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Research article

The Effects of Economic Growth, Financial Development, Trade Openness, and Energy Consumption on CO_2 Emission in Indonesia

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Abstract: This study investigates the effects of economic growth, financial development, trade openness, and energy consumption in Indonesia from 1980 to 2020. The analytical method used is autoregressive distributed lagged (ARDL) modeling. The data for the study is sourced from official websites such as the World Bank, Our World in Data, and British Petroleum. The study findings show that economic growth and energy consumption increase CO_2 emissions in Indonesia in both the short and long run. On the other hand, financial development and trade openness significantly reduce CO_2 emissions in Indonesia in the long run. In the short run, trade openness also helps decrease CO_2 emissions in Indonesia. However, the financial development variable does not significantly impact CO_2 emissions in Indonesia in the short run.

Keywords: CO_2 emission, economic growth, financial development, trade, energy consumption

JEL Classification: F18, Q51, Q56, Q54

Abstrak: Penelitian ini bertujuan untuk menyelidiki pengaruh pertumbuhan ekonomi, perkembangan sektor keuangan, keterbukaan perdagangan, dan konsumsi energi terhadap emisi karbon di Indonesia pada tahun 1980 hingga 2020. Metode analisis yang digunakan adalah pemodelan autoregressive distribution lagged (ARDL). Data penelitian ini bersumber dari situs resmi seperti Bank Dunia, Our World in Data, dan British Petroleum. Temuan penelitian menunjukkan bahwa pertumbuhan ekonomi dan konsumsi energi meningkatkan emisi CO_2 di Indonesia baik dalam jangka pendek maupun jangka panjang. Di sisi lain, pembangunan keuangan dan keterbukaan perdagangan secara signifikan mengurangi emisi CO_2 di Indonesia dalam jangka panjang. Dalam jangka pendek, keterbukaan perdagangan juga membantu menurunkan emisi CO_2 di Indonesia. Namun variabel perkembangan sektor keuangan tidak berdampak signifikan terhadap emisi CO_2 di Indonesia dalam jangka pendek.

Kata Kunci: emisi CO_2, pertumbuhan ekonomi, perkembangan finansial, perdagangan, konsumsi energi

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1. INTRODUCTION

Climate change has become a frequently discussed issue in the present time. It is a significant change in temperature and weather patterns over time. According to the UNFCCC, climate change can occur due to human activities that alter the natural climate variability and global atmospheric composition. The global atmospheric composition refers to greenhouse gases, including carbon dioxide, nitrogen, methane, etc. This thickening of the global atmosphere leads to heat-trapping, contributing to the greenhouse effect. Based on the report published by the IPCC in 2014, carbon dioxide is identified as the primary contributor to greenhouse gases, accounting for 76 percent, followed by methane at 16 percent, nitrogen at 6 percent, and fluorinated gases (f-gases) at 2

percent. This data was analyzed using global greenhouse gas data from the year 2010**.** The handling of climate change, which has been widely discussed, is incorporated into the concept of sustainable development (SDGs). The concept of sustainable development (SDGs) prioritizes present-day development considerations while considering the long-run processes and impacts that will affect future generations. Sustainable development has three main pillars: economy, social, and environment. In Indonesia, the SDGs target has become a priority in national development (Bappenas). Carbon emission is one of the main cause of climate change. This emission are released into the atmosphere causing the rise in earth's temperature. The intensity of economic acitvity is one of the major source of carbon emission. Moreover, most countries in the world strive for their economic growth because it improves the well-being of society in general.

The financial industry has a crucial role in the economic development and growth of a country. Nevertheless, the environmental implications of financial development have to be taken into consideration. A financial industry that promotes economic growth can result in increasing energy consumption (Islam et al., 2013; Shahbaz et al., 2017). Several studies regarding the nexus between financial development and carbon emissions show mixed results. Shahbaz et al. (2013) pointed out that financial development that was per capita access to domestic credit of the private sector supported lower carbon emissions per capita. Other studies reported a positive association between financial development and carbon emission (Boutabba, 2014; Cetin et al., 2018) However, Abbasi and Riaz (2016) investigated the effect of economic and financial development on carbon emissions in a small emerging economy and found that the financial development had negative effects on carbon emission both in the short-run and long run. Some other studies also showed negative linkages for instance Katircioglu and Taspinar (2017) in Turkey, Shahbaz et al. (2018) in France, Zaidi et al. (2019) in 17 APEC countries, Nasreen et al.(2015) in middle- and low-income countries.

Trade openness is another important factor that affects environmental quality. Trade openness could reduce environmental degradation (Shahbaz, Kumar Tiwari, et al., 2013). Trade openness in the form of financial openness and liberalization can attract a higher level of study and development creating technological innovations. Technological innovations lead to energy efficiency and hence lower carbon emissions. Gozgor (2017) using the dataset of OECD countries, obtained the same conclusion that trade openness was negatively associated with carbon emissions in the long run. In contrast, Dou et al. (2021) discovered that increasing trade openness had a direct and indirect positive impact on carbon emissions. Mahmood (2019) also found consistent results that trade openness increased CO_2 emissions in Tunisia. In addition, Fang et al. (2019) using panel data of 82 developing countries observed that not only the trade openness was positively associated with the carbon emissions but also there was a positive impact of the index export quality on the growth rate of carbon dioxide emissions.

Recent studies investigate the connection between economic growth and consumption of energy. Muhammad (2019) studied the linkage of economic growth, energy consumption, and CO_2 emissions on each other in emerging, developing, and Middle-East and North-African regions and found a positive relationship between economic growth and energy consumption in developed and emerging countries. A study in 170 countries by Wang et al. (2018) investigated the association of economic growth, carbon emission, urbanization, and economic development and found that positive associations existed in entire variables. Zhong et al. (2019) examined the association between electricity consumption and economic growth and found that the presence of short-run and long-run causalities among these two variables. Only limited papers investigated the effects of economic growth, financial development, trade openness, and energy consumption on CO_2 Emissions in individual countries. The previous studies found inconsistent findings and did not provide comprehensive economic, energy, and trade to sustain environmental quality. Thus, this study contributed in two ways: (i) It applies the ARDL approach for long-run relationships between variables. (ii) It uses more recent data than the previous study.

2. RESEARCH METHODS

2.1. Data

The data used in this study is secondary data published by the World Bank, British Petroleum, and Our World in Data. Due to data limitations, the data utilized consists of annual data for Indonesia covering the years 1980 to 2020. The elaboration of variables and their operational definitions are provided in Table 1:

Table 1. Data and Measurement

Variables	Operational Definition	Unit measurement	Data Source
Carbon Emission (CO_2)	A chemical compound of oxygen and carbon atoms covalently bonded in gaseous form at temperatures and pressures in the earth's atmosphere.	Tonnes per capita	Our World in Data
Economic Growth (Y)	The total value added created by all enterprise units in a country or the total value of final services and goods produced by all economic units.	GDP growth (constant 2015 US$)	World Bank
Financial Development (FD)	Financial resources offered to the private sector by other depository companies (deposit-accepting companies excluding central banks), for example, loans, purchases of non-capital securities, and trading of credit and other receivables, constitute a repayment claim.	Domestic credit to the private sector (% of GDP)	World Bank
Trade Openness (TO)	The total amount of imports and exports of services and goods assessed as a percentage of GDP (World Bank)	Total trade (% of GDP)	World Bank
Energy Consumption (EC)	Main energy source before it is converted into other forms of fuel energy	Exajoule	British Petroleum

2.2. Model specification

The study uses the co-integration and Autoregressive Distributed Lag (ARDL) to analyze the impact of economic growth, financial development, trade openness, and energy consumption on CO_2 emissions in Indonesia. To determine the ARDL form in the Vector Error Correction Model (VECM) framework, this study follows the model proposed by Ali et al. (2019). The model is specified as follows:

$$\begin{aligned}\Delta \ln CO_{2t} = {} & \beta_0 + \beta_1 lnCO_{2t-1} + \beta_2 lnFD_{t-1} + \beta_3 lnEC_{t-1} + \beta_4 lnY_{t-1} + \beta_5 lnTO_{t-1} + \\ & \sum_{i=1}^{p} \gamma_i \Delta \ln CO_{2t-1} + \sum_{j}^{q} \delta_j \Delta \ln FD_{t-j} + \sum_{i}^{q} \vartheta_l \Delta ln\, Y_{t-l} + \sum_{m}^{q} \eta_m \Delta ln\, EC_{t-m} + \\ & \sum_{m}^{q} \upsilon_n \Delta ln\, TO_{t-m} + \vartheta ecm_{t-1} + \varepsilon_t \end{aligned} \quad (1)$$

Where, $lnCO_2$ is the log of CO_2 emission; $lnFD$ is the log of financial development; $lnEC$ is the log of energy consumption; lnY is the log of economic growth; $lnTO$ is the log of trade openness; Δ is first difference variable; and subscript t denotes the time of periods.

The next step is identifying a cointegration relationship in the model estimation using the Cointegration Bound Test technique. The advantage of this method is that it allows the use of stationary variables at level I(0), first difference I(1), or a combination of both. However, this model does not permit stationary variables at the second difference. The stationarity of variables will be checked first using the Augmented Dickey-Fuller method. Additionally, the Bound Test technique is

suitable for small sample sizes compared to other cointegration techniques (Shahbaz, Arouri, et al., 2014). For small sample sizes in the range of 30 to 80 observations, Narayan & Smith (2005) have developed a set of asymptotic critical F values. The critical values will differ for large and small samples (Zhong et al., 2019). Referring to the number of observations, we use the critical F value developed by Narayan (2005) For lag selection criteria, researchers determine the optimum lag using the SIC criteria following Ali et al. (2019). The null hypothesis in this study implies that there is no cointegration between the variables. The alternative hypothesis in this study is the presence of cointegration in the variable.

The study variables are said to have a cointegrating or long-run relationship if the F-statistic calculation results are above or greater than the highest value or I(1). There is no cointegration relationship if the F-statistic calculation is below the lowest value or I(0). Then if the value of the F statistic is between the lowest value (I(0)) and the highest value (I(1)), the cointegration test becomes invalid (Pesaran et al., 2001).

$$ln\,CO_{2t} = \beta_0 \sum_{i=1}^{p} \gamma_i\, ln\, CO_{2t-1} + \sum_{j=0}^{q1} \delta_j\, ln\, FD_{t-j} + \sum_{p=1}^{q2} \vartheta_l\, ln\, Y_{t-l} + \sum_{p=1}^{q3} \eta_m\, ln\, EC_{t-m} + \sum_{p=1}^{q4} \upsilon_n\, ln\, TO_{t-m} + \varepsilon_t \quad (2)$$

After the long-run relationship is determined, the short-run and error correction can be obtained from Equation:

$$\Delta\, ln\, CO_{2t} = \beta_0 + \sum_{i=1}^{p} \gamma_i \Delta\, ln\, CO_{2t-1} + \sum_{j}^{q} \delta_j \Delta\, ln\, FD_{t-j} + \sum_{i}^{q} \vartheta_l\, \Delta ln\, Y_{t-l} + \sum_{m}^{q} \eta_m\, \Delta ln\, EC_{t-m} + \sum_{m}^{q} \upsilon_n\, \Delta ln\, TO_{t-m} + \vartheta ecm_{t-1} + \varepsilon_t \quad (3)$$

Where, Δ represents the variable first difference; $lnCO2$ represents the natural logarithm of carbon emissions; lnY for the natural logarithm of economic growth; $lnTO$ for the natural logarithm of trade openness; $lnFD$ for the natural logarithm of financial development; and $lnEC$ for the natural logarithm of energy consumption; ecm_{t-1} shows the convergence speed from the short-run to the long-run equilibrium path. ECM is the residual gained from the estimation of the cointegration model Equation (1). ε_t is error term. This study involves diagnostic tests in the form of LM test for serial corellation, RAMSEY RESET for linearity, for normality test using Jarque-Berra and for heteroscedaticity test with ARCH test. For stability test, CUSUM and CUSUMSQ tests were involved.

3. RESULTS AND DISCUSSION

Firstly, we tested the stationarity of the variables using the Augmented Dickey-Fuller method. The results of the stationarity test are displayed in Table 1. If the variables are not stationary at the level, we retest them at the first difference level. The stationarity test is necessary to check if the data is suitable for further testing in the cointegration bound test (which does not allow the data to be stationary at the second difference. The stationarity of the data is evident from the probability values that are less than 0.05. Based on our results, all the data has become stationary at the first difference level. Therefore, it fulfills the requirements for conducting the cointegration Bound test.

Table 2 presents the results of the cointegration-bound test. A variable is considered cointegrated if its F-statistic is greater than the critical value I(1) at a significance level of 5% (I(1)). The F-statistic value of 14.6297 is higher than the critical value I(1) at the 5% significance level. This shows that the variables in this study are cointegrated, and we reject the null hypothesis.

Table 2. Results of Unit Root test

Variables	Critical Value	ADF-test			
	(%)	Level	t-Statistic	1st difference	t-Statistic
Ln CO_2	1%	-3.610	-0.922	-3.610	-8.263*
	5%	-2.939		-2.939	
	10%	-2.608		-2.608	
Ln FD	1%	-3.610	-2.601	-3.610	-4.459*
	5%	-2.939		-2.939	
	10%	-2.608		-2.608	
Ln Y	1%	-3.606	-0.802	-3.610	-4.559*
	5%	-2.937		-2.939	
	10%	-2.607		-2.608	
Ln EC	1%	-3.606	-2.307	-3.610	-4.731*
	5%	-2.937		-2.939	
	10%	-2.607		-2.608	
Ln TO	1%	-3.606	-1.979	-3.610	-8.477*
	5%	-2.937		-2.939	
	10%	-2.607		-2.608	

Note: * represents significant at 5%
Sources: Secondary data processed by author (2023)

Since the variables have been cointegrated or have a long-run equilibrium relationship, we estimated equation (2). The results are displayed in Table 3.

Table 3. Result of ARDL Bound cointegration test

Model of estimation	F-Statistics	Significance Level (%)	Critical bound F-statistics	
			I(0)	I(1)
F(CO^2/FD,Y,EC,TO)	**14.6297***	10%	2.660	3.838
		5%	3.202	4.544
		1%	4.428	6.250

Note: * represents significant at 5%
Sources: Secondary data processed by author (2023)

Table 4 summarizes our results and shows that the financial development variable significantly negatively impacts CO_2 emissions in the long run. This means that financial development contributes to reducing CO_2 emissions in Indonesia. Specifically, if financial development increases by 1 percent in Indonesia, carbon dioxide decreases by 0.062 percent. These study findings are consistent with the results of Shahbaz et al. (2018) in France; Bashir et al. (2019a); Bashir et al. (2021b); and Shahbaz et al. (2013) in Indonesia. On the other hand, the economic growth variable has a significant positive impact on CO_2 emissions. This indicates that economic growth is associated with an increase in CO_2 emissions. Specifically, a 1 percent increase in economic growth results in a 0.387 percent increase in CO_2 emissions. These study findings align with previous studies conducted by Shahbaz et al. (2013) in Indonesia, Ali et al. (2016) in Nigeria, Salahuddin et al. (2018) in Kuwait, Dong et al. (2019), Begum et al. (2015) in Malaysia, and Lestari et al. (2020) in ASIAN emerging markets.

Energy consumption in Indonesia has a significant and positive effect on CO_2 emissions, which shows that a 1 percent increase in energy consumption will increase CO_2 emissions by 0.845 percent. The findings of this study are in line with studies conducted by Ali et al. (2016) in Nigeria, Dogan and Turkukel (2016) in the United States, Shahbaz et al. (2014) in Tunisia, and Shahbaz et al. (2013) in Indonesia. Trade openness variable significantly and negatively affects CO_2 emissions. An increase of 1 percent in trade openness contributes to a 0.19 percent reduction in CO_2 emissions. These study findings align with the studies conducted by Ali et al. (2016) in Nigeria, Dogan and Turkukel (2016) in the USA, and Shahbaz et al. (2013) in Indonesia.

Table 4. Results of ARDL Model Estimation

Dependent variable = $lnCO_2$			
Variables	**Coefficient**	**S.E.**	**t-Stat**
Long run Equation			
$Constant$	7.562**	3.213	2.354
$lnFD$	0.062**	0.023	-2.695
lnY	0.387*	0.126	3.085
$lnEC$	0.845*	0.146	5.805
$lnTO$	-0.190*	0.084	-2.247
Short run Equation			
$\Delta(lnCO2)_{t-1}$	0.261***	0.135	1.936
$\Delta(lnFD)$	-0.755	0.601	-1.256
$\Delta(lnY)$	0.670**	0.060	2.034
$\Delta(lnEC)$	0.803*	0.246	3.265
$\Delta(lnTO)$	-0.192**	0.073	-2.641
$ECM_{(t-1)}$	-0.881*	0.181	-4.853
Diagnostic test	**F-statistic**	**Prob. value**	
Normal test	1.313	0.519	
LM test	0.321	0.665	
ARCH test	1.734	0.181	
REMSAY test	0.085	0.772	

Note: *, ** and *** represent significance at 1%, 5% and 10% levels respectively
Sources: Secondary data processed by author (2023)

The short-run results are also presented in Table 4. The short-run dynamics of the variables show that economic growth also has a positive and significant impact on CO_2 emissions. This finding aligns with the study conducted by Ali et al. (2016) in Nigeria and Shahbaz et al. (2013) in Indonesia. Similarly, the energy consumption variable has a positive and significant impact on CO_2 emissions, which is consistent with the findings of Ali et al. (2016) in Nigeria, Shahbaz et al. (2014) in Tunisia, and Dogan and Turkekul (2016) in the US. However, the financial development variable does not significantly impact CO_2 emissions in the short run. This result aligns with the study conducted by Salahuddin et al. (2018) in Kuwait and Dogan and Turkekul (2016) in the US. The variable trade openness is negatively impacting CO_2 emissions in Indonesia. This result is consistent with the study conducted by Shahbaz et al. (2013) in Indonesia.

As expected by econometric theory, the error correction term is negative and statistically significant and exhibits convergence from the short run to the long run (Ali et al., 2019). This reaffirms the presence of a long-run relationship between the variables. The error correction coefficient is 0.88 or 88% adjustment occurred in a year (annual data). This implies that for any deviation to achieve full adjustment (100%), the time it takes to converge to long-run equilibrium is roughly 1.8 years.

We also included classical assumption tests in this study, as seen in Table 4. The classical assumption tests or diagnostic tests that we conducted include the Jarque-Bera test for normality, the LM test for serial correlation, the RAMSEY test for functional form, and the ARCH test for heteroskedasticity. The empirical results indicate that our model has passed all the classical assumption tests. This means that the model meets the assumptions of normality, lack of serial correlation, correct functional form, and homoscedasticity (absence of heteroskedasticity). As a result, the model is deemed valid and appropriate for the analysis conducted in the study.

The stability of the model is further confirmed by the Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Squares of Recursive Residuals (CUSUM of Squares) shown in Figures 1, respectively. In both Figures, the blue lines for CUSUM and CUSUMSQ are within the critical bounds and significant at the 5% level. This indicates that the model remains highly stable over the entire sample period.

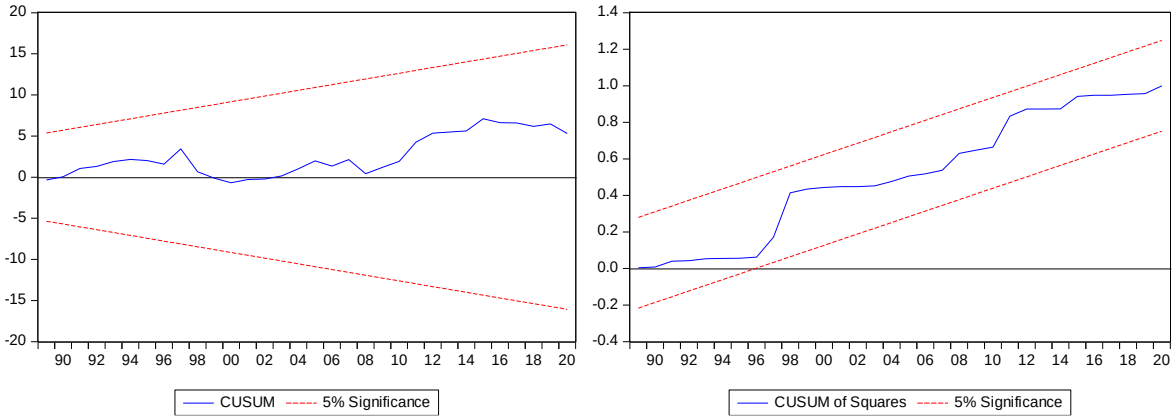

Figure 1. Result of CUSUM and CUSUMSQ test

4. CONCLUSIONS

This study aims to estimate the effect of economic growth, financial development, trade openness, and energy consumption in Indonesia on CO_2 emissions using annual data from 1980-2020. The stationary test results stated that all variables were stationary at the first difference level. As well as the cointegration test shows that the independent variable has a long-run equilibrium relationship with CO_2 emissions. This data has fulfilled all the researchers' diagnostic tests and has been considered stable, as seen in the CUSUM and CUSUMSQ tests. According to the results of ARDL estimation, the conclusions in this study are: (i) Economic growth has a positive and significant effect on CO_2 emissions. This happens because, in the efforts for economic growth carried out in Indonesia, the environmental impact still needs to be considered. Meanwhile, in the short-run, economic growth also has a positive significant effect on CO_2; (ii) Financial development in Indonesia has a significant and negative influence on CO_2 emissions.

This is in accordance with the expectations of previous researchers who also conducted study in Indonesia (Shahbaz et al., 2013), where CO_2 emissions can be reduced with the help of financial development. In Indonesia's case, the financial sector's role in reducing CO_2 emissions is done by issuing green bonds. Green bonds are funding for the corporate sector that is environmentally sound. The environmentally friendly corporate sector is projects related to renewable energy or green buildings;(iii) the Trade openness variable in this study has a negative and significant effect on CO_2 emissions both in the short and long run. This also indicates that trade openness participates in reducing CO_2 emissions. This happens because export and import activities in Indonesia have been selective in choosing environmentally friendly technologies and goods. For export activities, along with other countries' efforts to mitigate climate change by requiring environmentally friendly products. Indonesia also produces environmentally friendly technologies and products for export to compete internationally; (iv) Energy consumption variable has a significant and positive influence on CO_2 emissions both in the long and short run. This study also indicated that energy consumption is the main cause of increased CO_2 emissions compared to other variables. The findings of this paper propose that Indonesia should implement policies to reduce carbon emissions from fossil fuel. Indonesian government will need to encourage and promote renewable energy sources. Providing incentive for energy-efficient use will be choice of instrument to reduce CO_2.

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