumption that economic expansion inevitably leads to higher pollution levels. Furthermore, while DMB activities indicate a negative short-term impact on CO_2 emissions, private credit has a positive short-term correlation, indicating inefficiencies in directing credit towards environmentally sustainable initiatives. These findings illustrate the challenging role of banking in influencing environmental outcomes and emphasize the necessity for policies that facilitate green financing and investments in renewable energy. Banks can play a pivotal role in supporting sustainable development by promoting sustainability in their financial practices.

Keywords: Sustainable Banking, CO_2 Emissions, Private Credit, Economic Growth, Renewable Energy, Environmental Sustainability, Green Financing
JEL Classifications: G21, Q53, Q56, O13, C32

1. INTRODUCTION

The banking sector is a fundamental driver of economic activities, significantly contributing to Indonesia's gross domestic product (GDP). As of 2024, banking institutions in Indonesia manage assets amounting to USD 723 billion (Statista, 2024). Additionally, in 2022, the financial sector contributed 809.36 trillion Indonesian rupiahs to the national GDP (Statista, 2024). Despite these achievements, the rapid growth of the banking sector brings challenges, particularly concerning its environmental impact. Banking operations indirectly affect the environment by financing activities such as industrial expansion, infrastructure development, and natural resource exploitation, which can lead to deforestation, biodiversity loss, and pollution (Baloch et al., 2019; Johari et al., 2022a). These effects highlight the urgent need for sustainable practices within the financial industry. By adopting environmental, social, and governance (ESG) principles, promoting green financial products, and investing in renewable energy, banks can play a pivotal role in mitigating environmental degradation.

A useful framework for analyzing the relationship between economic growth and environmental quality is the Environmental

Kuznets Curve (EKC) theory. This theory posits that pollution initially rises as economies grow but eventually declines when they reach a certain level of income and development (Yilanci et al., 2023; Abbas, et al., 2021). However, the EKC theory is a simplification and may not fully capture the complex relationship between economic growth and environmental impact in all contexts. In Indonesia, the growth of the banking sector has driven energy-intensive activities, contributing to increased CO_2 emissions. While the EKC theory suggests a potential turning point where economic growth and environmental preservation coexist, the speed and extent to which this turning point occurs can be significantly influenced by the actions of the banking sector. To achieve this balance, banks must support renewable energy projects and environmentally friendly technologies. Such measures align with the EKC's premise of reducing emissions as income levels increase, paving the way for sustainable economic progress.

Previous research has investigated the relationship between financial sector development and CO_2 emissions, however many studies overlook the direct environmental impact of banking activities. For instance, Zhang (2021) found that banking sector growth in China positively correlates with higher CO_2 emissions due to increased financing of industrial and infrastructure projects. In contrast, Shahbaz et al. (2021) reported that financial development in India contributed to improved air quality by enabling investments in cleaner technologies. Similarly, Li et al. (2021) suggest that financial sector advancements can reduce emissions by facilitating renewable energy adoption. These contrasting findings underscore the complexity of this relationship, which varies depending on factors such as a country's industrial structure, energy policies, and the extent of financial sector reforms. Additionally, the specific role of banking activities within the financial sector can vary significantly across countries.

This study addresses these gaps by examining the dynamic relationship between banking development, GDP growth, renewable energy consumption (REC), and CO_2 emissions in Indonesia. The analysis uses the Autoregressive Distributed Lag (ARDL) model, which is well-suited for examining short- and long-term relationships between variables, especially in datasets with mixed integration orders. By employing this approach, the study provides a comprehensive understanding of how banking activities influence environmental outcomes in Indonesia. Furthermore, by focusing on the Indonesian context, this study contributes to the literature by examining the relationship between banking and environmental impact in a specific emerging market economy with unique characteristics. The findings are intended to guide policymakers in formulating strategies that leverage financial sector growth to support sustainable development. Specifically, the study emphasizes the need for banks to finance renewable energy projects, adopt ESG criteria, and align their operations with national sustainability goals.

This paper is organized as follows: Section 2 critically reviews existing literature on the nexus between banking development and CO_2 emissions, identifying key gaps and limitations. Section 3 outlines the ARDL methodology and explains its relevance to this research. Section 4 presents the results and their implications, while Section 5 concludes with strategic recommendations for balancing economic growth with environmental sustainability in Indonesia.

2. LITERATURE REVIEW

2.1. Environmental Kuznets Curve (EKC) Theory

Grossman and Krueger (1991) introduced the Environmental Kuznets Curve (EKC) hypothesis to explore the complex relationship between economic development, energy consumption, and CO_2 emissions. Their seminal work challenged the conventional notion of a straightforward, linear relationship between economic progress and environmental degradation. The EKC theory posits that environmental quality may initially deteriorate during the early stages of economic development, likely due to increased industrial activity and energy consumption. However, it suggests that after reaching a certain income level, further GDP leads to improved environmental quality. This is attributed to several factors, including technological advancements, higher environmental awareness, and more stringent environmental regulations (Huang et al., 2021; Leitão et al., 2021). As a pivotal driver of economic development, the banking sector significantly influences this dynamic. Expanding banking activities facilitates greater capital availability, boosting industrial growth and infrastructure development (Chang and Zhang, 2022; Johari et al., 2022b; Noman et al., 2023; Nguyen and Lu, 2024). While this can spur economic progress, it often results in heightened energy consumption and increased CO_2 emissions, thus contributing to environmental degradation (Bekun, 2022). This dual impact of banking sector growth underscores the complexity of the relationship between economic development and CO_2 Emissions.

Despite its valuable insights, the EKC hypothesis has certain limitations that must be addressed to understand the relationship between GDP and environmental impact fully. One major criticism is that it may oversimplify the multifaceted interactions between various economic sectors and environmental outcomes. Additionally, the EKC theory does not account for the specific roles and impacts of different economic drivers, such as the banking sector, which can have unique and significant effects on environmental quality. Further consideration of the banking industry's role is crucial for a more comprehensive understanding of the EKC hypothesis. The sector's influence on both economic activities and environmental outcomes necessitates a nuanced approach to analyzing its impact. For instance, the types of projects funded by banks, the environmental policies they adhere to, and their investment in green technologies can significantly alter the trajectory of environmental quality in a developing economy. While the EKC hypothesis provides a valuable framework for understanding the relationship between economic development and environmental quality, it requires refinement to incorporate the specific impacts of sectors like banking. Achieving a more holistic and precise comprehension of this relationship is essential for informing future environmental policy decisions. Integrating a detailed analysis of the banking sector's role will enhance the relevance and applicability of the EKC theory, guiding more effective strategies for sustainable development.

2.2. Banking-Sector Development on Carbon Emissions

The significance of banking development (BSD) in ensuring economic sustainability has been the subject of considerable research interest in recent studies (Samour et al., 2022; Wang et al., 2023). A comprehensive examination of the correlation between BSD and renewable energy consumption (REC) and their influence on CO_2 levels reveals nuanced interactions across different regions and periods. For instance, Samour et al. (2022) reported a significant decrease in CO_2 emissions in South Africa, attributed to the combined impacts of BSD and REC. This suggests that financial sector growth, when coupled with renewable energy investments, can lead to environmental benefits. However, contrasting evidence from Radulescu et al. (2022) in OECD countries indicates a decline in CO_2 Emissions linked to BSD, despite the positive impact of renewable energy. This highlights the complexity of the relationship and suggests that BSD alone may not be sufficient to achieve CO_2 Emissions. Further supporting the positive role of BSD and REC, Wang et al. (2023) demonstrated in their research on Germany that these factors are significant in diminishing CO_2 emissions. Conversely, Khan and Rehan (2022) observed in China that BSD was associated with short-term increases in CO_2 emissions, indicating that the benefits of BSD on environmental outcomes might be delayed or contingent on other factors. Similarly, Mehmood (2022) identified trends in N-11 countries where BSD initially led to higher emissions over the specified timeframe.

These findings underscore the nuanced and context-specific relationship between BSD, REC, and CO_2 emissions, emphasizing the need for tailored approaches to CO_2 Emissions initiatives in different settings. The diversity of outcomes across studies suggests that the impact of BSD on CO_2 emissions is not uniform and is influenced by regional characteristics, the stage of economic development, and the specific nature of financial sector growth. To integrate these studies into a cohesive narrative, it is essential to synthesize and compare their findings critically. For example, the positive impact of BSD and REC in South Africa and Germany might be due to effective policy frameworks and strong regulatory environments that promote green investments. In contrast, the negative impacts observed in OECD countries and China could reflect inadequate integration of environmental considerations in banking practices or the predominance of high-emission industries in the economic structure. Furthermore, the theoretical framework underpinning this analysis, particularly the Environmental Kuznets Curve (EKC) theory, requires deeper exploration. The EKC posits that environmental degradation initially increases with GDP but eventually decreases as economies mature and adopt cleaner technologies. This theory is relevant for understanding the potential turning point at which BSD can shift from contributing to environmental degradation to promoting sustainability. However, the current literature review needs to explain better how the EKC theory informs the study's hypotheses and research questions.

2.3. GDP on Carbon Emissions

Numerous studies, see, for example, Lv et al. (2019); Rjoub et al. (2021), and Gohar, et al. (2022) across diverse regions have illuminated the complex and multifaceted relationship between GDP and CO_2 emissions. Teng et al. (2021) investigated developed economies within the Organization for Economic Co-operation and Development (OECD), finding a distinct association between GDP and CO_2 emissions. This suggests that even in advanced economies, where environmental regulations and green technologies are more prevalent, GDP can still drive CO_2 emissions. Similarly, Raihan and Tuspekova's (2022) study on Peru, a developing nation in South America, revealed a significant correlation between GDP and CO_2 emissions. This indicates that the GDP-CO_2 emissions link is prevalent across different stages of development. The findings underscore the universality of this relationship, suggesting that as nations progress economically, their environmental impact often intensifies, irrespective of their development status. Expanding the geographical scope, Zmami and Ben-Salha (2020) focused on the Gulf Cooperation Council (GCC) nations, highlighting the global nature of this phenomenon. These oil-rich economies, characterized by rapid GDP fueled by fossil fuels, tend to have higher CO_2 emissions. This scenario is particularly relevant for understanding the environmental challenges faced by resource-dependent economies, where economic expansion is closely tied to exploiting natural resources.

Taking the methodological approach a step further, Wang et al. (2023) employed the Autoregressive Distributed Lag (ARDL) approach to analyze G7 countries, a group of leading industrialized nations. Their study corroborated previous research findings, demonstrating a significant correlation between GDP and CO_2 emissions. The ARDL method's ability to handle different orders of integration and provide robust short-term and long-term estimates makes it particularly suitable for this type of analysis. While these studies consistently find a positive correlation between GDP and CO_2 emissions across various regions, the specific dynamics of this relationship differ based on factors such as a country's industrial structure, energy mix, and environmental policies. For instance, countries heavily relying on fossil fuels for energy production may experience a stronger link between GDP and CO_2 emissions compared to nations investing heavily in renewable energy sources. Despite the wealth of research on the GDP-CO_2 emissions nexus, there remains a significant gap in understanding the interplay between banking sector development (BSD), renewable energy consumption (REC), and CO_2 emissions, particularly in the context of Indonesia. This gap is crucial given Indonesia's unique economic and environmental landscape, characterized by rapid GDP, significant banking sector expansion, and a pressing need for sustainable energy solutions.

2.4. Renewable Energy Consumption on CO_2

The substantial body of research examining the impact of renewable energy on CO_2 emissions underscores its potential for significant reductions, particularly in nations with substantial carbon footprints (Naqvi et al., 2022; Yang, et al., 2023; Kartal et al., 2023). This literature highlights the transformative potential of renewable energy integration in mitigating environmental impacts, especially in contexts where traditional energy sources dominate. For instance, Bekun (2022) focused on India and illustrated how renewable energy adoption can substantially reduce CO_2 emissions within specific national contexts. This empirical evidence aligns with findings from Azam et al. (2021) and Adebayo et al. (2022), who empirically demonstrated a negative correlation between renewable energy use and CO_2 emissions. Their studies support the environmental benefits of renewable energy technologies, reinforcing their role in global sustainability efforts. Further strengthening this perspective, Khan et al. (2020) examined BRICS nations (Brazil, Russia, India, China, and South Africa) and highlighted the significant role of renewable energy in mitigating CO_2 emissions across diverse emerging economies. This research underscores the global significance of renewable energy in addressing environmental challenges and advancing sustainable development goals.

Despite these advancements, gaps in the literature remain that warrant further exploration. One critical gap is the need for more detailed studies on the specific dynamics of renewable energy adoption and its impact on CO_2 emissions in Indonesia. While existing research provides valuable insights from global and regional perspectives, a deeper understanding of Indonesia's unique socio-economic and environmental context is essential. This includes considering factors such as regulatory frameworks, infrastructure limitations, and socio-political dynamics that may influence the effectiveness of renewable energy policies.

3. DATA SOURCES, DATA DESCRIPTION, AND METHODOLOGY

3.1. Data Sources and Data Description

This chapter lays the groundwork for a comprehensive investigation into the complex interplay between banking sector development, GDP, renewable energy consumption (REC), and carbon dioxide (CO_2) emissions in Indonesia. By establishing clear objectives, the study aims to elucidate the dynamics of these factors over a significant period, spanning from 1990 to 2020, address potential issues arising from autocorrelation (serial correlation within the data) and heteroscedasticity (unequal variance of residuals), the data series were transformed using logarithms. This transformation addresses data variance issues and enhances statistical model estimations' accuracy. Table 1, a pivotal reference tool, offers a concise yet comprehensive overview of the variables under scrutiny. It delineates crucial details, including the names of the dependent and independent variables, their descriptions, the logarithmic transformations applied, and the respective data sources. This systematic presentation not only assists researchers in comprehending the fundamental elements of the study but also establishes a foundation for subsequent analyses and interpretations. By establishing a robust methodological framework and providing a clear roadmap for data analysis, this chapter equips researchers with the necessary tools to navigate the intricate relationships among Banking Development, GDP, REC, and CO_2 emissions in Indonesia. The study's rigorous analysis and interpretation aim to contribute valuable insights to environmental economics and sustainable development. These insights empower policymakers and pave the way for a sustainable future.

3.2. Methodology

This study utilises the Autoregressive Distributed Lag (ARDL) approach, a robust econometric technique developed and refined by Pesaran et al. (1999; 2001), to analyse the relationships between the variables of interest. It is a robust method for testing cointegration bounds, offering unique advantages over other approaches. One distinguishing feature of the ARDL bound test is its flexible lag length structure, which allows for more nuanced modelling of dynamic relationships among variables. Numerous empirical studies have underscored the versatility and effectiveness of the ARDL framework in analysing diverse datasets. Its ability to capture complex economic dynamics across different time horizons and data dimensions has made it a preferred choice for researchers seeking to understand and model economic phenomena. The ARDL approach drives methodological innovation and empirical inquiry in econometric research, contributing significantly to our understanding of economic relationships and their policy implications. The subsequent section of this study outlines the analytical steps involved in applying the ARDL methodology. It provides a visual representation in Figure 1, enhancing clarity and facilitating comprehension of the research process.

3.2.1. Econometric model

Researchers have conducted advanced econometric analysis to study the relationships between banking development, GDP, and REC and how these factors collectively affect CO_2 Emissions. These variables are expected to significantly influence CO_2 levels in both the short and long term. This study utilises a comprehensive analytical framework comprising four distinct models under the Environmental Kuznets Curve (EKC) paradigm to thoroughly evaluate banking development's influence on CO_2 Emissions. The model examines the relationship between several variables to determine their impact on sustainability indicators. This phenomenon leads to the mathematical representation of the model as follows: (1)

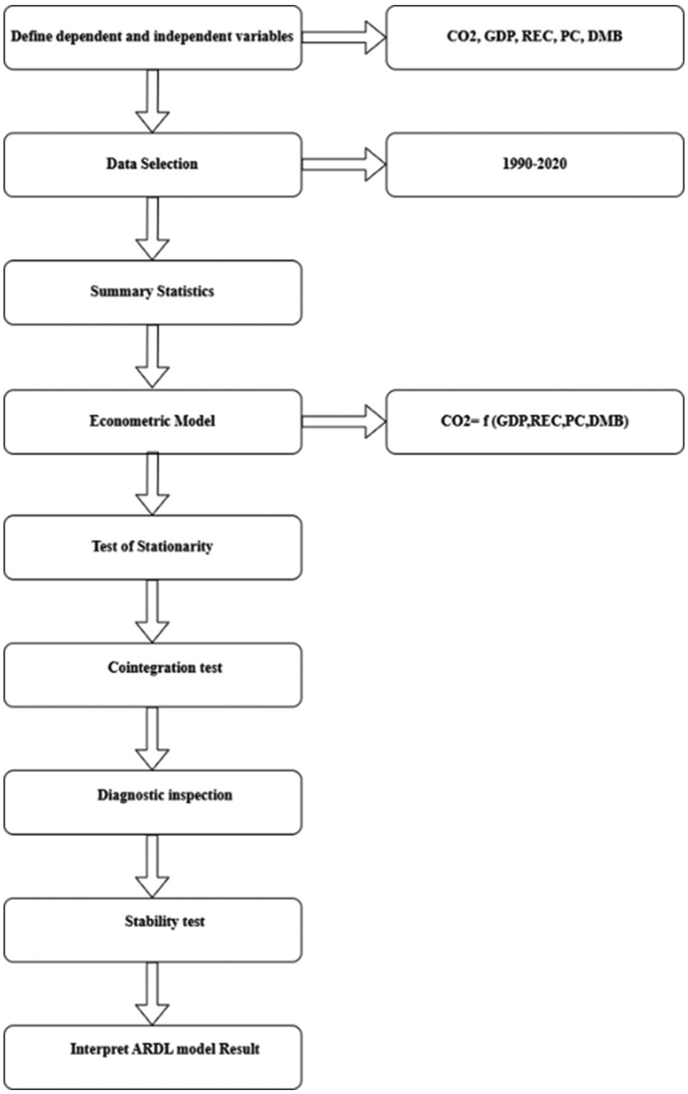
$$CO_2t = f\,(GDPt, GDP2t, RECt, DMBt, PCt)$$

CO_2t stands for CO_2 Emissions, a key measure of environmental pollution. GDP represents the total value of all goods and services produced in a country measured in US dollars (USD). To account for inflation, GDPt is adjusted to constant 2015 values, where 100 represents the value of all goods and services produced in 2015. Renewable energy consumption (InRECit), measured in terawatt-hours (TWh) annually, plays a crucial role in this study. It captures a nation's shift towards cleaner energy sources like solar or wind,

Table 1: The variables, measurements, and data sources were subjected to testing

Variable tests	Indicator	Assessment	Source of the data
Carbon Emissions	CO_2	Metric tons of carbon emissions per person	Our world of data
Renewable energy consumption	REC	TWh (terawatt-hours) annually	Our world of data
GDP	GDP	GDP per capita (USD) constant to 2015	World Bank -Open Data
Banking development "Deposit money banks"	DMB	Deposit money bank assets as a percentage of GDP (%)	The Global Financial Development Database- World Bank
Banking development "Private credit"	PC	Private credit from the deposit money banking sector as a proportion of GDP (%)	The Global Financial Development Database- World Bank

Figure 1: Analytical steps and provides a visual representation



which are expected to contribute to lower CO_2 emissions. The banking sector development indicators, InDMBt (deposit-to-GDP ratio) and InPCt (private credit-to-GDP ratio) offer insights into how financial activity might influence CO_2 emissions. InDMBt reflects a country's savings and investment potential, which could be directed towards clean technologies or financing high-polluting industries. Similarly, InPCt, representing credit availability for the private sector, could stimulate GDP that may initially increase CO_2 emissions if reliant on carbon-intensive industries. However, this credit could also be used for clean technology investments, potentially leading to a more sustainable future in the long term. The analysis suggests that further GDP might be associated with declining CO_2 emissions beyond a certain level of development. This finding aligns with and empirically supports the Environmental Kuznets Curve (EKC) theory. The following section delves into the specific econometric model used in this research.

$$CO_2t = \tau0+\tau1GDPt+\tau2GDP2t+\tau3RECt+\tau4DMBt+\gamma5PCit+\varepsilon t$$

The coefficients of the regressors are represented by τ1, τ2, τ3, τ4 and τ5, while τ0 denotes the intercept, and εt is the error term. Equation (2) can be expressed in logarithmic form as follows:

$$LnCO_2t = \tau0 + \tau1LnGDPt+\tau2LnGDP2t+\tau3\ LnRECt+ \tau4LnDMBt+\gamma5LnPCt + \varepsilon t$$

3.2.2. Test of stationarity

This study employs the unit root test to assess stationarity among the variables. Stationarity holds paramount importance as it ensures the reliability and accuracy of the data across various sectors. Given the utilisation of time series in the current study, detecting stationarity among variables is imperative, as highlighted by (Polcyn et al., 2023). Unit root testing plays a vital role in this regard, helping to discern whether variables exhibit stationarity. (Dickey and Fuller, 1979) proposed the Augmented Dickey-Fuller (ADF) bound method, one of several approaches employed in the study to address this concern.

3.2.3. Cointegration test

Cointegration tests are essential in economic analysis, providing insight into economic variables' behaviour over short and long periods. The test, also known as a bound test, is precious for variables with mixed-order integration up to the first order. The significance of lagged level variables in the error correction term is tested using the F-test. In contrast, the coefficient of the lagged dependent variable is examined using a t-test. Establishing critical limits involves utilising the F-distribution to ascertain the existence of enduring connections between variables. A higher F-value than the critical limit indicates a significant relationship between the variables, while a lower F-value suggests no significant relationship.

$$\Delta LnCO_2t = \tau0 + \tau_1 LnGDP_{t-1} + \tau_2 LnGDP2_{t-1} + \tau_4 LnREC_{t-1} + \tau_5 LnDMB_{t-1} + \tau_6 LnPC_{t-1} +$$

Once a long-term statistical relationship (cointegration) between the variables and CO_2 emissions is established, the study delves deeper. Equation (4) estimates the long-run coefficients, essentially revealing how much each variable (like renewable energy consumption or banking sector indicators) influences CO_2 emissions in the long term. The analysis then shifts its focus to short-term fluctuations. By incorporating this operator along with an "optimal lag length" (z), the study examines how short-term changes in the independent variables (e.g., a sudden increase in renewable energy use) affect CO_2 emissions in the short term. However, the system does not permanently deviate from its long-term equilibrium. Similarly, the error correction mechanism (ECM) captures the tendency of the system to return to its long-term equilibrium after short-term fluctuations. The error correction time (ECT) estimated in this analysis quantifies the speed at which this adjustment back to equilibrium occurs. A negative and statistically significant ECT coefficient indicates that deviations from long-term equilibrium are corrected relatively quickly. Conversely, a positive or insignificant coefficient suggests a slower adjustment process. The essential advantage of the ARDL approach lies in its ability to simultaneously analyse both long-term relationships (through equation (4)) and short-term dynamics (through the error correction term in equation (5)). This allows for a more comprehensive understanding of how the variables influence CO_2 emissions in the short and long run.

$$\Delta LnCO_2t = \tau0 + \tau_1 LnGDP_{t-1} + \tau_2 LnGDP2_{t-1} + \tau_4 LnREC_{t-1} + \tau_5 LnDMB_{t-1} + \tau_6 LnPC_{t-1} +$$

where θ is the ECT's coefficient.

3.2.4. Diagnostic inspection

This study employs a comprehensive suite of diagnostic tests to fortify the methodological approach and credibility of the analysis. These tests encompass a range of statistical assessments aimed at detecting and addressing potential sources of bias and inconsistency within the empirical framework. The ARCH LM test, proposed by 0, is utilised to discern heteroscedasticity, an essential consideration in ensuring the reliability of the variance estimates. Similarly, the Breusch-Godfrey approach is applied to identify and rectify any instances of serial correlation, which may compromise the independence of error terms. Finally, the Durbin-Watson test is employed to detect autocorrelation, a phenomenon that can distort the estimation of parameter coefficients. Through precisely applying these diagnostic procedures, this study endeavours to uphold the highest standards of empirical integrity and statistical validity in its analysis.

3.2.5. Stability test

The stability of models with autoregressive is a crucial aspect of empirical analyses. To enhance this aspect of our research, this paper uses the CUSUM and CUSUM of squares methods. These methodologies are indispensable tools for detecting structural changes and variations in regression coefficients within the model framework. The CUSUM test and the CUSUM of squares approach are indispensable tools for assessing the stability of econometric models with autoregressive structures. While the CUSUM test scrutinises cumulative residuals, capturing the cumulative effect of deviations from expected values over time, the CUSUM of squares approach focuses on aggregate residuals, providing insights into the overall dispersion of residuals. By monitoring the cumulative sum of these residuals, both techniques facilitate the detection of structural modifications and alterations in regression coefficients, thus ensuring the stability of the model over its entire application period. According to stability criteria, the model is deemed stable when the blue plots consistently remain within the orange plot lines at a 5% significance level. Conversely, the model's stability is compromised if the blue plots deviate beyond these boundaries.

4. FINDING AND DISCUSSION

Descriptive statistics for the variables examined in the study are presented in Table 2. This table encompasses 31 observations spanning from 1990 to 2020 in Indonesia. The similarity between the mean and median values suggests a symmetrical distribution, which may indicate normality in the data distribution. By examining the mean and median values, researchers can gauge the central tendency of the variables, providing insights into their typical levels. The similarity between these measures suggests that the data may follow a symmetric distribution, indicating that observations are equally likely to occur on either side of the mean. This symmetry, if present, supports the assumption of normality, which is often desirable for statistical analyses. Additionally, the kurtosis values below 3 indicate platykurtic characteristics, indicating that the distribution has lighter tails and is less peaked than a normal distribution. These insights not only aid in understanding the central tendency and variability of the data but also inform subsequent analytical decisions, ultimately enhancing the validity and reliability of the study's findings.

Table 2: Descriptive statistics

Variable	CO_2	LNGDP	REC	PC	DMB
Mean	2.704.763	5.409.525	2.769.466	4.026.290	1.390.645
Median	2.698.668	5.397.335	2.638.821	4.146.000	1.345.010
Maximum	2.769.466	5.538.933	2.769.466	5.918.000	1.683.977
Minimum	2.638.821	5.277.642	2.638.821	1.977.000	1.160.836
Standard deviation	406.574	813.148	665.292	1.139.554	154.148
Skewness	174.058	174.058	245.535	−120.769	301.355
Kurtosis	1.716.185	1.716.185	1.855.099	2.035.559	2.016.466
Jarque-Bera	2.285.432	2.285.432	1.396.179	1.276.796	1.718.690
Probability	318.952	318.952	480.197	528.138	423.439
Sum	8.384.764	1.676.953	865.024	1.248.150	4.311.000
Sum of squares of deviations	4.959.068	1.983.627	1.233.521	3.895.747	712.852
Observations	31	31	31	31	31

Table 3 presents unit root estimations using the Augmented Dickey-Fuller (ADF) methodology, a commonly used method for evaluating the stationarity of time series data. The results suggest that the variables being studied show non-stationarity at their initial levels. However, after applying the first differencing, which involves computing the difference between consecutive observations, the variables become stationary. Stationarity is an essential assumption in time series analysis as it guarantees that the statistical characteristics of the data remain consistent throughout time. The ADF technique improves the reliability of future analyses, such as regression modelling and forecasting, by proving stationarity through first differencing. This helps to address concerns related to non-stationary data, such as spurious regression. Overall, the findings from Table 3 underscore the importance of pre-processing techniques like first differencing in preparing time series data for rigorous statistical analysis.

The study opted for the ARDL (Autoregressive Distributed Lag) approach because it is particularly well-suited for situations where the variables might have a long-term equilibrium relationship (cointegration) alongside short-term fluctuations. This characteristic aligns perfectly with the research question, which seeks to understand how various factors influence CO_2 emissions in the short and long term. To confirm the appropriateness of the ARDL approach, the researchers employed a statistical test called the bound test (Table 4). This test focuses on the F-statistic, a measure of how well the model, in this case, the ARDL model, explains the relationship between the variables and CO_2 emissions. A higher F-statistic indicates a better fit. The results were quite convincing. The F-statistic reached a value of 19.9085, significantly higher than the critical F-value of 4.37 at a 1% significance level. This "significance level" tells us the probability of this result happening by chance. In this case, a 1% significance level means there is only a 1% chance that such a high F-value could occur if there were no real relationship between the variables and CO_2 emissions. The statistically significant F-value exceeding the critical value provides strong evidence for cointegration. In simpler terms, this suggests that the variables included in the study (like renewable energy consumption or banking sector indicators) and CO_2 emissions exhibit a long-term equilibrium relationship. This means that even if these variables deviate from their long-term average levels in the short term, they tend to move together in the long run.

Table 3: ADF unit root test estimates

Variables	Level	First difference
CO_2	0.8695	0.0000
REC	0.8769	0.0001
Ln GDP	0.9166	0.0037
DMB	0.5894	0.0004
PC	0.2473	0.0032

Table 4: ARDL bounds test results

F-statistic	Value	Significance level (%)	I (0)	I (1)
Value of F-statistic	19.9085	10	2.2	3.09
K	4	5	2.56	3.49
Critical value bounds	0.1-0.01	2.50	2.88	3.87
		1	3.29	4.37

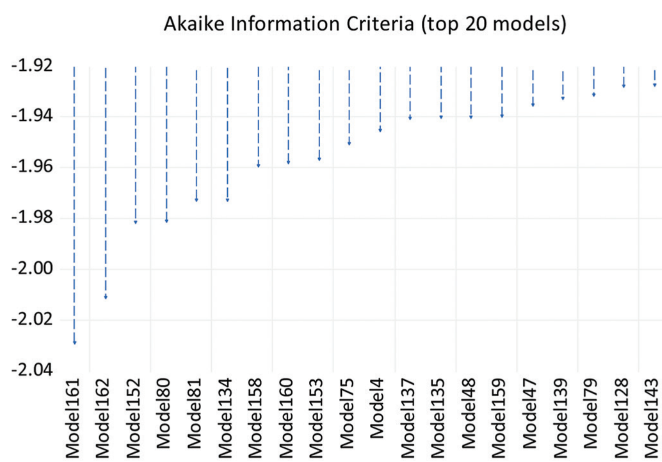


Table 5 presents the ARDL model's comprehensive results and highlights the analysed variables' direct and lasting effects. It is worth noting that not all coefficients show statistical significance, indicating that the variable effects differ between variables. The study reveals a significant negative relationship between GDP (GDP), banking sector development, and CO_2 emissions in Indonesia. This aligns with the Environmental Kuznets Curve (EKC) theory, suggesting an inverted U-shaped curve where emissions initially rise with GDP but eventually decline as the

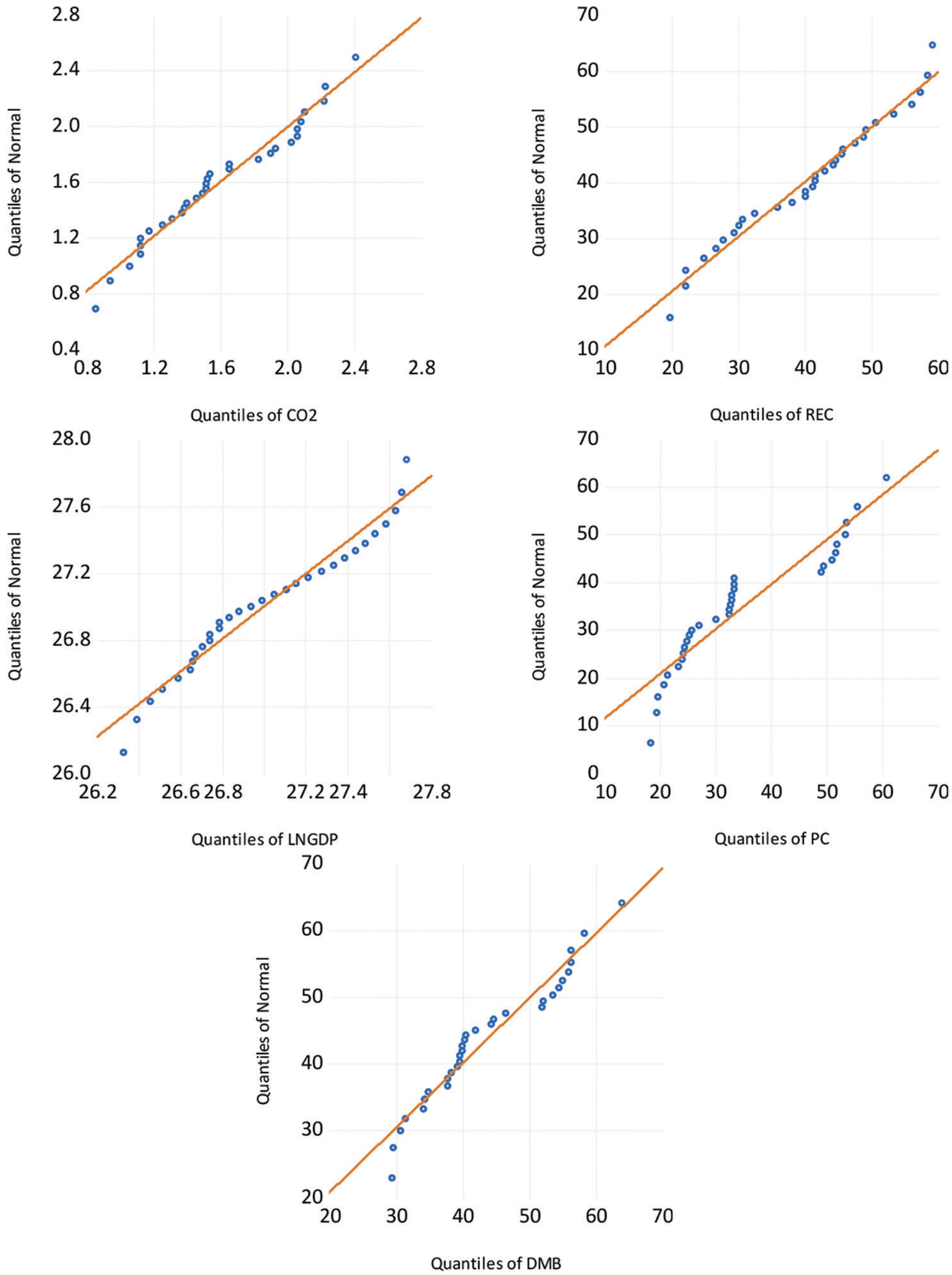
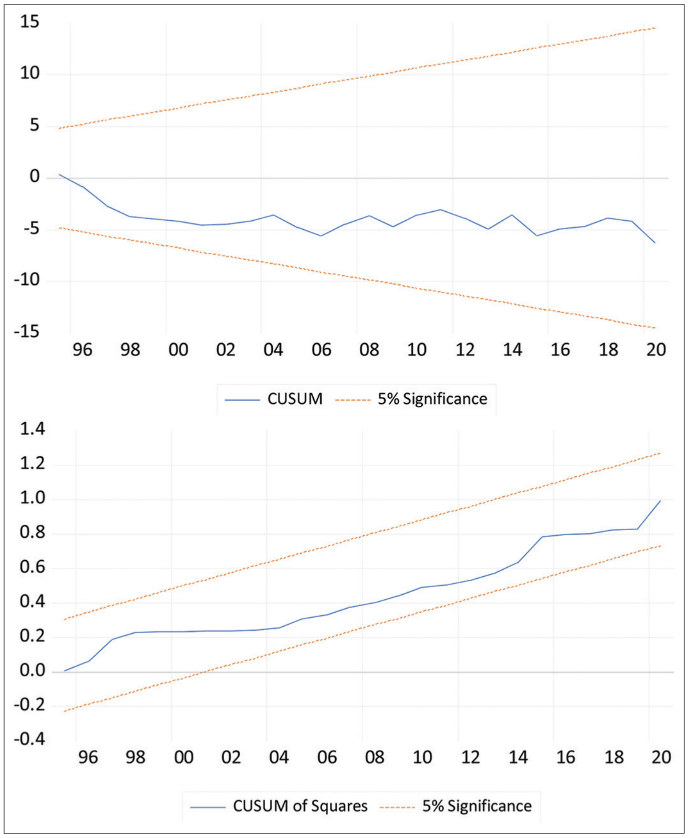


Table 5: ADL's long-run and short-term results

Variables	Long-run			Short-term		
	Coefficient	t-statistic	P-value	Coefficient	t-Statistic	P-value
LNGDP	−0.225832	−1.821018	0.0886*	−0.538278	−1.879765	0.0797*
REC	−0.035633	−5.374112	0.0001***	−0.046711	−6461726	0.0000***
DMB	−0.004623	−1.403405	0.1809	−0.016746	−3.380506	0.0041***
PC	1.49E-05	0.040236	0.9920	0.009037	2.723215	0.0157**
C	0.004580	0.009734	0.470586	0.019018	0.461504	0.6511
R2	0.897057					
Adjusted R2	0.821565					

economy matures. In this case, a 1% increase in GDP leads to a 0.22% decrease in CO_2 emissions in the long term and a 0.53% decrease in the short term. These findings are supported by previous research by Jena et al. (2022), Murshed and Dao (2022), Mehmood et al. (2022), Adebayo et al. (2023), and Uche et al. (2023), all of which highlight the validity of the EKC phenomenon in Indonesia. The findings of this study illuminate the intricate interrelationship between GDP and ecological sustainability, offering valuable insights for academic and policy researchers. These results provide researchers and policymakers with crucial new information about the complex link between economic development and CO_2 Emissions.

Figure 2: Plot of CUSUM and CUSUMQ tests



This study highlights the potential of renewable energy to reduce CO_2 emissions in Indonesia significantly. There is a strong negative correlation between renewable energy consumption and carbon emissions. In other words, as Indonesia uses more renewable energy, its CO_2 emissions decline. This effect is evident both in the long term (coefficient: −0.035633) and the short term (coefficient: −0.046711), with high statistical significance (1% level). This evidence demonstrates that even modest increases in renewable energy use can considerably impact reducing CO_2 emissions, which in turn affects ecosystem health in the present and future. Adewuyi et al. (2021) reached similar broad conclusions about the beneficial effect of renewable energy use in reducing CO_2 emissions, consistent with the observed decrease in carbon emissions. There are clear opportunities to advance CO_2 Emissions in Indonesia by utilising renewable energy sources, such as solar and wind power, which the country relies heavily on. Given the factors above, Indonesia should enhance its endeavours to enhance energy efficiency by amplifying the promotion and allocation of resources towards renewable energy sources. A more environmentally sustainable future is within reach thanks to Indonesia's commitment to developing renewable energy sources, allowing the country to reduce carbon emissions further. This study highlights the importance of renewable energy in achieving CO_2 Emissions in Indonesia and emphasises the need for continued support and commitment in this area.

This analysis reveals intricate correlations between the rise of the banking sector and the emission of CO_2 in Indonesia. A strong inverse correlation was seen between the deposit of money in banks (DMB) and carbon emissions in the short run. This data suggests a 1% rise in DMB is linked to a 0.016% decline in carbon emissions. Nevertheless, this adverse correlation lacks a lasting element. This implies that the impact of DMB on carbon emissions is likely to be temporary. In contrast, private financing exhibits a favourable and substantial correlation with carbon emissions during a brief period. This is supported by the empirical observation that for every 1% growth in the banking sector, there is a corresponding 0.009% rise in carbon emissions. This contradictory pattern highlights the challenge of balancing the expansion of the banking industry with the goal of promoting CO2 Emissions. The results align with prior studies conducted by Samour et al. 2022 and Obiora et al. 2023, indicating a direct correlation between the expansion of the banking industry and the increase in carbon emissions. The surge in banking operations, along with the nation's dependence on fossil fuels as its predominant energy supply, has led to a rise in carbon emissions. The study suggests reallocating loans towards ecologically acceptable initiatives as a solution to this challenge. Indonesia can promote GDP and address carbon emissions and CO_2 Emissions by allocating resources to renewable energy and environmentally viable projects. This approach prioritises the implementation of sustainable environmental measures to achieve both long-term CO_2 Emissions and economic benefits.

This study delves into the intricate interplay between banking development and CO_2 Emissions in Indonesia, revealing a nuanced relationship that evolves. While deposit money banks (DMB) show a short-term negative influence on emissions, private credit presents a contrasting short-term positive impact. These results highlight the need to consider the temporal evolution of bank development when assessing banks' environmental impacts. The banking sector's pivotal role in facilitating carbon emissions underscores the necessity of implementing strategic measures to reduce environmental impact while promoting GDP. Channelling credit into green energy investments is a promising approach to promoting sustainable development in Indonesia. By harnessing the momentum of banking development to promote environmentally friendly initiatives, Indonesia can pave the way towards a greener, more resilient economy that prioritises environmental stewardship and economic prosperity.

The diagnostic tests conducted in this study aimed to ensure the reliability and stability of the models employed. Table 6 presents a summary of the diagnostic test results. These tests are essential to assess various aspects of the model, including autocorrelation, normality, variance stability, and overall model specification. The results indicate that the proposed model meets acceptable standards across these critical criteria, indicating its robustness and suitability for analysing the relationship between the investigated variables. Autocorrelation tests help determine whether there is any systematic pattern in the residuals, which could indicate a need for model refinement. Normality tests assess whether the residuals are normally distributed, which is crucial for accurate statistical inference. Variance stability tests ensure that the variance of the residuals remains constant over time, validating the model's predictive capability. Finally, model specification tests verify that the chosen model adequately represents the underlying relationships among the variables. Overall, these diagnostic tests

Table 6: Diagnostic tests results

Diagnostic tests	P-value	Decision
Breusch-Godfrey serial correlation LM test	0.2111	There is no serial correlation
Breusch-Pagan-Godfrey heteroscedasticity test	0.6762	There is no heteroscedasticity
Jarque-Bera test	0.81667	The residuals are normally distributed.

provide confidence in the reliability and validity of the findings derived from the model analysis.

To assess stability, this study employs two statistical techniques, namely cumulative sum of squares (CUSUM) and cumulative sum of squares (CUSUM-squared). These techniques are illustrated in the figure 2. The CUSUM and Cusum-squared methods determine stability by analysing whether the blue plot lies within the orange plot line (indicating the 5% significance level). The model is considered stable if the blue plot is consistently within these lines. However, if there is a deviation, stability will be affected. The figures demonstrate that all residuals are within the boundary lines, indicating stability. The CUSUM and CUSUM squared tests indicate that the blue plot remains within the orange plot boundaries at the 5% significance level, thereby confirming the stability of the regression coefficients and the overall model.

5. CONCLUSIONS AND IMPLICATIONS

This research examines the impact of Indonesia's banking sector growth on CO_2 emissions through its financial support for economic activities. This support can either contribute to higher emissions or promote the use of cleaner energy alternatives. Our findings indicate that the banking sector exerts a dual influence on emissions, both increasing and decreasing them. The ARDL model was employed to examine the interrelationship between banking development, GDP, renewable energy utilization, and CO_2 levels. Our analysis demonstrates that as Indonesia's economy expands, the banking sector initially facilitates emissions-intensive activities, resulting in elevated CO_2 levels. However, over time, the banking sector's support for cleaner technologies and renewable energy adoption contributes to a decline in emissions, aligning with the Environmental Kuznets Curve (EKC) theory.

The use of renewable energy is of paramount importance in the reduction of emissions. Deposit banks will probably result in a temporary reduction of emissions by supporting savings and investments in sectors that are less carbon-intensive. However, private loans may have a temporary increase in emissions due to the financing of activities that depend on fossil fuels. It is noteworthy that different types of banking activities have varying impacts on emissions. Deposit banks will temporarily decrease emissions, while private loans will temporarily increase them.

The results of our study highlight the potential for targeted banking sector interventions to significantly influence emissions and advance sustainable development. By directing financial resources toward renewable energy projects and environmentally friendly ventures, banks can serve as a primary catalyst for green innovation and sustainable economic growth. A balanced approach, which combines economic growth, the adoption of renewable energy sources, and strategic involvement of the banking sector, is essential for the reduction of CO_2 emissions in Indonesia. The banking sector has the potential to serve as a driving force for sustainability by investing in renewable energy projects and environmentally friendly ventures. This dual strategy is consistent with global sustainability goals and reinforces the banking sector's role as a catalyst for green innovation and sustainable economic development. This strategic alignment positions the banking sector as a principal actor in Indonesia's endeavours to attain a more environmentally sustainable and resilient economy.

In order to optimize the banking sector's potential for emissions reduction, policymakers must develop frameworks that provide incentives for green investments while simultaneously discouraging the allocation of financial resources to high-emission activities. This aligns with global sustainability goals and positions the banking sector as a catalyst for green innovation and sustainable economic growth. To ensure a balance between economic growth and environmental protection, the banking sector must take proactive steps to lead sustainable development initiatives. By prioritizing investments in green technologies and renewable energy, banks can contribute to Indonesia's efforts to reduce CO_2 emissions and position the country as a leader in sustainable economic practices.

Although our research provides valuable insights, it nevertheless has limitations. Focusing on Indonesia may limit the generalizability of our findings to other countries with different economic and environmental contexts. To enhance the scope of future research, it would be beneficial to compare multiple countries, analyze different banking products, and examine the impact of policy changes on the banking sector's role in emissions reduction. Furthermore, exploring long-term environmental impacts using metrics like biodiversity loss and water quality could provide a more comprehensive understanding of the banking sector's sustainability impact.

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