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EVALUATING THE ROLE OF FORESTED AREA, AGRICULTURAL LAND, ENERGY CONSUMPTION AND FOREIGN DIRECT INVESTMENT ON CO_2 EMISSIONS IN INDONESIA

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Abstract:

Environmental concerns have steadily gained attention as the economy has grown more rapidly. This ultimately impedes the growth of a high-quality economy. Several factors, namely forested area, agricultural land, energy consumption and foreign direct investment, have contributed significantly to economic expansion while simultaneously deteriorating the environment in the short and long run. Hence, this study empirically examines the effect of forested area, agricultural land, energy consumption and foreign direct investment on CO_2 emissions in the case of Indonesia from 1990 to 2020 by employing the autoregressive distributed lags (ARDL) approach. The results indicate that forested area negatively and significantly impacts CO_2 emissions in the short and long run. However, agricultural land, energy consumption and foreign direct investment positively influence CO_2 emissions in the long run. Moreover, agricultural land and foreign direct investment demonstrate a negative relationship with CO_2 emissions, whereas energy consumption positively affects CO_2 emissions in the short run. Thus, the results are insightful for policymakers to develop efficient strategies to reduce carbon emissions and eradicate environmental deterioration in Indonesia.

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CO_2 Emissions, Forests, Agricultural Land, Energy Consumption, Foreign Direct Investment

Introduction

The natural environment has been changing continuously on a global level. According to Ellis et al. (2010), about 50% of the habitat was unoccupied, and 45% was classified as semi-natural in the 1700s. However, the scenario has changed; about 20% of semi-natural and 25% of totally natural states remain on the earth's land surface, with human settlements now making up around 55% of the earth's land surface. The capacity of technology to help humanity achieve an unmatched level of economic growth at the expense of environmental deterioration may be the main factor. The generation of electricity and heat, which are responsible for over 25% of greenhouse gas (GHG) emissions, as well as the usage of forests, agriculture, and other land uses, which contribute to about 24% of emissions, are factors contributing to the environment's decline (IPCC, 2014). The second-largest emitter, the forest industry, has generated conflicting opinions. Several studies from the past claim that forests act as a carbon sink by absorbing CO_2 emissions from the atmosphere, and some support that forests are the primary source of carbon dioxide (CO_2) emissions (Aziz et al., 2020). Deforestation is predicted to release around three billion tonnes of CO_2 emissions yearly into the environment, while the biomass of forests is responsible for absorbing around 300 billion tonnes of CO_2 emissions from the atmosphere (Baccini et al., 2012; Raihan et al., 2022). Nearly half of Indonesia's land comprises forests, contributing significantly to the global carbon balance. Based on Figure 1, these forests cover around one million square kilometres (World Bank, 2022). Therefore, there is a need to address the issue of the forest's ability to lower CO_2 emissions in Indonesia (Figure 2).

Agriculture is another important industry in the economy, in addition to forestry. One of the world's largest agricultural producers, Indonesia depends heavily on the agriculture industry for its economic growth. In 2020, 13.7 per cent of Indonesia's GDP was generated by agriculture (World Bank, 2022). Given its extensive use of fossil fuels, the agriculture industry is considered the largest source of air pollution (Rauf et al., 2018). In addition, the output of agriculture is correlated with economic growth, thereby fostering consumer interest in goods, services, and a cleaner environment, and it also increases the capacity of the government to implement environmental laws (Raihan et al., 2022). Hence, whether Indonesia's agricultural industry is compatible with environmental sustainability must be addressed (Figure 3). Furthermore, energy consumption is another aspect contributing to the degradation of the environment. In order to supply the world's energy needs, fossil fuels are used, which harms the environment (Koçak & Şarkgüneşi, 2017). An industry must produce more to support economic expansion, and this higher energy consumption is inevitable, contributing to carbon emissions (Rahman, 2021). Based on Figure 4, the primary cause of environmental degradation in Asia is the consumption of energy (EIA, 2017). To achieve more remarkable economic growth, environmental standards in developing nations were eroded, which had a long-lasting effect on industrialisation and development. Despite the Indonesian government's introduction of sustainable development plans, the nation still relies on non-renewable energy, including coal and fossil fuels, to meet the rising need, leading to a rise in carbon emissions (Alam, 2022).

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Therefore, it is vital to investigate the possible effects of energy consumption on CO_2 emissions in Indonesia.

Moreover, urbanisation has improved the nation's infrastructure, bringing more foreign investors to set up operations. Foreign investment, however, has the potential to either raise or lessen environmental deterioration (Pujiati et al., 2023). Foreign direct investment (FDI) mainly contributes to pollution as it carries undesirable technology to the host country (Munir & Ameer, 2020). A country's capital inflows may have a significant environmental impact, subject to the technology utilised and environmental protection laws and regulations (Panait et al., 2022). FDI has been shown to have a favourable impact on CO_2 emissions in lower-middle income nations, according to Danlami et al. (2018). Recent research, however, asserted that FDI flows might also lower CO_2 emissions due to advancements in technology and management practices (Wang et al., 2019). Nevertheless, the investigation into how FDI affects environmental deterioration in Indonesia has yet to yield any conclusive results (Figure 5).

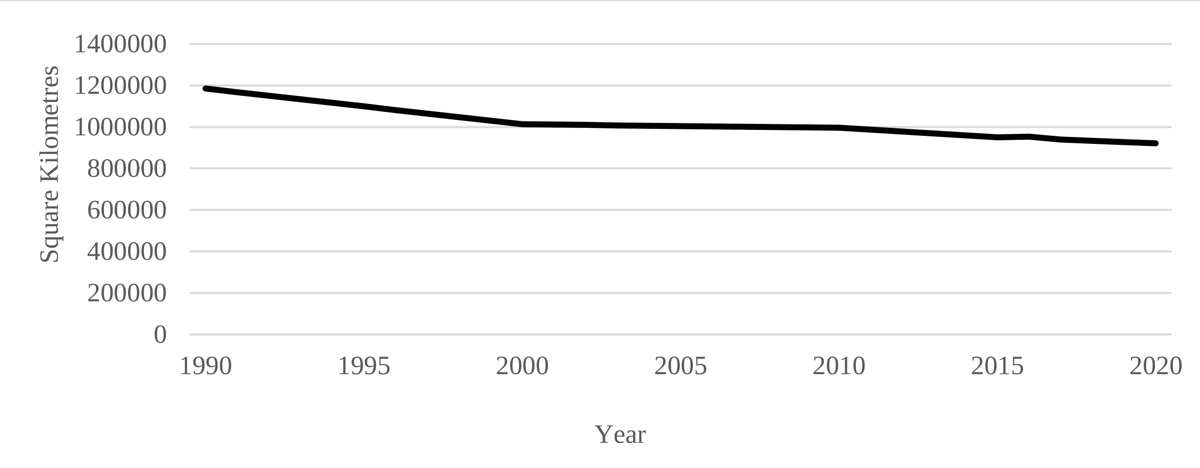

Figure 1: Annual Trend of Forest Area in Indonesia
Source: World Development Indicator Database

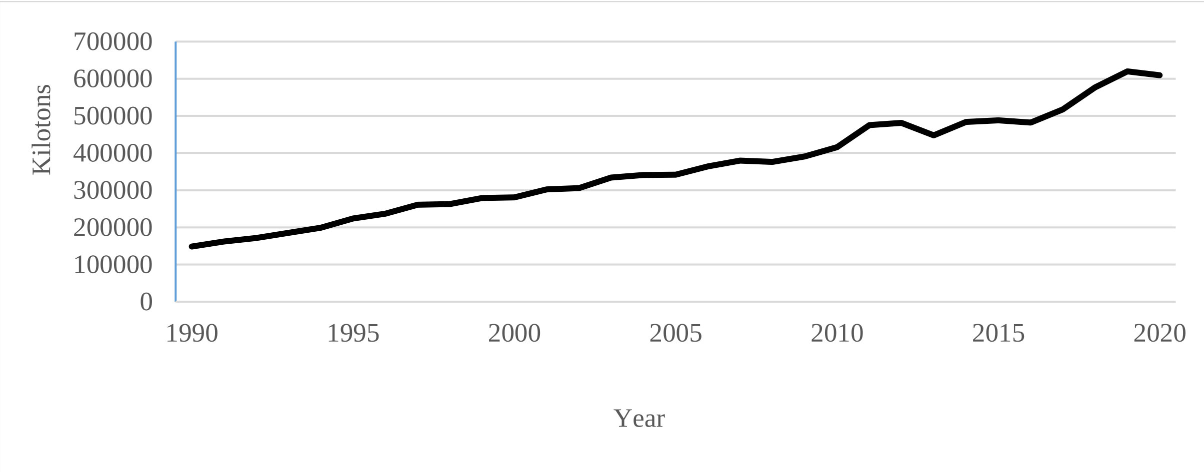

Figure 2: Annual Trend of CO_2 Emissions in Indonesia
Source: World Development Indicator Database

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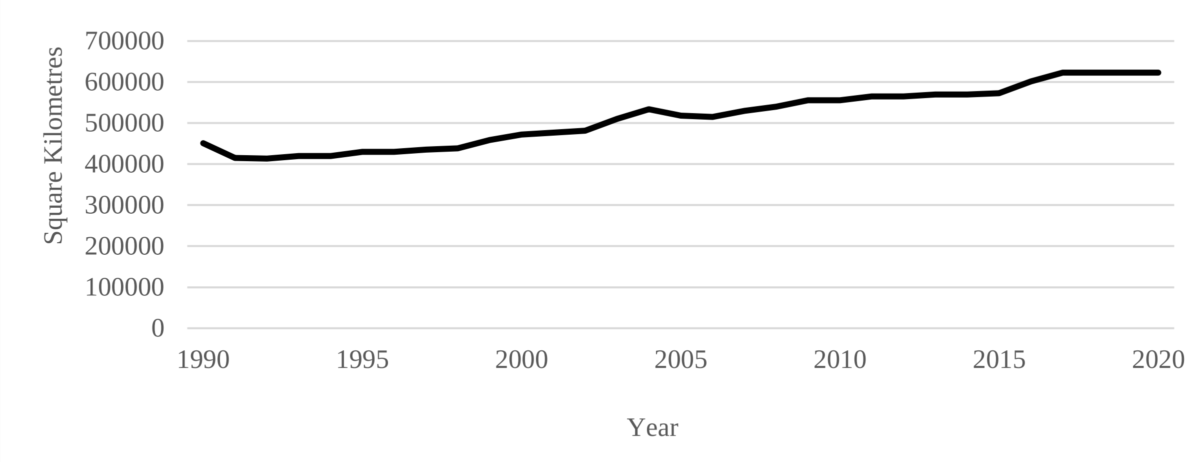

Figure 3: Annual Trend of Agriculture Land in Indonesia
Source: World Development Indicator Database

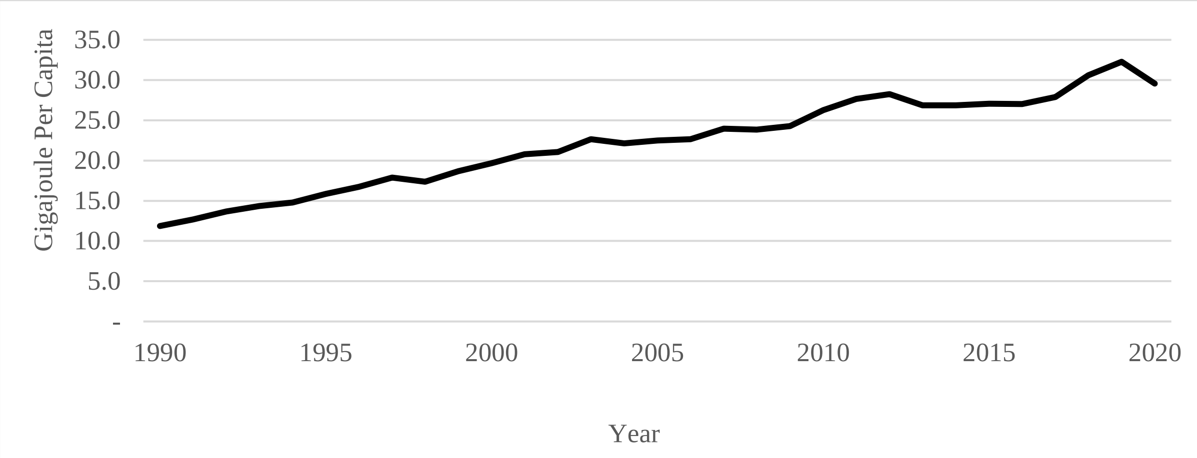

Figure 4: Annual Trend of Energy Consumption in Indonesia
Source: BP Statistical Review of World Energy Database

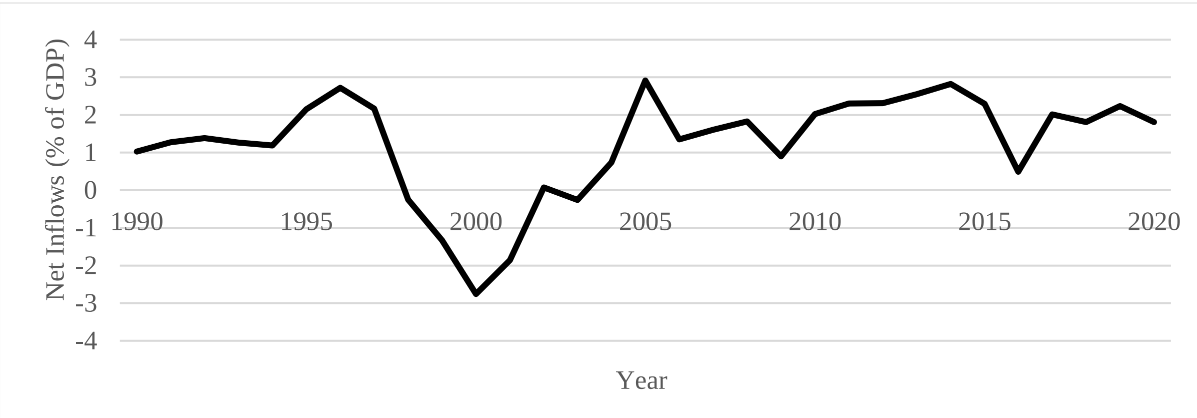

Figure 5: Annual Trend of Foreign Direct Investment in Indonesia
Source: World Development Indicator Database

Environmental concerns have steadily gained attention as the economy has grown more rapidly. This ultimately impedes the growth of a high-quality economy. To strike a balance between mitigating climate change and sustainable growth, the Indonesian government must

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consider the capacity to reduce emissions. By examining the influence of CO_2 emissions drivers, it is possible to address how Indonesia may reduce emissions. Although it has become a widely discussed problem globally, there is a lack of investigations examining the link between CO_2 emissions and factors that reduce them in the case of Indonesia over the short and long run. Several factors, namely forested area, agricultural land, energy consumption and foreign direct investment, have contributed significantly to economic expansion while simultaneously deteriorating the environment in the short and long run. To address this research gap, this study employs the Autoregressive- Distributed Lag (ARDL) method to investigate the effects of forested area, agricultural land, energy consumption and foreign direct investment on CO_2 emissions in Indonesia. This study will be helpful since it contributes to Indonesia's policies and current literature in many ways. First, this study attempt to investigate the short-run and long-run relationship between the effect of forested area, agricultural land, energy consumption and foreign direct investment on CO_2 emissions in Indonesia. Second, this study employed the most recent and complete data from 1990 to 2020. Finally, this paper provides policymakers in Indonesia with more reliable and comprehensive data for developing practical policies in low carbon economies, sustainable forest management, green agriculture, cleaner energy, and less polluting FDI. The study's results also serve as a reference for other developing countries looking to embrace environmentally sustainable practices while simultaneously stepping up their mitigation and adaptation efforts for climate change.

The paper's remaining sections are organised as follows. Section 2 provides a brief literature review. Section 3 explains the data, model specification and econometric technique used in the analysis. Section 4 discusses and reports the empirical results. Finally, Section 5 presents the conclusion and some policy recommendations.

Literature Review

Forest is responsible for maintaining the balance of the ecosystem. The loss of forests as the second largest source of carbon dioxide is expected to have a massive impact on the environment (Van Der Werf et al., 2009). Despite the forest's importance in CO_2 emission, only a few researchers discuss the linkage quantitatively. Studies conclude that forested area is negatively related to carbon emission. Waheed et al. (2018) employed the annual data of Pakistan and found that an increase in forest area can reduce CO_2 emission significantly in both the short and long run. In the case of Malaysia, Begum et al. (2020) indicated that shrinking the forested area by one hectare gives rise to three kilotons of carbon emission. Besides, this result is robust to multiple estimation methods in a study by Raihan and Tuspekova (2022b). The study utilised the time series data from Brazil from 1990 to 2019 and found that forested area is significant in cushioning CO_2 emission. The result is robust to the autoregressive distributed lag (ARDL) approach and the dynamic ordinary least squares (DOLS) method. More specifically, Arifanti et al. (2021) investigated the effect of mangrove deforestation on carbon emissions in the case of Indonesia. According to the study, preservation of the existing mangrove forest is considered the most practical measure to slow down the rise of CO_2 concentration in the atmosphere. The idea is echoed by Raihan and Tuspekova (2022c) in Russia's case, stating that forest expansion by 1% is estimated to reduce CO_2 emission by 4.29%.

Land used for agricultural purposes has become one of the significant sources of CO_2 emission, which is responsible for 14 to 30% of greenhouse gas emissions (Reynolds & Wenzlau, 2012; Holly, 2015). This is due to the sizeable use of non-renewable energy sources and fertilisers rich in nitrogen in agriculture (Aziz et al., 2020). Recent studies have been carried out with various econometric estimation methods across different countries. Waheed et al. (2018) showed that agriculture production is a significant source of carbon emissions in Pakistan. Raihan et al. (2022) suggested that agricultural land expansion contributes positively to CO_2 emission in the case of Malaysia using the bounds testing (ARDL) method. The study found that a 1% expansion in agricultural land is estimated to increase CO_2 emission by 0.84% in the long term. Besides, time series data of Peru from 1990 to 2018 employed by Raihan and Tuspekova (2022c) indicated that increased agricultural land deteriorates the environment quality through increased CO_2 emission. The result is robust to bounds testing and Dynamic Ordinary Least Squares (DOLS) approaches.

Generally, most of the previous literature agreed that land use for agriculture is positively related to CO_2 emission. However, there are some exceptions. In the case of Turkey, Dogan (2016) found that agriculture production is negatively related to CO_2 emission. A similar result was reported in ASEAN countries when Liu et al. (2017) employed time series data from 1970 to 2013, indicating that agriculture value-added leads to the mitigation of CO_2 emission. The finding gained support from Jebli and Youssef (2017) in the case of North African countries by applying some econometrics such as Ordinary Least Square, Fully Modified Ordinary Least Square and Dynamic Ordinary Least Square methods. The same goes for the studies by Wang et al. (2020), Anwar et al. (2019), and Rafiq et al. (2016). Due to the controversy in the empirical study on the effect of the agriculture sector on the environment quality, particularly on CO_2 emission, this study attempts to clarify the linkage between the two variables further.

The past literature has established a positive linkage between energy consumption and CO_2 emission due to energy use, particularly conventional sources such as coal and oil, stimulating greenhouse gas emissions. By applying the dynamic autoregressive distributed lag (ARDL) approach, Khan et al. (2019) reported that energy consumption positively affected CO_2 emissions in Pakistan by employing data from 1971 to 2016. Along the same line, Adebayo and Kalmaz (2021) found similar results in Egypt from 1971 to 2014 using ARDL, Fully Modified Ordinary Least Square and Dynamic Ordinary Least Square methods. The same goes for the cases of Turkey (Kirikkaleli & Kalmaz, 2020), Nigeria (Odugbesan & Adebayo, 2020), Mexico (Adebayo, 2020), and Indonesia (Adebayo, 2021). Generally, previous studies suggested that energy consumption is not environmentally friendly as it accelerates the emission into the atmosphere, creating a greenhouse effect that threatens the environment.

Foreign direct investment is another factor of CO_2 emission that received great attention. The literature concerning the effect of foreign direct investment on CO_2 emissions consists of both pollution haven and halo hypothesis. The studies supporting the pollution haven hypothesis suggested that foreign direct investment causes environmental degradation, leading to higher energy consumption (Salahuddin et al., 2018). The studies that supported the pollution haven hypothesis found that increasing foreign direct investment increases CO_2 emissions (Ren et al., 2014; Salahuddin et al., 2018; Essandoh et al., 2020). Ren et al. (2014), in a study employing data from eighteen industries in China ranging from 2000 to 2010, indicated that foreign direct investment deteriorates the environment by increasing CO_2 emissions. Besides, Salahuddin et al. (2018) proved the same in the case of Kuwait by employing data from 1980 to 2013 using bound testing. Essandoh et al. (2020) further clarified that the hypothesis is particularly true in the case of emerging economies.

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In contrast, studies also came up with results that support the pollution halo proposition. The literature argues that foreign direct investment brings green technologies that benefit the environment (Tang & Tan, 2015; Zhang & Zhou, 2016; Suarguesng et al., 2018; Jebli et al., 2019). In the case of Vietnam from 1976 to 2009, it was found that foreign direct investment affected CO_2 emissions negatively (Tang & Tan, 2015). While in the case of China, the result is similar by employing data from 1995 to 2010 using the Stochastic Impacts by Regression on Population, Affluence, and Technology model. Along the same line, Sung et al. (2018) found that foreign direct investment improves environmental quality in China using data from 2002 to 2015.

Other than the haven-halo hypothesis, the researchers suggested that foreign direct investment either has no effect on CO_2 emission (Lee, 2013; Mahmood et al., 2020) or they have a nonlinear relationship (Chandran & Tang, 2013; Xie et al., 2020). Based on past studies, there still needs to be a consensus in the literature on the effect of foreign direct investment on CO_2 emission. Therefore, it is one of the objectives of this study to further clarify the connection between the two variables.

Methodology

Data

The present study performs an empirical analysis of the effect of forested area, agricultural land, energy consumption and foreign direct investment on CO_2 emissions in Indonesia by employing the Autoregressive- Distributed Lag (ARDL) cointegration approach. This study serves the forested area, agricultural land, energy consumption and foreign direct investment as the independent variables, whereas CO_2 emissions as the dependent variable. Annual time series data from 1990 to 2020 are used in this research. All variables are converted into a logarithm form except the foreign direct investment variable. The variables of forested area, agricultural land, foreign direct investment and CO_2 emissions were retrieved from the World Development Indicator database. At the same time, energy consumption was obtained from the BP Statistical Review of World Energy database. The CO_2 emissions (LCO_2) variable is measured in kilotons (kt), forest area (LFA) and agricultural land (LAL) is measured in square kilometres (sq. km), energy consumption (LEC) is measured in energy consumption Gigajoule (GJ) per capita, and foreign direct investment (FDI) is measured in net inflows (% of GDP).

Specification of the model

For CO_2 emissions, forests serve a crucial dual function. Carbon sequestration is the process by which forests and their tree biomass remove and store atmospheric CO_2. The CO_2 is discharged into the atmosphere due to deforestation and vegetation chopping. Since deforestation contributes significantly to carbon dioxide emissions in Southeast Asia, especially in Indonesia, this study attempts to determine the possibility of forested areas decreasing emissions. Hence, using the following function, the effect of forested area, agricultural land, energy consumption and foreign direct investment on CO_2 emissions was examined:

$$\mathrm{CO2_t} = f(\mathrm{FA_t};\ \mathrm{AL_t};\ \mathrm{EC_t};\ \mathrm{FDI_t}) \quad (1)$$

where $\mathrm{CO2_t}$ is the CO_2 emissions at time t; $\mathrm{FA_t}$ is the forested area at time t; $\mathrm{AL_t}$ is denoted as agricultural land at time t; $\mathrm{EC_t}$ is denoted as energy consumption; and $\mathrm{FDI_t}$ is denoted as foreign direct investment at time t.

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Additionally, Equation (1) can be used to construct the following empirical model:

$$CO2_t = \beta_0 + \beta_1 FA_t + \beta_2 AL_t + \beta_3 EC_t + \beta_4 FDI_t + \varepsilon_t \quad (2)$$

where coefficients of each independent variable are denoted as β_1, β_2, β_3, and β_4. The intercept and error term are represented by β_0 and ε_t.

Equation (2) may be further organised logarithmically as shown below:

$$LCO2_t = \beta_0 + \beta_1 LFA_t + \beta_2 LAL_t + \beta_3 LEC_t + \beta_4 FDI_t + \varepsilon_t \quad (3)$$

There are various steps in the methodological discussion. In the first step, the unit root test is performed to examine whether the time-series variables in Equation (3) have stationary features to avoid spurious regression. To verify the order of integration among the variables, the augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) unit root test are used to evaluate all variables in levels and the first difference. In the second step, the Autoregressive Distributed Lag (ARDL) bounds test to cointegration suggested by Pesaran et al. (2001) is employed. This test offers a way to evaluate events in the short and long run. The ARDL bounds test is shown below in Equation (4):

$$\Delta LCO2_t = \beta_0 + \beta_1 LCO2_{t-1} + \beta_2 LFA_{t-1} + \beta_3 LAL_{t-1} + \beta_4 LEC_{t-1} + \beta_4 FDI_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LFA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LAL_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LEC_{t-i} + \sum_{i=1}^{q} \gamma_5 \Delta FDI_{t-i} + \mu_t \quad (4)$$

where Δ is the first difference operator, μ_t is a white-noise disturbance term, and q is the optimum lag length in the Equation (4). We start to estimate Equation (4) based on ordinary least squares (OLS) and conduct an F-test to determine the joint significance of lagged levels of the variables involved. The primary purpose of this procedure is to identify the long-run relationship among the variables. The null hypothesis of no cointegration ($H_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$) against alternative of cointegration ($H_1 \neq \beta_1 \neq \beta_2 \neq \beta_3 \neq \beta_4 \neq 0$) will be tested. The null hypothesis is not rejected if the calculated F-statistic is less than the value of the lower bound. This indicates that there is no long-run relationship among the variables. However, if the calculated F-statistic is more than the value of the upper bound. This reveals that there is a long-run relationship among the variables. On the other hand, if the calculated F-statistic falls between the lower and upper bound, the result is inconclusive. In the last step, we employ the error correction model (ECM) based on the Figure (3). In order to confirm the convergence of the short-run dynamics linked to the long-run equilibrium, the sign of the lagged error correction (ECT) coefficient must be statistically significant and negative. The error correction model is expressed below:

$$\Delta LCO2_t = \beta_0 + \beta_1 \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LFA_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta LAL_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LEC_{t-i} + \sum_{i=1}^{q} \gamma_5 \Delta FDI_{t-i} + \lambda ECT_{t-1} + \mu_t \quad (5)$$

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Where λ is represented the adjustment parameter's speed, displaying the rate of convergence from the short run to the long run. Diagnostic analysis is carried out to ensure appropriate statistical techniques are applied to the model. The stability of the long-run coefficient and short-run dynamics are evaluated in accordance with Pesaran (1997) using the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals. (CUSUMSQ).

Empirical Results and Discussion

This study performed the Augmented Dickey Fuller (ADF) and PhillipsPerron (PP) unit root tests to examine the order of integration of the variables and determine the possibility of performing ARDL. The results in the Table 1 revealed that forested area and agricultural land variables are stationary at level or integrated at I(0), whereas CO_2 emissions, energy consumption and foreign direct investment variables are non-stationary at levels but stationary at first differences or integrated at I(1). Hence, we are allowed to perform ARDL with the combination order of integration in the study's variables given that Pesaran et al. (2001) indicated that ARDL is appropriate with the mix of I(0) and I(1)variables.

Table 1: Unit Root Test Results

Variables	Augmented Dickey-Fuller (ADF)		Phillips-Perron (PP)	
	At level	At First difference	At level	At First difference
LCO2	-2.7145	-4.5051***	-3.2015	-6.2059***
LFA	-3.4821*	-1.3512	-4.0625***	-3.6549*
LAL	-2.7004	-4.8186***	-4.6744***	-11.6242***
LEC	-1.4765	-5.2471***	-1.7715	-8.0281***
FDI	-2.9273	-5.0673***	-2.3896	-5.0673***

Note: ***, * represent 1%, and 10% of significance level respectively.

Following confirmation of the series' stationarity properties, we carry out the ARDL bounds test for cointegration value to examine whether there is a long-run relationship among the variables. The result of the ARDL cointegration was shown in Table 2, which revealed that the computed F-statistic (6.1036) is more than 10%, 5% and 1% of upper critical bound in the order zero and one. This indicates that the null hypothesis of no cointegration is rejected at all significance levels. This can conclude that a steady state long run relationship exists amongst CO_2 emissions, forested area, agricultural land, energy consumption and foreign direct investment. Since there is a long-run relationship among the variables, we were able to determine long-run coefficients, which are displayed in Table 3.

Table 2: Bounds Test for Cointegration Test

Test Statistic	Value	Significance level	Critical Value	
			I(0)	I(1)
F-statistic	6.1036			
		1%	4.28	5.84
		5%	3.058	4.223
		10%	2.525	3.56
Null Hypothesis: No Cointegration				

Note: The critical value is taken from Pesaran et al., (2001). Table C. Case II: restricted intercept and no trend.

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The results of the long run elasticities for CO_2 emissions and its determinants are presented in Table 3 (Panel B). The estimated results reveal that forested area negatively and significantly impacts CO_2 emissions in the long run. This result implies that a 1% increase in forested area could lead to 2.09% decrease in CO_2 emissions. This result is consistent with the finding of Begum et al. (2020) which demonstrates that deforestation, or the loss of one acre of forests, causes an increase of three kilotons of carbon dioxide emissions in Malaysia. Moreover, Aziz et al. (2020) show that the effect of forestry on CO_2 emissions is negative and significant relationship in Pakistan by using Quantile ARDL approach. Besides, the dynamic panel data method's finding shows that forests significantly lower CO_2 emissions worldwide, though the impacts differ by region. For every 1% rise in world forest area, a 0.11% decrease in CO_2 emissions is predicted, all else being equal (Parajuli et al., 2019). Likewise, Raihan and Tuspekova (2022) claim that Turkey's association between the forest area and CO_2 emissions is significantly negative. This is because forests absorb CO_2 from the atmosphere and store it in their vegetation and soil, they improve the quality of Turkey's climate. Increasing forest areas helps to increase the amount of carbon that forests store, which slows down the long-term degradation of the environment. The most cost-effective method of halting environmental degradation and reducing climate change is increasing forest carbon storage.

On the other hand, at a 1% significance level, the estimated long-run coefficient of agricultural land is significantly positive, indicating that an increase of 1% in agricultural land is associated with an increase of 0.67% in CO_2 emissions. This result is reconfirmed the finding of Parajuli et al. (2019) based on the panel data of 86 countries which reveal that CO_2 emissions rise by 0.15% for every 1% growth in agricultural area. However, though it is inconsistent, Europe has a stronger correlation with agricultural area than other regions. This finding suggests that the agriculture industry in Europe is becoming more automated and commercialised, requiring more farm supplies and increasing the amount of emissions produced. In addition, Aydoğan and Vardar (2020) report that agriculture has a positive effect on CO_2 emissions indicates that the emerging seven (E7) nations continue to produce agricultural products using fossil fuels. Similarly, in the case of the G20's developing countries, agriculture has a favourable impact on CO_2 emissions, which can be attributed to their significant global agricultural share. The primary sources of carbon emissions in modern agriculture are the large amounts of fossil fuels and fertiliser produced, along with emissions from animal output and crops (Qiao et al., 2019).

The effect of energy consumption on CO_2 emissions shows a significant and positive relationship in the long run. As a 1% rise in energy consumption could result in an increase of 0.61% in CO_2 emissions. This result is supported by Adebayo et al. (2020) in which CO_2 emissions and energy use have a positive relationship for MINT (Mexico, Indonesia, Nigeria and Turkey) countries using panel data analysis. Likewise, Zmami and Ben-Salha. (2020) reveal that the long-term effects of energy usage on CO_2 emissions are significant and positively associated in Gulf Cooperation Council countries by employing Pooled Mean Group and panel Autoregressive Distributed Lag approach. Similarly, the foreign direct investment also positive significant influenced CO_2 emissions. The CO_2 emissions increase by 2.32% for every 1% increase in the foreign direct investment. This result concurs with past studies of Aller et al. (2021), which implies that increased carbon emissions are linked to increased FDI inflows. Developed nations frequently invest in developing nations with more relaxed environmental laws or environmental taxes to increase their revenues. It causes polluting firms in developed nations to relocate to these developing regions. Consequently, when FDI-led economic activity expands, carbon emissions in the host nations rise. Shahbaz et al. (2019)

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investigated how FDI inflows affected carbon emissions in the United States, and the findings indicate that FDI inflows raise carbon emissions. FDI inflows have not decreased carbon dioxide emissions as the Environmental Kuznets Curve theory projected, despite the United States being a developed nation.

Table 3 (Panel A) displays the results of short run dynamics CO_2 emissions and its determinants. The estimated results show that forested area have substantial adverse effect on CO_2 emissions as the similar case of long run. Notably, a 1% increase in the forested area would lead to a 2.51% decrease in CO_2 emissions. Conversely, agricultural land and foreign direct investment have statistical negative effect on CO_2 emissions as not similar stand with long run. However, energy consumption holds its position of increasing CO_2 emissions as similar in the long run. According to theory, the coefficient of error correct term (ECT) is negative, statistically significant at 1%, and lower than one. The coefficient value implies that any divergence from variables' long run equilibrium will be adjusted and converge to long run equilibrium level at 0.18% yearly.

Table 3: ARDL Estimation Results

Independent Variable	Dependent Variable: LCO2		
	Coefficient	Standard Error	T-statistic
Panel A: Short Run Dynamics			
ΔLFA	-2.5068**	0.9348	-2.6816
ΔLAL	-0.9205***	0.2313	-3.9787
ΔLEC	0.2722**	0.1034	2.6315
ΔFDI	-0.0185***	0.0055	-3.3188
Panel B: Long Run Relations			
LFA	-2.0981***	0.5084	-4.1264
LAL	0.6675***	0.2042	3.2683
LEC	0.6129***	0.1405	4.3611
FDI	0.0232***	0.0054	4.2524
Constant	31.0409***	8.5189	3.6438
ECT (-1)	-0.0185***	0.0055	-3.3188

Notes: ECT is the error-correction term is the coefficient value of the normalised cointegrating equation. **, *** represents null rejection at 5% and 1% level of significance, respectively.

Additionally, we performed diagnostic tests, shown in Table 4, to demonstrate the consistency and effectiveness of our model. The results demonstrate that our model successfully addressed the four (4) time series issues of serial correlation, functional form, normality, and heteroscedasticity. Since the null hypothesis cannot be rejected for any of the four (4) test findings, it is clear that our model can address every one of the modelling issues. In Figure 6 and 7, the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUM of squares) demonstrate the model's stability. According to the plots of the CUSUM and CUSUMSQ statistics, which are clearly inside the critical boundaries. This indicates that all of the coefficients in the model are stable across the sample period.

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Table 4: Diagnostics Checking Results

Test Statistic	F-statistic	Prob. Values
a: Normality	4.1434	0.1259
b: Serial correlation	2.2989	0.1626
c: Functional form	0.6401	0.5523
d: Heteroscedasticity	0.0109	0.9892
e: CUSUM	Stable	
f: CUSUMSQ	Stable	

Notes: a= Jarque-Bera test, b= Breush-Godfrey LM test, c= Ramsey's RESET test, d= ARCH test, e= Stability test by Cumulative Sum, f= Stability test by Cumulative Sum of Squares.

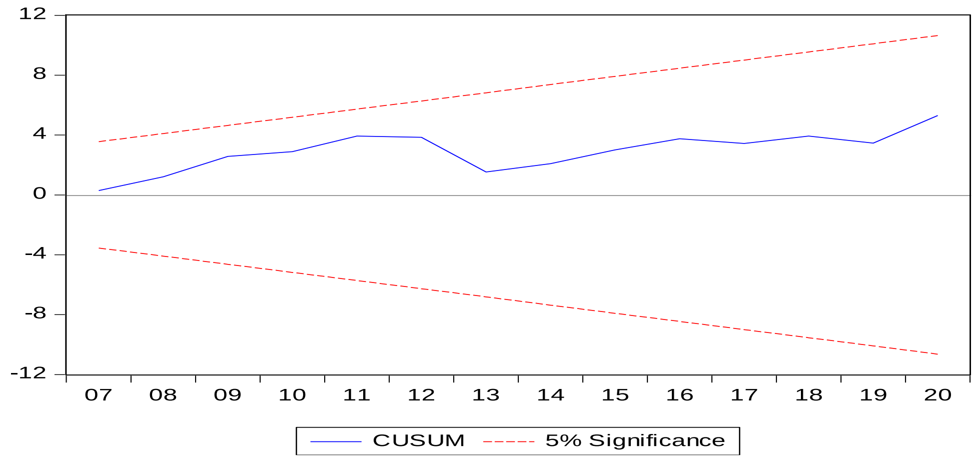

Figure 6: Plot of Cumulative Sum of Recursive Residuals

Source: All Authors

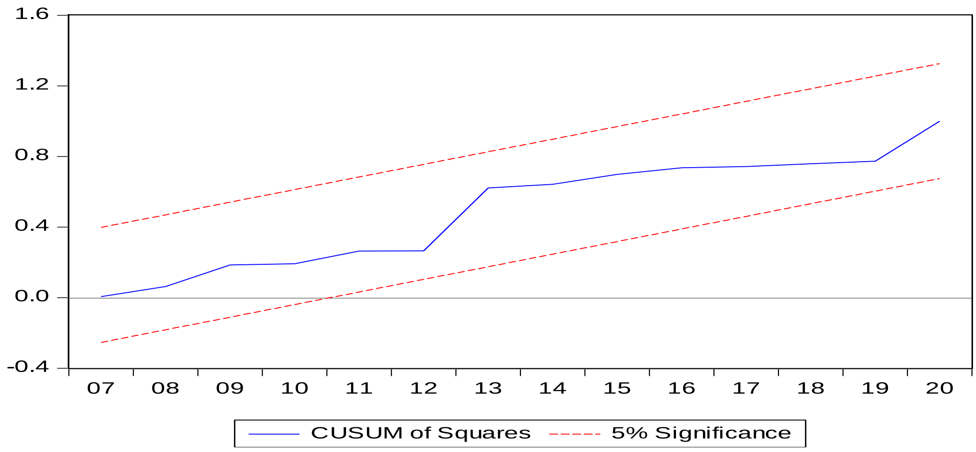

Figure 7: Plot of Cumulative Sum of Squares of Recursive Residuals

Source: All Authors

Conclusion and Policy Recommendations

Using time series data from 1990 to 2020, this study investigated the effect of forested area, agricultural land, energy consumption and foreign direct investment on CO_2 emissions. The result of the ARDL cointegration demonstrates a long-run relationship amongst CO_2 emissions, forested area, agricultural land, energy consumption and foreign direct investment. The empirical finding in the long run suggests that forested area has a negative and significant impact on CO_2 emissions in Indonesia for the sample period. On the other hand, agricultural land, energy consumption and foreign direct investment positively influence CO_2 emissions in the long run. The negative relationship between forested area and CO_2 emissions remains the same even in the short run dynamics. However, agricultural land and foreign direct investment negatively impact CO_2 emissions in the short run. While energy consumption positively affected CO_2 emissions.

Following the findings of the study, some policy recommendations are formed. Indonesia's policy maker is recommended to formulate efficient environmental policies with a stronger emphasis on lowering CO_2 emissions through improving forest ecosystems. The policy maker has to increase funding for forestry projects and put strict forest regulations and policies in place in order to minimise CO_2 emissions caused by deforestation. By preventing destruction in Indonesia's forests, which are home to a diverse range of species, strong forest conservation measures are crucial to safeguarding biodiversity. Besides, the forestry industry in Indonesia has tremendous tourist potential, and promoting ecotourism might help the nation's economy. Moreover, through putting into practice various forestry-based mitigation strategies, including agroforestry, urban forestry, wood-based bioenergy, reforestation, and afforestation. On the other hand, the government should assist the transition to cleaner, more efficient energy sources in agriculture in order to increase agricultural output over the long term. For instance, government should encourage the use of renewable energy, especially clean renewable energy like solar and wind, as it increases agricultural output and reduces CO_2 emissions. Furthermore, subsidies for renewable energy use in agriculture would increase the sector's competitiveness on international markets while reducing CO_2 emissions.

Furthermore, the country's sustainable growth would be enhanced by creating and implementing sensible laws to restrain Indonesia's energy usage and manufacturing sector procedures. CO_2 emissions levels will continue to be controlled if the policy maker assigns CO_2 emissions restrictions on enterprises and industry. To mitigate the pollution, policy maker should impose the stringent punishment or high taxes for those polluters who break the rules. Promoting renewable energy in Indonesia should be a higher priority for policy maker. Since the use of renewable energy may aid in the reduction of emissions, Indonesia must adopt policies to lower the cost of renewable energy and discourage the use of fossil fuels in businesses and families. For instance, to lower pollution, research and development of green technology should be executed. Moreover, FDI inflows have been shown to contribute to economic development, but they may also harm the environment, which lowers the standard of economic development. Therefore, policymaker is urged to develop practical solutions to enhance the effectiveness of policies that are unique to pollution emissions. Policymaker is advised to use their wisdom in selecting the greener or less polluting FDI.

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