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Islamic Banking Finance and Environmental Sustainability: Sector-Level Analysis from Indonesia

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ABSTRACT

This study aims to analyse the effect of sectoral financing by Islamic banking on greenhouse gas emissions (CO_2 and CH_4) in Indonesia, both in the short and long term. Using monthly time series data from January 2015 to December 2020, this study applies the autoregressive distributed lag (ARDL) and error correction model (ECM) approaches to capture the dynamics of sectoral relationships with emissions. Five main financing sectors are analysed, namely trade, construction, manufacturing, agriculture-forestry, and transportation-communication, with energy consumption and industrial price index as control variables. The estimation results show that financing the trade sector significantly reduces CO_2 emissions, while the construction, transportation-communication, and energy consumption sectors increase CO_2 emissions. No significant effect of financing on CH_4 emissions was found, indicating that sharia financing is not yet directed at the methane-producing sector. The ECM model confirms that the transportation-communication sector contributes to CO_2 reduction in the short term, and there is a correction mechanism for long-term equilibrium. This study provides an original contribution to the study of Islamic-based green finance by presenting a sectoral approach and the use of two emission indicators. The findings are practically relevant for designing Islamic green financing policies, as well as supporting the achievement of Indonesia's net zero emission target. This study also underlines the importance of integrating maqāṣid al-sharī'ah values into financial sustainability policies.

Keywords: Islamic Banking Financing, Environmental Sustainability, CO_2, CH_4, Autoregressive Distributed Lag
JEL Classifications: G21, Q01, Q56, Q58

1. INTRODUCTION

Global climate change is currently one of the most crucial challenges for the sustainability of the world's ecosystems and economy (Gyimah et al., 2024). The increasing concentration of greenhouse gases (GHGs), especially carbon dioxide (CO_2) and methane (CH_4), has exacerbated global warming, resulting in rising sea levels, extreme weather events, and ecosystem degradation (Wu et al., 2024). These two gases play a major role in trapping heat in the atmosphere, making understanding their sources and solutions an international policy priority (Marinaș et al., 2018). Global commitments such as the Paris Agreement and the sustainable development goals (SDGs) encourage countries to significantly reduce emissions in order to keep global temperature rise below 2°C (Adeleye et al., 2022; Dissanayake et al., 2023).

Indonesia, as a developing country with rapid economic growth, is one of the main contributors to greenhouse gas (GHG) emissions, especially carbon dioxide (CO_2) and methane (CH_4) (Cahyo et al., 2023). Based on World Development Indicator data, in 2020 Indonesia's CO_2 emissions were recorded at 563,197 kilotons, while CH_4 emissions were 333,994.9 kilotons. Recognizing how significant the impact is, the Indonesian government has committed to cutting emissions by 29% on its own and up to 41% with international assistance by 2030. It has also outlined a long-term goal of reaching carbon neutrality, or net zero emissions, by 2060 (Yin, 2023). In an effort to achieve these targets, the financial sector plays a strategic role, not only as a driving force for the economy, but also as an agent of change through support for environmentally friendly sustainable financing (Saleem et al., 2022).

In this context, Islamic banking has emerged as an important part of the national financial system, which is not only based on financial principles but also on ethical values, justice, and sustainability (Muhammad et al., 2020). The rapid growth of the Islamic banking industry in Indonesia is accompanied by efforts to integrate sustainability values through green financing schemes (Faizi et al., 2024). The principle of maqashid al-syariah emphasizes the environment (hifz al-bi'ah) as part of life protection (hifz al-nafs) and encourages Islamic banking to play a role in efforts to reduce GHG emissions (Julia and Kassim, 2020). Several Islamic banks in Indonesia have shown their commitment to these principles, for example, by including sustainability elements in their sustainability reports.

However, most previous studies examining the relationship between the financial sector and the environment still focus on aggregate indicators such as the financial development index or total financing, without considering specific financing sectors. In addition, the literature examining the relationship between Islamic financing and the environment is still limited and tends to focus only on CO_2 emissions. There has been no empirical study that simultaneously evaluates the effect of sectoral financing by Islamic banking on the two main types of GHG emissions—CO_2 and CH_4—especially in the Indonesian context. In fact, a sectoral approach is needed considering that emission intensities differ between sectors, and their respective contributions to the environment are not homogeneous.

Therefore, this study aims to analyze the short-term and long-term relationship between Islamic banking sectoral financing and CO_2 and CH_4 emission levels in Indonesia, using the autoregressive distributed lag (ARDL) and error correction model (ECM) approaches. This study also aims to identify the most significant financing sectors in influencing emission reductions, as well as assess the speed of adjustment towards long-term equilibrium if there is a deviation in the system. To support empirical validity, this study also considers energy consumption and industrial price index as control variables that affect emissions.

This study provides scientific contributions in three main aspects. First, the use of two types of GHG emissions as environmental indicators makes this analysis more comprehensive than studies that only focus on CO_2. Second, the sectoral approach in Islamic banking financing—using the five largest sectors as independent variables—provides a depth of analysis that is rarely found in previous studies. Third, the context of Indonesia as a country with the largest Muslim population and a dual financial system offers relevant policy contributions for other developing countries with similar characteristics.

This study is expected to provide academic and practical benefits. Academically, this study expands the literature on the role of Islamic finance in the transition to a low-carbon economy. Practically, the findings of this study can be used by regulators and industry players to design more environmentally friendly financing policies that are in line with Islamic principles. This study can also encourage stronger integration between sustainable development strategies and Islamic banking development at the national level. This article is organized into five sections: Chapter 1 presents the introduction, Chapter 2 discusses the literature review and theoretical framework, Chapter 3 explains the research methodology, Chapter 4 presents the empirical results and analysis, and Chapter 5 presents the conclusions and policy implications.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

This section presents a critical review of relevant literature on the relationship between bank financing, especially Islamic banking, and greenhouse gas emissions, namely carbon dioxide (CO_2) and methane (CH_4). The literature analyzed includes basic theories on greenhouse gas emissions, the impact of financial sector development on environmental quality, the contribution of Islamic banking in sustainable financing, and the role of sectoral financing in encouraging or reducing emissions. This review serves as a basis for building a theoretical and empirical framework and in formulating research hypotheses.

2.1. Greenhouse Gas Emissions: CO_2 and CH_4

CO_2 is the main greenhouse gas released into the atmosphere due to the combustion of fossil fuels by the transportation and industrial sectors (Zhang et al., 2020). Although it plays a role in maintaining climate balance, excessive CO_2 concentrations trigger global warming and environmental degradation (Muradov, 2017). On the other hand, CH_4 has a warming potential 25 times higher than CO_2 in a 100-year period and comes from agricultural, livestock, waste, and mining activities (Shi et al., 2025). In environmental economic studies, these two gases are positioned as important indicators of the quality of sustainable development. While most research focuses on CO_2, the contribution of CH_4 to climate change is now receiving greater attention, especially in sector-based mitigation policies (Sun et al., 2022).

2.2. Financial Development and Environmental Impact

Theoretically, financial sector development can encourage energy efficiency and implement environmentally friendly technologies through easier and cheaper financing (Green Solow Model). However, the literature shows mixed results. Several studies show a positive effect of financial development on emission reduction. Hasni et al.. (2023) stated that financial stability reduces CO□ emissions in APEC countries, while Ren et al.. (2023) highlighted the role of finance in reducing poverty and improving long-term environmental quality. In contrast, Nguyen and Le (2024) showed that in Vietnam, financial growth actually increased emissions despite increasing renewable energy consumption, due to the lack of supervision of carbon-intensive investments.

Furthermore, studies such as Liu and Liu (2021) and Shahbaz et al.. (2021) found that the relationship between finance and emissions is non-linear, depending on the regional economic structure. For example, an inverted-U or M-shaped pattern illustrates that finance initially increases emissions, but after reaching a certain threshold, emissions decrease (Tenaw and Beyene, 2021). This finding emphasizes the importance of considering national contexts and development stages when evaluating the impact of the financial sector on the environment (Tran et al., 2023).

2.3. Islamic Banking and Sustainable Finance

Islamic banking has ethical and sustainability principles that refer to the values of maqashid al-shariah, including environmental protection. Studies such as Solarin (2019) and Eddine et al.. (2023) show that Islamic financing can support emission reductions, especially if allocated to environmentally friendly projects. However, Abduh et al.. (2022) and Irfany et al.. (2024) emphasize that Islamic financing that is not explicitly directed to the green sector can still contribute to emissions, especially in the heavy industry sector. In Indonesia, Iskandar et al.. (2020) noted that the limited integration of green finance principles has limited the contribution of Islamic financing to emission mitigation. Islamic banking in OIC countries also faces challenges such as the lack of green financing products and the absence of incentives for environmentally friendly projects (Kamalu and Ibrahim, 2021). Therefore, the effectiveness of Islamic finance in supporting sustainable development is highly dependent on its sectoral allocation strategy.

2.4. Sectoral Financing and Greenhouse Gas Emissions

Studies on the impact of financing on emissions are generally still aggregate and rarely differentiate their impacts by sector. In fact, the characteristics of the sector receiving the financing greatly determine the type and magnitude of emissions produced. For example, financing the construction sector tends to increase CO_2 emissions due to the use of high-carbon materials (Meo and Abd Karim, 2022). The agriculture and forestry sectors are more relevant to CH_4 emissions from enteric fermentation and organic waste (El-Hawwary et al., 2022). Meanwhile, the trade sector (Ansari et al., 2020), the processing industry (Benhelal et al., 2021), and the transportation (Wang et al., 2020) and communication (Khan et al., 2022) show variations in emissions depending on the energy intensity and technology used. With a sectoral approach, this study attempts to fill the gap in the literature by empirically testing the impact of Islamic banking financing on five main sectors on two types of greenhouse gases separately, in the context of Indonesia.

2.5. Literature Gaps and Research Contributions

There are several important gaps in the previous literature. First, most studies only examine CO_2 emissions and ignore the role of CH_4, although both contribute significantly to global warming. Second, studies on the sectoral impacts of Islamic financing on the environment are still very limited. Third, most studies use a static approach, without distinguishing between short-term and long-term effects. This study contributes to addressing these gaps by presenting empirical evidence from Indonesia—the most populous Muslim country with a growing Islamic financial system. By incorporating two emission indicators (CO_2 and CH_4), five financing sectors, and dynamic approaches (ARDL and ECM), this study is expected to enrich the discourse on green finance in developing countries and strengthen the integration of Islamic financial values into environmental policies.

Based on previous literature and arguments, the research hypothesis is formulated as follows:

H_1: Islamic banking financing in the wholesale and retail (WHR) sector has a negative impact on CO_2 emissions. Trade sector financing has the potential to support low-carbon product distribution and logistics efficiency.

H_2: Islamic banking financing in the construction sector (CTR) has a positive impact on CO_2 emissions. This sector is known as a high emitter due to the use of cement, steel, and fossil fuels.

H_3: Islamic banking financing in the manufacturing industry sector (PRC) has a positive impact on CO_2 emissions. The manufacturing industry contributes significant emissions from energy consumption and manufacturing processes.

H_4: Islamic banking financing in the agriculture and forestry (AFR) sector has a negative impact on CH_4 emissions. Green allocation in this sector can support sustainable agriculture and forest restoration.

H_5: Islamic banking financing in the transportation, warehousing, and communication (TWC) sector has a negative impact on CO_2 and CH_4 emissions. Digitalization and efficient logistics in this sector have the potential to reduce greenhouse gas emissions.

This hypothesis will be tested using the ARDL and ECM approaches to evaluate the short-term and long-term relationships of each sector on CO_2 and CH_4 emissions in Indonesia.

3. DATA AND METHODOLOGY

3.1. Research Design

This study uses an explanatory quantitative approach, because it aims to explain the relationship between sectoral financing by Islamic banking and greenhouse gas emissions in Indonesia. This study utilizes time series data with a focus on short-term and long-term analysis using an econometric approach. The main model used in this study is the autoregressive distributed lag (ARDL) which is equipped with short-term estimation through the error correction model (ECM) to capture the dynamics of adjustment towards long-term equilibrium.

3.2. Data and Methodology

This study empirically aims to examine the short-term and long-term dynamic relationship between sectoral financing by Islamic banks and environmental degradation, using a cointegration framework. The data used are monthly secondary data covering the period from January 2015 to December 2020. The dependent variables in this study consist of two types of greenhouse gases, namely carbon dioxide (CO_2) and methane (CH_4) emissions, which are taken from the World Development Indicators (WDI) - World

Bank. These two variables were chosen because they are the main components contributing to climate change, especially in Indonesia.

Independent variables include financing of the main economic sectors by Indonesian Islamic banks, namely: Wholesale and retail trade (WHR), construction (CTR), manufacturing industry (PRC), agriculture and forestry (AFR), and transportation, warehousing, and communication (TWC). This information is obtained from Islamic Banking Statistics published by the financial services authority (OJK). As control variables, total energy consumption (ENC) and industrial price index (IPI) are used, which represent energy intensity and economic growth, respectively. ENC data are sourced from the Ministry of Energy and Mineral Resources, while IPI is from the Central Statistics Agency (BPS). All variables are transformed into natural log-form for variance stability, ease of interpretation of elasticity, and to minimize differences in data digits. Operational definitions of the variables are shown in Table 1.

The initial step in the analysis is to perform a stationarity test on all variables using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) approaches. This test ensures that there are no variables that are I(2), because ARDL cannot be applied to data with second-order integration (Kripfganz and Schneider, 2023). After verifying stationarity, the optimal lag of the model is determined using the Akaike Information Criterion (AIC), to ensure efficient and accurate model specifications (Ghouse et al., 2018).

Next, a Bound Test is conducted to test the existence of a long-term relationship (cointegration) between variables. This test compares the F-statistics of the estimated results with the lower limit (I[0]) and upper limit (I[1]). If the F value is higher than the upper limit, then cointegration is confirmed. This test refers to the approach developed by Pesaran et al.. (2001) and strengthened by Narayan (2005) for small sample adjustments. After cointegration is confirmed, the ARDL model is used to estimate the long-term relationship between variables. Mathematically, the general form of the ARDL (p, q1, q2., qk) model is:

$$Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=1}^{k} \sum_{l=0}^{q_j} \beta_{jl} X_{jt-l} + \varepsilon_t \quad (1)$$

Where Y_t is the dependent variable ($\ln CO_2$ or $\ln CH_4$), and X_{jt} are the independent and control variables. An econometrics model called autoregressive distributed lag (ARDL) demonstrates how a variable was affected by itself in the prior period. Selecting the optimal ARDL model for short- or long-term estimate is crucial. Under these circumstances, figuring out the ideal latency becomes crucial to obtaining the optimal model. Stated differently, an ARDL model regresses a variable across its historical values as well as the historical and current values of many external variables (Fabozzi et al., 2006). The ARDL version is estimated in this work using conditional error correction (EC), which is the ARDL technique for cointegration. Two models make up the model used in this study:

$$\begin{aligned}\Delta \ln CO2_t = {} & \alpha_0 + \sum_{i=1}^{p} \Psi_i \Delta \ln CO2_{t-i} + \sum_{i=0}^{p} \theta_i \Delta \ln WHR_{t-i} + \\ & \sum_{i=0}^{p} \Omega_i \Delta \ln CTR_{t-i} + \sum_{i=0}^{p} \Upsilon_i \Delta \ln PRC_{t-i} + \sum_{i=0}^{p} \Pi_i \Delta \ln AFR_{t-i} + \\ & \sum_{i=0}^{p} \Gamma_i \Delta \ln TWC_{t-i} + \sum_{i=0}^{p} \psi_i \Delta \ln IPI_{t-i} + \sum_{i=0}^{p} \Lambda_i \Delta \ln ENC_{t-i} + \\ & \delta_1 \ln CO2_{t-i} + \delta_2 \ln WHR_{t-i} + \delta_3 \ln CTR_{t-i} + \delta_4 \ln PRC_{t-i} + \\ & \delta_5 \ln AFR_{t-i} + \delta_6 \ln \mathrm{TWC}_{t-i} + \delta_7 \ln IPI_{t-i} + \delta_8 \ln ENC_{t-i} + v_t \end{aligned} \quad (2)$$

$$\begin{aligned}\Delta \ln CH4_t = {} & \alpha_0 + \sum_{i=1}^{p} \gamma_i \Delta \ln CO2_{t-i} + \sum_{i=0}^{p} 6_i \Delta \ln WHR_{t-i} + \\ & \sum_{i=0}^{p} c_i \Delta \ln CTR_{t-i} + \sum_{i=0}^{p} (_i \Delta \ln PRC_{t-i} + \sum_{i=0}^{p} \eta_i \Delta \ln AFR_{t-i} + \\ & \sum_{i=0}^{p} \theta_i \Delta \ln TWC_{t-i} + \sum_{i=0}^{p} h_i \Delta \ln IPI_{t-i} + \sum_{i=0}^{p} \mu_i \Delta \ln ENC_{t-i} + \\ & \delta_1 \ln CO2_{t-i} + \delta_2 \ln WHR_{t-i} + \delta_3 \ln CTR_{t-i} + \delta_4 \ln PRC_{t-i} + \\ & \delta_5 \ln AFR_{t-i} + \delta_6 \ln \mathrm{TWC}_{t-i} + \delta_7 \ln IPI_{t-i} + \delta_8 \ln ENC_{t-i} + v_t \end{aligned} \quad (3)$$

Table 1: Operational definition of variables

Variable	Variable type	Indicators/measurements	Unit/scale	Data source
Carbon emissions (CO_2)	Independent	Total carbon dioxide emissions per month	Kiloton CO_2/month	WDI World Bank
Methane emissions (CH_4)	Independent	Total methane emissions per month	Kiloton CH_4/month	WDI World Bank
Trade sector financing	Independent	The amount of Islamic Bank financing in the wholesale and retail trade sector	Billion Rupiah	Islamic Banking Statistics OJK
Construction sector financing	Independent	The amount of Islamic Bank financing in the construction sector	Billion Rupiah	Islamic Banking Statistics OJK
Manufacturing industry financing	Independent	The amount of Islamic Bank financing to the manufacturing industry sector	Billion Rupiah	Islamic Banking Statistics OJK
Agriculture and forestry sector financing	Independent	The amount of Islamic Bank financing in the agriculture, forestry and fisheries sectors	Billion Rupiah	Islamic Banking Statistics OJK
Transportation sector financing	Independent	The value of sharia financing in the transportation, warehousing and communications sectors	Billion Rupiah	Islamic Banking Statistics OJK
Energy consumption	Control	The amount of oil consumption	Kiloton	WDI World Bank
Economic growth	Control	Industrial production index as a proxy for economic growth	Industrial production index	WDI World Bank

Where lnWHR, lnCTR, lnPRC, lnAFR, lnTWC is the natural logarithm for wholesale and retail trade financing, construction financing, processing industry financing, agriculture and forestry financing, and transportation warehousing and communications financing respectively. $\ln CO_2$ and lnCH4, reflect the greenhouse gas emission of CO_2 and CH4. Last, lnIPI and lnENC are the control variables of reveal economic growth and energy consumption.

After the long-run model is estimated, the short-run relationship is analyzed using the error correction model (ECM), which includes an error correction term (ECT) as an indicator of adjustment to deviations from long-run equilibrium. A significant and negative ECT coefficient indicates that the system will return to equilibrium after a short-run disturbance. The long-term components of the equation are subjected to simple regression to estimate the ECT.

$$\ln CO2_t = \alpha_0 + \sum_{i=1}^{p}\alpha_1\Delta\ln CO2_{t-i} + \sum_{i=0}^{p}\alpha_2\Delta\ln WHR_{t-i} + \sum_{i=0}^{p}\alpha_3\Delta\ln CTR_{t-i} + \sum_{i=0}^{p}\alpha_4\Delta\ln PRC_{t-i} + \sum_{i=0}^{p}\alpha_5\Delta\ln AFR_{t-i} + \sum_{i=0}^{p}\alpha_6\Delta\ln TWC_{t-i} + \sum_{i=0}^{p}\alpha_7\Delta\ln IPI_{t-i} + \sum_{i=0}^{q}\alpha_8\Delta\ln ENC_{t-i} + \upsilon_t \quad (4)$$

$$\ln CH4_t = \alpha_0 + \sum_{i=1}^{p}\alpha_1\Delta\ln CO2_{t-i} + \sum_{i=0}^{p}\alpha_2\Delta\ln WHR_{t-i} + \sum_{i=0}^{p}\alpha_3\Delta\ln CTR_{t-i} + \sum_{i=0}^{p}\alpha_4\Delta\ln PRC_{t-i} + \sum_{i=0}^{p}\alpha_5\Delta\ln AFR_{t-i} + \sum_{i=0}^{p}\alpha_6\Delta\ln TWC_{t-i} + \sum_{i=0}^{p}\alpha_7\Delta\ln IPI_{t-i} + \sum_{i=0}^{p}\alpha_8\Delta\ln ENC_{t-i} + \omega_t \quad (5)$$

The residuals from each of equations 4 through 5 are obtained once the regression has been completed, it is called an error correction term (ECT). The next step is to estimate the ARDL coefficient by substituting the error correction term (ECT) for the long-term ARDL equation's parts. This means that equations 2 and 3 will be written as follows:

$$\Delta\ln CO2_t = \beta_0 + \sum_{i=1}^{p}\beta_1\Delta\ln CO2_{t-i} + \sum_{i=0}^{p}\beta_2\Delta\ln WHR_{t-i} + \sum_{i=0}^{p}\beta_3\Delta\ln CTR_{t-i} + \sum_{i=0}^{p}\beta_4\Delta\ln PRC_{t-i} + \sum_{i=0}^{p}\beta_5\Delta\ln AFR_{t-i} + \sum_{i=0}^{p}\beta_6\Delta\ln TWC_{t-i} + \sum_{i=0}^{p}\beta_7\Delta\ln IPI_{t-i} + \sum_{i=0}^{q}\beta_8\Delta\ln ENC_{t-i} + \psi ECT_{t-1} + \vartheta_t \quad (6)$$

$$\Delta\ln CH4_t = \beta_0 + \sum_{i=1}^{p}\beta_1\Delta\ln CO2_{t-i} + \sum_{i=0}^{p}\beta_2\Delta\ln WHR_{t-i} + \sum_{i=0}^{p}\beta_3\Delta\ln CTR_{t-i} + \sum_{i=0}^{p}\beta_4\Delta\ln PRC_{t-i} + \sum_{i=0}^{p}\beta_5\Delta\ln AFR_{t-i} + \sum_{i=0}^{p}\beta_6\Delta\ln TWC_{t-i} + \sum_{i=0}^{p}\beta_7\Delta\ln IPI_{t-i} + \sum_{i=0}^{q}\beta_8\Delta\ln ENC_{t-i} + \psi ECT_{t-1} + \vartheta_t \quad (7)$$

Where Δ is the first difference of the operator, β's is the coefficients contributing to the short-term dynamics of the model's convergence to equilibrium, and ψ is the speed of adjustment. In the time series model, an error term with a lag parameter refers to the application of a specific error term from a prior period. In addition to the current independent variables, this model takes the prior period's error term into account as a predictor. Solving the autocorrelation and capturing the temporal dynamics are crucial. The model can produce a prediction that is more accurate and dependable by using lag error components.

The validity of the model specification is tested through various diagnostic tests. The residual distribution is evaluated using the Jarque-Bera test to ensure normality, while autocorrelation is tested through the Lagrange multiplier (LM) test. The possibility of heteroscedasticity is tested using the Breusch-Pagan-Godfrey approach, and the model specification is checked through the Ramsey RESET test. This test aims to ensure that the model meets the classical assumptions of linear regression so that the estimation results are reliable.

The selection of ARDL as the main method has a strong methodological basis. This model is flexible in handling data with mixed integration levels (I[0] and I[1]), and is very suitable for time series data with a limited number of observations. ARDL also allows simultaneous identification of long-term and short-term relationships, without requiring pre-testing for cointegration as in the Johansen approach. Other references such as Nkoro and Uko (2016) also support the reliability of ARDL in the context of developing countries. With this systematic methodological approach, the study is expected to provide solid empirical evidence regarding the sectoral contribution of Islamic bank financing to reducing greenhouse gas emissions in Indonesia in the short and long term.

4. RESULTS AND DISCUSSION

The empirical analysis in this study aims to examine how financing of key sectors by Islamic banking contributes to reducing greenhouse gas emissions in Indonesia, focusing on the two most dominant types of emissions, namely carbon dioxide (CO_2) and methane (CH_4). To answer this objective, the autoregressive distributed lag (ARDL) approach is used within the cointegration and error correction model (ECM) framework, considering the characteristics of monthly time series data from January 2015 to December 2020 which shows a combination of integration at the level and first order.

The results of the stationarity test using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) methods show that not all variables are stationary at the same level. Some variables are at level I(0), while others are at I(1). This supports the use of ARDL as an appropriate estimation approach. The results of the ADF and PP unit root tests are shown in Table 2.

Based on the Akaike information criterion (AIC), the optimal models used are ARDL (1, 1, 4, 3, 4, 2, 0, 1) for the CO_2 model and ARDL (3, 1, 3, 0, 4, 2, 0, 1) for the CH_4 model. This combination of lag orders shows the complexity of the dynamics of short-term interactions between variables in both models (Figure 1).

The results of the bounds test on both models show F-statistic values that are convincingly higher than the upper bound values at all levels of significance (1%, 5%, and 10%), both for the CO_2 model (F = 11.70) and CH_4 (F = 6.27). This indicates a long-term cointegration relationship between the variables analyzed, in other words, sharia sector financing has a stable structural relationship with greenhouse gas emission levels. In addition, a series of diagnostic tests show that the model used is free from autocorrelation (Lagrange Multiplier test), heteroscedasticity (Breusch-Pagan-Godfrey), and specification errors (RESET test), and passes the normality test (Jarque-Bera). This strengthens the reliability of the model before entering the main estimation (Table 3).

Long-term estimations for the CO_2 model show several important results (Table 4). Financing for the construction sector (CTR), transportation and communication (TWC), and energy consumption (ENC) has a significant positive effect on CO_2 emissions. This indicates that these sectors are still highly dependent on fossil fuels and high-emitting infrastructure. In contrast, the wholesale and retail trade (WHR) sector shows a significant negative effect on CO_2, which can be explained by the transition to energy efficiency and sustainability standards in large-scale trade activities, including possible green incentives from Islamic banking financing. This finding is in line with previous literature showing that the trade and logistics sector is often a pioneer in the adoption of environmentally friendly technologies (Solarin, 2019; Hariyadi et al., 2025). However, the agriculture sector (AFR), manufacturing industry (PRC), and industrial price index (IPI) do not show a significant effect, indicating the need for further research on the effectiveness of green financing allocation in these sectors.

For the CH_4 model, the long-term estimation results show that none of the sector financing variables have a significant effect on CH_4

Table 2: Results of variable stationarity tests

Variable	ADF				PP			
	Model CO_2		Model CH_4		Model CO_2		Model CH_4	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
$\ln CO_2$	0.0504	0.9147	-	-	0.7496	0.5323	-	-
$\ln CH_4$	-	-	0.0255**	0.8423	-	-	0.7580	0.4425
lnWHR	0.5830	0.0001***	0.5830	0.0001***	0.5359	0.0001***	0.5359	0.0001***
lnCTR	0.9730	0.0000***	0.9730	0.0000***	0.9640	0.0000***	0.9640	0.0000***
lnPRC	0.2155	0.0000***	0.2155	0.0000***	0.1968	0.0001***	0.1968	0.0001***
lnAFR	0.1590	0.0000***	0.1590	0.0000***	0.0964*	0.0000***	0.0964*	0.0000***
lnTWC	0.5239	0.0000***	0.5239	0.0000***	0.5301	0.0000***	0.5301	0.0000***
lnIPI	0.0094**	0.0001***	0.0094**	0.0001***	0.0163**	0.0001***	0.0163**	0.0001***
lnENC	0.1669	0.9114	0.1669	0.9114	0.7147	0.7135	0.7147	0.7135

Significant at: *10, **5, and ***1% levels. ADF: Augmented Dickey-Fuller, PP: Phillips-Perron

Table 3: Results of the bounds test for cointegration

Model	K	Test statistic (F-statistic)	Critical value bound							
			10%		5%		2.5%		1%	
			I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
CO_2	7	11.70187	2.03	3.13	2.32	3.50	2.60	3.84	2.96	4.26
CH_4	7	6.265393	2.06	3.23	2.31	3.53	2.61	3.85	2.92	4.22

Figure 1: Akaike information criterion information criteria

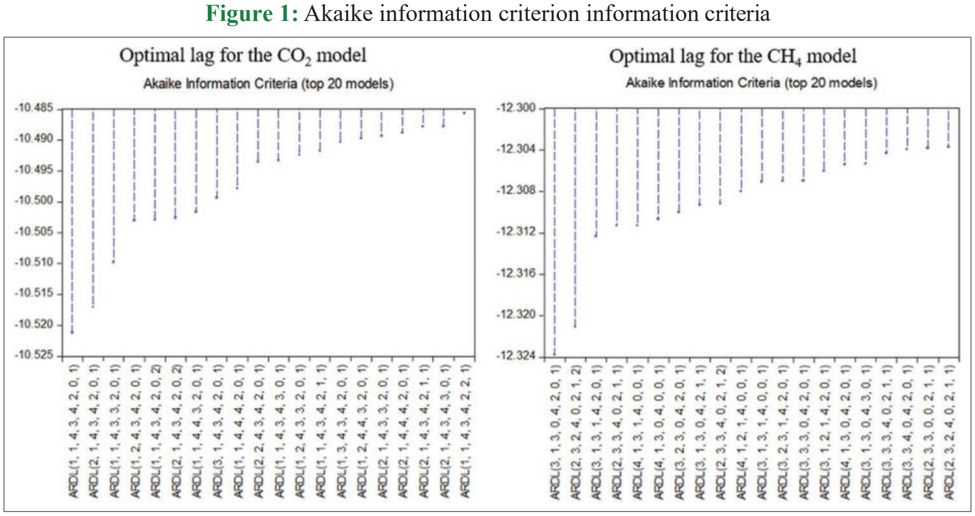

Table 4: Results of autoregressive distributed lag estimation - CO_2 model

Variable	Model CO_2			
	Coefficient	SE	t-statistic	P-value
lnCO₂(−1)	1.1284	0.0477	23.6521	0.0000***
lnWHR	0.0074	0.0081	0.9268	0.3591
lnWHR(−1)	0.0259	0.0080	3.2041	0.0025***
lnCTR	−0.0111	0.0048	−2.3266	0.0247**
lnCTR(−1)	0.0162	0.0055	2.9335	0.0053***
lnCTR(−2)	−0.0058	0.0057	−1.0132	0.3165
lnCTR(−3)	−0.0011	0.0053	−0.1946	0.8466
lnCTR(−4)	−0.0122	0.0042	−2.8656	0.0064***
lnPRC	−0.0048	0.0081	−0.5915	0.5572
lnPRC(−1)	0.0097	0.0091	1.0621	0.2940
lnPRC(−2)	−0.0030	0.0085	−0.3622	0.7189
lnPRC(−3)	−0.0202	0.0078	−2.5758	0.0134**
lnAFR	−0.0037	0.0053	−0.7058	0.4840
lnAFR(−1)	−0.0072	0.0054	−1.3438	0.1859
lnAFR(−2)	0.0059	0.0051	1.1512	0.2558
lnAFR(−3)	0.0147	0.0052	2.8151	0.0073***
lnAFR(−4)	−0.0056	0.0041	−1.3531	0.1829
lnTWC	−0.0153	0.0056	−2.7224	0.0093***
lnTWC(−1)	0.0092	0.0068	1.3584	0.1812
lnTWC(−2)	−0.0178	0.0056	−3.1326	0.0031***
lnIPI	−0.0023	0.0031	−0.7356	0.4659
lnENC	0.7298	0.0497	14.6681	0.0000***
lnENC(−1)	−0.8567	0.0523	−16.3631	0.0000***
C	0.5307	0.2027	2.6182	0.0121**

SE: Standard errors

Table 5: Results of autoregressive distributed lag estimation - CH_4 model

Variable	Model CH_4			
	Coefficient	SE	t-statistic	P-value
lnCH₄(−1)	1.1602	0.0823	14.0856	0.0000***
lnCH₄(−2)	−0.0234	0.1386	−0.1689	0.8666
lnCH₄(−3)	−0.1502	0.0867	−1.7321	0.0900*
lnWHR	0.0025	0.0031	0.8155	0.4190
lnWHR(−1)	0.0081	0.0032	2.4443	0.0184**
lnCTR	−0.0042	0.0018	−2.3601	0.0226**
lnCTR(−1)	0.0092	0.0021	4.2811	0.0001***
lnCTR(−2)	−0.0031	0.0023	−1.3419	0.1862
lnCTR(−3)	−0.0029	0.0017	−1.6325	0.1094
lnPRC	−0.0036	0.0031	−1.1463	0.2576
lnAFR	0.0007	0.0022	0.3504	0.7276
lnAFR(−1)	−0.0016	0.0021	−0.7765	0.4414
lnAFR(−2)	0.0011	0.0021	0.5251	0.6021
lnAFR(−3)	0.0032	0.0019	1.6785	0.1000
lnAFR(−4)	−0.0041	0.0016	−2.4121	0.0199**
lnTWC	−0.0048	0.0022	−2.1544	0.0365**
lnTWC(−1)	0.0037	0.0027	1.3728	0.1764
lnTWC(−2)	−0.0043	0.0022	−1.9023	0.0634*
lnIPI	−0.0001	0.0012	−0.1189	0.9059
lnENC	0.1391	0.0198	6.9999	0.0000***
lnENC(−1)	−0.1424	0.0179	−7.9234	0.0000***
C	0.2199	0.3383	0.6499	0.5189

SE: Standard errors

emissions, although the direction of the coefficients is generally negative (Table 5). This can be interpreted as an indication that Islamic banking has not explicitly targeted financing to methane-producing sectors such as intensive agriculture or organic waste management. On the other hand, CH_4 emissions themselves naturally have a smaller contribution than CO_2 in the energy and industrial sectors, although their global warming effects are much greater per unit of gas. Thus, the effectiveness of financial interventions on CH□ may require a more targeted and project-based approach.

In the short-run estimation using the ECM model, results are consistent with theoretical expectations (Table 6). The CO_2 model shows that the TWC variable has a significant negative effect on emissions, while ENC has a strong positive effect. In addition, CTR and PRC show positive effects through their lags, reflecting the delayed effect of sector financing on emissions. Most importantly, the coefficient of the error correction term (CointEq[−1]) is −0.2315 and is significant ($P = 0.0046$), indicating that about 23% of the deviation from the long-run equilibrium will be corrected in one period. This is evidence of a healthy dynamic adjustment mechanism in the CO_2 model (Table 7).

For the CH_4 model, the ECM results show that ENC still has a positive impact on emissions, while TWC has a negative impact. Several lag variables show marginal significance, indicating a delayed response from the system to changes in financing inputs. The CointEq(−1) for this model is −0.0133 and is significant ($P = 0.0072$), although the value is very small. This suggests that the CH_4 system has a very slow short-term correction mechanism—an important finding that needs to be considered in formulating effective green financing policies for methane emissions (Table 8).

The stability test of the model parameters was conducted using the CUSUM method on the residuals. The graphical results show that all CUSUM lines are within the 5% interval limits throughout the estimation period, indicating that there are no significant structural changes and that the model parameters are stable over time. This is the final validation that the model can be used reliably to generate evidence-based policy recommendations (Figure 2).

When compared to previous literature, the findings of this study are consistent with studies conducted by Shahbaz et al.. (2013), Solarin (2019), and Iskandar et al.. (2020), which state that financing by the banking sector, especially Islamic banking, can be an important instrument in influencing environmental quality—either positively or negatively depending on the financed sector and the green standards applied. However, the absence of a significant effect on CH_4 reflects the lack of explicit attention to the non-CO_2 environmental dimension in the current financing scheme. This emphasizes the need for reformulation of project assessment and improvement of a more specific green incentive framework at the micro level.

Overall, the results of this study imply that the effectiveness of Islamic financing in reducing greenhouse gas emissions is highly dependent on the type of sector being financed, the energy structure of the sector, and the commitment to implementing sustainability principles by financial institutions. In the future, the integration of the values of maqāṣid al-sharī'ah and environmental sustainability needs to be strengthened through environmental impact assessments in the Islamic financing process, as well as the development of more targeted green financial products to support Indonesia's net zero emission target by 2060.

Figure 2: Result of model stability test

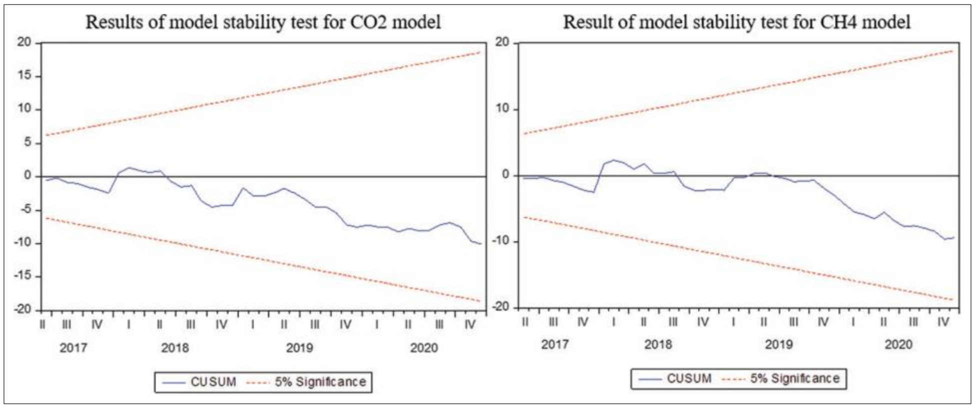

Table 6: Results of long-term test

Variable	Model CO_2				Model CH_4			
	Coefficient	SE	t-statistic	P-value	Coefficient	SE	t-statistic	P-value
lnWHR	−0.2596	0.0919	−2.8227	0.0071***	−0.7928	2.3553	0.3366	0.7379
lnCTR	0.1099	0.0214	5.1261	0.0000***	−0.0835	0.3104	−0.2692	0.7890
lnPRC	0.1428	0.0894	1.5974	0.1173	−0.2693	0.7756	−0.3473	0.7299
lnAFR	−0.0305	0.0345	−0.8843	0.3813	−0.0463	0.2467	−0.1877	0.8519
lnTWC	0.1863	0.0538	3.4629	0.0012***	−0.4112	1.3333	−0.3084	0.7592
lnIPI	0.0181	0.0155	1.1707	0.2480	−0.0113	0.0940	−0.1201	0.9049
lnENC	0.9876	0.0523	18.8723	0.0000***	−0.2477	1.4559	−0.1701	0.8656

SE: Standard errors

Table 7: Results of error correction model test for the autoregressive distributed lag CO_2 model

Variable	Coefficient	SE	t-statistic	P-value
D(lnWHR)	0.0074	0.0061	1.2344	0.2236
D(lnCTR)	−0.0111	0.0074	−1.4898	0.1434
D(lnCTR[−1])	0.0058	0.0056	1.0407	0.3037
D(lnCTR[−2])	0.0011	0.0035	0.2946	0.7696
D(lnCTR[−3])	0.0122	0.0038	3.1656	0.0028***
D(lnPRC)	−0.0048	0.0078	−0.6131	0.5429
D(lnPRC[−1])	0.0030	0.0061	0.5109	0.6119
D(lnPRC[−2])	0.0202	0.0112	1.7948	0.0795*
D(lnAFR)	−0.0037	0.0045	−0.8387	0.4061
D(lnAFR[−1])	−0.0059	0.0047	−1.2501	0.2179
D(lnAFR[−2])	−0.0147	0.0091	−1.6172	0.1130
D(lnAFR[−3])	0.0056	0.0061	0.9208	0.3621
D(lnTWC)	−0.0153	0.0068	−2.2343	0.0306**
D(lnTWC[−1])	0.0178	0.0074	2.3908	0.0212**
D(lnIPI)	−0.0023	0.0021	−1.1060	0.2747
D(lnENC)	0.7298	0.0888	8.2163	0.0000***
CointEq(−1)	0.1284	0.0430	2.9853	0.0046***

SE: Standard errors

Table 8: Results of error correction model test for the autoregressive distributed lag CH_4 model

Variable	Coefficient	SE	t-statistic	P-value
D(lnCH4[−1])	0.1736	0.0928	1.8693	0.0680*
D(lnCH4[−2])	0.1502	0.0613	2.4464	0.0183**
D(lnWHR)	0.0025	0.0025	0.9936	0.3256
D(lnCTR)	−0.0042	0.0027	−1.5519	0.1275
D(lnCTR[−1])	0.0031	0.0027	1.1468	0.2574
D(lnCTR[−2])	0.0029	0.0014	1.9484	0.0575*
D(lnPRC)	−0.0036	0.0026	−1.3405	0.1866
D(lnAFR)	0.0007	0.0019	0.3954	0.6944
D(lnAFR[−1])	−0.0011	0.0016	−0.6271	0.5336
D(lnAFR[−2])	−0.0032	0.0024	−1.3241	0.1920
D(lnAFR[−3])	0.0041	0.0024	1.6435	0.1071
D(lnTWC)	−0.0048	0.0026	−1.8365	0.0727*
D(lnTWC[−1])	0.0043	0.0023	1.8811	0.0663*
D(lnIPI)	−0.0001	0.0011	−0.1428	0.8870
D(lnENC)	0.1391	0.0400	3.4734	0.0011***
CointEq(−1)	−0.0133	0.0398	−0.3357	0.7386

SE: Standard errors

5. CONCLUSION AND POLICY IMPLICATIONS

This study aims to analyze how financing of key sectors by Islamic banking in Indonesia can contribute to reducing greenhouse gas emissions, especially carbon dioxide (CO_2) and methane (CH_4). Using monthly time series data from January 2015 to December 2020, this study applies the autoregressive distributed lag (ARDL) approach, complemented by bounds testing and error correction model (ECM) cointegration tests, to evaluate short- and long-run relationships. The five largest financing sectors by Islamic banking—wholesale and retail trade, construction, manufacturing, agriculture and forestry, and transportation and communication—are tested along with control variables such as energy consumption and industrial price index.

The analysis results show that in the long term, financing in the wholesale and retail sector significantly reduces CO_2 emissions. This indicates that this sector is starting to adopt energy efficiency technologies and compliance with environmental standards, possibly due to financing that supports environmentally friendly investments. In contrast, financing in the construction, transportation and communication, and energy consumption sectors actually increases CO_2 emissions significantly, reflecting the still high dependence on fossil fuel sources. For CH_4, although most financing variables show a negative direction, none are statistically significant in the long-term estimation. This indicates that Islamic financing has not been explicitly directed to sectors that contribute significantly to methane emissions, such as organic waste or livestock.

In the short term, the ECM results show that the transportation and communication (TWC) sector contributes significantly to the reduction of CO_2, while energy consumption (ENC) has a strong positive effect on the increase of CO_2 and CH□ emissions. The error correction coefficient (CointEq[−1]) values are −0.2315 for the CO_2 model and −0.0133 for CH_4, respectively, both of which are significant, indicating that the model has a valid adjustment mechanism to the long-term equilibrium after short-term shocks. The model stability test through CUSUM also confirms that all model parameters are stable throughout the observation period.

This study contributes to the growing literature on the relationship between Islamic finance and environmental sustainability, with a more detailed approach through the analysis of the financing sector and the separation of CO_2 and CH_4 as environmental indicators. Most previous studies have focused only on CO_2 or used aggregate financial indicators. Thus, this finding provides a more specific understanding of the actual impact of Islamic finance on the environmental dimension.

Based on these findings, there are several policy recommendations that can be proposed. First, Islamic financial institutions need to strengthen environmental evaluation in the financing process, especially in sectors that have been proven to contribute significantly to carbon emissions. This evaluation can be integrated into the financing feasibility assessment mechanism, including aspects of environmental risk and compliance with sustainability standards. Second, supervisory authorities such as the Financial Services Authority (OJK) can formulate special regulations and incentives to encourage Islamic green financing, such as the obligation to assess environmental impacts and sustainability reporting based on maqāṣid al-sharī'ah. Third, innovation in Islamic financial products needs to be developed to support environmentally friendly projects, such as renewable energy financing, green sukuk, or ESG-based investment schemes that comply with sharia principles. Fourth, synergy between Islamic banking, the Ministry of Environment, and local governments needs to be strengthened in order to align the flow of financing funds with Indonesia's net zero emission target and the Sustainable Development Goals (SDGs) agenda.

Despite its important contribution, this study has several limitations. First, it uses aggregate sector finance data and only covers two types of greenhouse gases due to data limitations. Second, not all finance sectors are analyzed at a micro level or based on specific projects. Therefore, further research can consider using micro data (e.g. bank or project level), as well as including other greenhouse gases such as N_2O or fluorinated gases (HFCs) to broaden the scope of environmental analysis. Cross-country studies among Muslim-majority countries or OIC members can also enrich the understanding of the global consistency of the environmental performance of the Islamic finance sector.

In conclusion, Islamic banking financing in Indonesia shows real potential in supporting environmental quality improvement, especially in reducing CO_2 emissions. However, to maximize its impact, a more selective, transparent, and sustainability-oriented financing approach is needed—one that is not only in accordance with Islamic principles, but also supports long-term ecological responsibility and climate resilience.

REFERENCES

Abduh, M., Buys, W.A., Aziz, S.A. (2022), Exploring the relationship between Islamic financial development, energy consumption, and environmental quality. International Journal of Energy Economics and Policy, 12(2), 426-430.

Adeleye, B.N., Olohunlana, A.O., Ibukun, C.O., Soremi, T., Suleiman, B. (2022), Mortality rate, carbon emissions, renewable energy and per capita income nexus in Sub-Saharan Africa. PLoS One, 17(9), e0274447.

Ansari, M.A., Haider, S., Khan, N.A. (2020), Does trade openness affects global carbon dioxide emissions: Evidence from the top CO_2 emitters. Management of Environmental Quality An International Journal, 31(1), 32-53.

Benhelal, E., Shamsaei, E., Rashid, M.I. (2021), Challenges against CO_2 abatement strategies in cement industry: A review. Journal of Environmental Sciences, 104, 84-101.

Cahyo, H., Purnomo, S.D., Octisari, S.K., Surveyandini, M., Sundari, S., Purwendah, E.K. (2023), Environment, population, and economy on CO_2 emission in Indonesia. International Journal of Energy Economics and Policy, 13(6), 295-303.

Dissanayake, H., Perera, N., Abeykoon, S., Samson, D., Jayathilaka, R., Jayasinghe, M., Yapa, S. (2023), Nexus between carbon emissions, energy consumption, and economic growth: Evidence from global economies. PLoS One, 18(6), e0287579.

El-Hawwary, A., Brenzinger, K., Lee, H.J., Veraart, A.J., Morriën, E., Schloter, M., Ho, A. (2022), Greenhouse gas (CO_2, CH4, and N2O) emissions after abandonment of agriculture. Biology and Fertility of Soils, 58(5), 579-591.

Faizi, F., Kusuma, A.S., Widodo, P. (2024), Islamic green finance: Mapping the climate funding landscape in Indonesia. International Journal of Ethics and Systems, 40(4), 711-733.

Fabozzi, F. J., Focardi, S. M., Kolm, P. N. (2006), Financial modeling of the equity market: from CAPM to cointegration. Hoboken, New Jersey: John Wiley & Sons.

Ghouse, G., Khan, S.A., Rehman, A.U. (2018), ARDL Model as a Remedy for Spurious Regression: Problems, Performance and Prospectus. [MPRA Paper].

Gyimah, J., Hayford, I.S., Nyantakyi, G., Adu, P.S., Batasuma, S., Yao, X. (2024), The era of global warming mitigation: The role of financial inclusion, globalization and governance institutions. Heliyon, 10(1), e23471.

Hariyadi, E., Wong, W.K., Johari, S.M., Shafiai, M.H.M. (2025), Promoting sustainable banking: The role of private credit in reducing CO_2 emissions in Indonesia. International Journal of Energy Economics and Policy, 15(2), 32.

Hasni, R., Dridi, D., Ben Jebli, M. (2023), Do financial development, financial stability and renewable energy disturb carbon emissions? Evidence from Asia-pacific economic cooperation economics. Environmental Science and Pollution Research, 30(35), 83198-83213.

Irfany, M.I., Syam, M.I.N., Haq, D.A. (2024), The impact of Islamic finance on carbon emissions: Lessons from OIC Countries. International Journal of Energy Economics and Policy, 14(3), 198-205.

Iskandar, A., Possumah, B.T., Aqbar, K. (2020), Islamic financial development, economic growth and CO_2 emissions in Indonesia. Journal of Islamic Monetary Economics and Finance, 6(2), 353-372.

Julia, T., Kassim, S. (2020), Exploring green banking performance of Islamic banks vs conventional banks in Bangladesh based on Maqasid Shariah framework. Journal of Islamic Marketing, 11(3), 729-744.

Kamalu, K., Ibrahim, W.H.B.W. (2021), Islamic banking development and financial inclusion in OIC member countries: The moderating role of institutions. Journal of Islamic Monetary Economics and Finance, 7(3), 527-544.

Khan, H., Weili, L., Khan, I. (2022), Examining the effect of information and communication technology, innovations, and renewable energy consumption on CO_2 emission: Evidence from BRICS countries. Environmental Science and Pollution Research, 29(31), 47696-47712.

Kripfganz, S., Schneider, D.C. (2023), ardl: Estimating autoregressive distributed lag and equilibrium correction models. The Stata Journal, 23(4), 983-1019.

Liu, X., Liu, X. (2021), Can financial development curb carbon emissions? Empirical test based on spatial perspective. Sustainability, 13(21), 11912.

Marinaș, M.C., Dinu, M., Socol, A.G., Socol, C. (2018), Renewable energy consumption and economic growth. Causality relationship in Central and Eastern European countries. PLoS One, 13(10), e0202951.

Meo, M.S., Abd Karim, M.Z. (2022), The role of green finance in reducing CO_2 emissions: An empirical analysis. Borsa Istanbul Review, 22(1), 169-178.

Muhammad, A.M., Basha, M.B., AlHafidh, G. (2020), UAE Islamic banking promotional strategies: An empirical review. Journal of Islamic Marketing, 11(2), 405-422.

Muradov, N. (2017), Low to near-zero CO_2 production of hydrogen from fossil fuels: Status and perspectives. International Journal of Hydrogen Energy, 42(20), 14058-14088.

Narayan, P.K. (2005), The saving and investment nexus for China: Evidence from cointegration tests. Applied Economics, 37(17), 1979-1990.

Nguyen, V.C.T., Le, H.Q. (2024), The impact of ICT infrastructure, technological innovation, renewable energy consumption and financial development on carbon dioxide emission in emerging economies: New evidence from Vietnam. Management of Environmental Quality: An International Journal, 35, 1233-1253.

Nkoro, E., Uko, A.K. (2016), Autoregressive distributed lag (ARDL) cointegration technique: Application and interpretation. Journal of Statistical and Econometric Methods, 5(4), 63-91.

Ren, X., Zhao, M., Yuan, R., Li, N. (2023), Influence mechanism of financial development on carbon emissions from multiple perspectives. Sustainable Production and Consumption, 39, 357-372.

Saleem, H., Khan, M.B., Mahdavian, S.M. (2022), The role of green growth, green financing, and eco-friendly technology in achieving environmental quality: Evidence from selected Asian economies. Environmental Science and Pollution Research, 29(38), 57720-57739.

Shahbaz, M., Destek, M.A., Dong, K., Jiao, Z. (2021), Time-varying impact of financial development on carbon emissions in G-7 countries: Evidence from the long history. Technological Forecasting and Social Change, 171, 120966.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K., Leitão, N. C. (2013), Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renewable and sustainable energy reviews, 25, 109-121.

Shi, Y., Wei, X., Sheng, L., Yang, X. (2025), Effects of nitrogen fertilization on soil CH4, CO_2, and $N2_O$ emissions and their global warming potential in agricultural Peatlands. Agronomy, 15(1), 115.

Solarin, S.A. (2019), Modelling the relationship between financing by Islamic banking system and environmental quality: Evidence from bootstrap autoregressive distributive lag with Fourier terms. Quality Quantity, 53(6), 2867-2884.

Sun, X., Cheng, X., Guan, C., Wu, X., Zhang, B. (2022), Economic drivers of global and regional CH4 emission growth from the consumption perspective. Energy Policy, 170, 113242.

Tenaw, D., Beyene, A.D. (2021), Environmental sustainability and economic development in Sub-Saharan Africa: A modified EKC hypothesis. Renewable and Sustainable Energy Reviews, 143, 110897.

Tran, T., Tran, Q., Vu, N.T., Vo, D.H. (2023), Renewable energy, Urbanization, financial development and environmental degradation in the ASEAN countries. Environment and Urbanization ASIA, 14(1), 10-23.

Wang, C., Wood, J., Wang, Y., Geng, X., Long, X. (2020), CO_2 emission in transportation sector across 51 countries along the Belt and Road from 2000 to 2014. Journal of Cleaner Production, 266, 122000.

Wu, N., Zhang, Z., Lin, B. (2024), Responses of financial stress and monetary policy to global warming: Evidence from China. International Review of Financial Analysis, 92, 103092.

Yin, M. (2023), Sustainable management of ecosystem services and climate adaptation strategies: Achieving synergy between ecology and climate. Innovation in Science and Technology, 2(5), 28-32.

Zhang, Z., Pan, S.Y., Li, H., Cai, J., Olabi, A.G., Anthony, E.J., Manovic, V. (2020), Recent advances in carbon dioxide utilization. Renewable and Sustainable Energy Reviews, 125, 109799.