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Revisiting the Effect of FDI and Trade Openness on Carbon Dioxide in Indonesia: Modelling the Environmental Kuznets Curve

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ABSTRACT

This research reexamines the relationship between foreign direct investment (FDI) and trade openness (TO) on carbon emissions in Indonesia by using the Environmental Kuznets Curve (EKC) approach. Thus, economic growth and urbanization variables are introduced in the study to depict the level of sustainable development in Indonesia. The study was conducted by utilizing the Autoregressive Distributed Lag (ARDL) approach, covering the period from 1990 to 2020. The primary findings reveal that FDI positively impacts carbon emissions both in the short and long term. On the other hand, trade openness is found to have a positive influence only in the long term, with no effect in the short term. Economic growth, which is reflected by the Environmental Kuznets Curve (EKC), exhibits a U-shaped pattern, while urbanization significantly influences carbon emissions in both the short and long term. This shows that economic development in Indonesia is somewhat bend away from sustainable development. Based on these results, it is recommended that FDI and trade openness is directed towards promoting better technology which are environmental friendly. Furthermore, promoting the consumption of green goods is essential for fostering a sustainable development, and efforts should be made to reduce the rate of urbanization.

Keywords: Carbon Emission, Foreign Direct Investment, Trade Openness, EKC
JEL Classifications: C22, F18, Q56

1. INTRODUCTION

Indonesia is a developing country and will enter the middle-income status in 2022. As such, efforts to reach a developed economy status are intensively carried out. According to the Central Statistics Agency of Indonesia databased, Indonesia has consistently experienced economic growth of over 5% regularly with the only exception is in 2021, when economic growth is negative due to the worldwide COVID-19 pandemic. In order to bounce back from the suppressing worldwide pandemic, various formulations have been made such as attracting large scale investment and increase in international trade. Albeit the situation, Indonesia have already gearing up towards promoting greater liberalization decades ago except that the pandemic has put more pressure to double up the efforts.

However, one should not ignore the consequences of economics development which is an increase in greenhouse gas emissions. In light of pressing issues on climate change and global warming, a collective efforts must be taken in promoting a more sustainable development approach and Indonesia should be taking part in controlling it. Among of contributor to the climate change a global warming is carbon dioxide (CO_2) emissions and it have received a special attention from researchers and policy makers. Until now, CO_2 has been identified as the largest contributor to greenhouse gases (Haug and Ucal, 2019). This situation has by large effect human survival and conducive housing area (Dauda et al., 2021). This alarming global situation must put Indonesia policy makers into attention to be part of collective effort in reducing the issue.

Therefore, this study focuses on two main variables that are believed to be the main engine to greenhouse effect in Indonesia namely; foreign direct investment (FDI) and trade openness (Husnain et al., 2024; Sanusi and Dickason-Koekemoer, 2024). According to Marques and Caetano (2022), FDI may impacts an economy in two directions. The first direction is the presence of FDI may create a skilled workforce and the emergence of more environmental friendly technological advancement. The second direction is through the entry of FDI certainly prioritizes environmental regulation issues. This type of investment will be present in a country if there is ease in certain regulations. The resulting impact is not only for momentary but has also long-lasting effects. Bakhsh et al. (2017) argue that the contribution of FDI is important for the economy because they usually carry a larger external financing that bridges the lack of domestic investment. Furthermore, it is undisputable that FDI can also increase skilled labor and productivity all together. This is aligned with Marques and Caetano (2022) and Bakhsh et al. (2017) who throw the same opinion that investment act as the engine for economic growth and investment is also a free good. However, there will be the greatest sacrifice, especially jeopardizing the environment.

On the other hand, trade openness should provide an important signal that the countries of origin and destination must co-operate in developing the economy and at the same time promoting sustainable development approach. Indonesia as a developing country are still plague with very limited capabilities who still mainly trades raw materials products rather than high value-added goods. This approach seems to put sustainable economic development at bay and jeopardizing environmental at fast lane. Based on the World Bank databased, Indonesia's economic growth is largely contributed by international trade activities (exports and imports) and hence putting the questions the rate of speed on environmental degradation. It was recorded in 2022 as much as 45.39% of Indonesia's GDP are contributed by trade liberalization. This was supported by Ertugrul et al. (2016) where an increase in international trade has simultaneously increased carbon emissions, especially for developing countries. Perhaps this may due to lack of green technology adoption as a result of higher cost of investment setting up.

Given the situation, this research contributes in several ways. First, this study empirically investigates the EKC hypothesis in the case of Indonesia where there is still lack of study focusing on the issue in this setting. Furthermore, previous studies are mostly discussed on developed countries or a group of countries in a panel setting. Studies in Indonesia are still relatively thin and a country specific analysis may provide better policy recommendation which may promote better sustainable development insight in this case of study. In addition, Indonesia is one of 10 countries contributing to the world by 2-3%. Second, the study uses the Autoregressive Distributed Lag (ARDL) method to see the short-term and long-term effects. Third, the researcher was inspired by the studies of Shahbaz et al. (2017), Hille et al. (2019), and Marques and Caetano (2022) so that they include elements of FDI and open trade where both variables are important keys in the economy but also contribute to carbon emissions. Generally, FDI and open trade are studied separately. Thus, this study is very important.

2. LITERATURE REVIEW

The literature on carbon emissions and their determination has developed enormously until today. However, researchers only limit the literature that is directly related to this research, especially regarding carbon emissions (CO_2), economic growth (GDP) from the perspective of the environmental Kuznets curve theory (EKC), urbanization, foreign direct investment (FDI), and open trade. Haug and Ucal (2019) investigated the relationship between trade and FDI on CO_2 emissions in Turkey. This study uses a non-linear approach in the form of NARDL. The results show that GDP per capita forms an inverted U theory where an increase in income in the second stage will reduce CO_2. Meanwhile, negative FDI, in the long run, has an effect but not a positive one. Imports cause an increase in CO_2 in the long run with a positive effect. Meanwhile, exports have no effect in positive impact, but export cuts will reduce CO_2. Ertugrul et al. (2016) tested the relationship between open trade and CO_2 in 10 developing countries that produce emissions. Based on the VECM method, EKC was found to vary. Inverted U occurs in Turkey, India, China, and Korea. While U occurs in Brazil and Indonesia. Open trade is a positive sign, and Indonesia has a large impact compared to others. Li and Haneklaus (2022a) reconfirmed the EKC in China with ARDL. The findings are inverted U-shaped, and open trade has a positive effect. Similar results were found in G7 countries by Li and Haneklaus (2022b) by modifying the model to the ARDL panel. In the case of Pakistan, Shahbaz et al. (2017) found open trade to have a positive and significant effect in the short and long run. A recent study by Mngumi et al. (2023) in BRICS from the AMG approach. The results of their study explain that FDI in the early stages has a negative effect on CO_2, but when FDI is quadratic, it finds a positive effect. While EKC found an inverted U. However, Haseeb et al. (2018) found a U relationship in the BRICS region in Russia and India.

Dauda et al. (2021) examined the CO_2 problem in Africa. The study used several variations of estimation, such as OLS, FEM, and GMM. This study found that innovation development has a suppressive impact on CO_2. Similar to economic growth, EKC found an inverted U. Meanwhile, open trade was found to have a negative effect, and urbanization had a positive effect. However, Nathaniel et al. (2019) found that urbanization had a negative effect on the FMOLS, DOLS, and CCR approaches. Wang and Zhang (2021) conducted a different sample approach in groups of high-, middle-, and low-income countries. Based on the FMOLS estimate, globally, open trade has a negative impact on CO_2 and is similar to each group of countries except low-income countries. Economic growth is known to have a positive effect. Mahmood et al. (2020) proved in their research that urbanization significantly impacts carbon emissions in Saudi Arabia. The same thing also happened in the SAARC Region, where Afridi et al. (2019) found that urbanization significantly impacted increasing carbon emissions by around 0.49%.

Omri et al. (2014) conducted a dynamic panel study (GMM) in three regions, namely Europe and North Asia, Latin America and the Caribbean, and the Middle East, North Africa, and the Sub-Sahara. Their study's results prove that FDI positively impacts

CO_2 in two regions except Europe and North Asia. Marques and Caetano (2022) conducted research in OECD countries focusing on FDI and CO_2. The model used is ARDL. The estimation results show that FDI has no impact on CO_2 in the short term but in the long term. Specifically, it was found that FDI in certain sectors, such as mining, drives CO_2 in the short term.

Bakhsh et al. (2017) provide a more detailed picture of FDI in Pakistan. Their study used the 3LS method. Model improvements in FDI have a positive effect on carbon emissions. However, if FDI is a technology, then carbon emissions will decrease. The findings are similar to Hille et al. (2019) in Korea. Derindag et al. (2023) studied CO_2 in 20 industrial sectors in India with a different approach. Their study used the threshold regression method on open trade and FDI. The results show that open trade does not affect CO_2 in the panel approach. Meanwhile, moderation between FDI and technology causes a significant decrease in CO_2. However, on a certain scale, FDI has a negative impact, but open trade at 1.41% can still suppress CO_2. Hoa et al. (2023) tested FDI and CO_2 in Vietnam and found that FDI was negative. From the asymmetric ARDL perspective, Saqib and Dinca (2023) explain that FDI can mitigate CO_2 problems in countries investing in clean energy technology.

3. METHODOLOGY

3.1. Data

The objective of this study is to establish the relationship between FDI and Indonesia's trade openness on carbon emissions. In addition to the variables, this study also includes income per capita and the square of income per capita and urbanization as a control variable to the Kuznets curve theory (EKC) hypothesis. The data was collected from 1990 to 2020. Carbon emissions are measured in metric tons per capita, economic growth is measured in constant 2015 income per capita in dollars, urbanization is measured in the number of urban population people, and foreign direct investment is measured by investment coming into the country as a percentage of GDP, and the ratio of the sum of exports and imports to GDP in percentage units measures open trade. All of the data are taken from the World Development Indicator (WDI). Table 1 summarized the detail information on the variables and their measurements.

The relationship between the variables is formed in the following functions:

$$CO_{2t} = f(GDP_t, GDPSQ_t, URB_t, FDI_t, TO_t) \quad (1)$$

Where CO_2 is carbon emissions, GDP is per capita income, GDPSQ is the square of per capita income, URB is urbanization, FDI is foreign direct investment, and TO is open trade. Equation (1) is transformed into a natural logarithm form to reduce the problems of normality, heteroscedasticity, and autocorrelation (Ikhsan et al., 2022; Fachrurrozi et al., 2022) and to help induce stationarity (Langnel and Amegavi, 2020). FDI and TO are not transformed because they are already in percent form. The transformation form is takes the following equation:

Table 1: Data and source

Variable	Operational variables	Expected sign	Source
CO_2	Carbon emissions from fossil burning are measured in metric tons per capita.	N/A	WDI
GDP	GDP divided by population measured in constant 2015 dollars	+/−	WDI
GDPSQ	Quadratic of GDP	−/+	Author calculation
URB	The number of urban population	+	WDI
FDI	FDI net inflow as a percentage of GDP	+/−	WDI
TO	The ratio of the total sum of exports and imports to GDP in percentage	+/−	WDI

WDI: World development indicator, FDI: Foreign direct investment, TO: Trade openness, CO2: Carbon emissions

$$lnCO_{2t} = \sigma_0 + \sigma_1 lnGDP_t + \sigma_2 lnGDPSQ_t + \sigma_3 lnURB_t + \sigma_4 FDI_t + \sigma_5 TO_t + \epsilon_t \quad (2)$$

Where t is the time from 1990 to 2020, σ_0 is a constant, σ_1-σ_5 are the coefficients of the research variables, and ϵ_t is the residual term.

3.2. The Strategic of Econometrics

The study analyzed the short-term and long-term relationships using the autoregressive distributed lag (ARDL) method introduced by Pesaran et al. (2001). The ARDL method has been widely used and offers several advantages. First, the method can be used with small samples (Ikhsan and Amri, 2023). Second, it can handle the problems of autocorrelation, heteroscedasticity, and endogeneity benefited by the use of lag in the model (Ahmed et al., 2019). Third, this method can be applied to different level of integrations variable, be it I(0) or *I(1),* or integrated at the *I(1)* level (Shahbaz, 2013; Ahmed et al., 2021). Fourth, the ARDL method can be used in the form of one equation or in the form of a vector. Fifth, the coefficients are estimated based on OLS. The form of the ARDL model is as follows:

$$\begin{aligned}\Delta lnCO2_t = {} & \gamma_0 + \sum_{k=1}^{p}\beta_{1k}\Delta lnCO2_{t-k} + \sum_{k=0}^{p}\beta_{2k}\Delta lnGDP_{t-k} \\ & + \sum_{k=0}^{p}\beta_{3k}\Delta lnGDPSQ_t + \sum_{k=0}^{p}\beta_{4k}\Delta lnURB_t \\ & + \sum_{k=0}^{p}\beta_{5k}FDI_t + \sum_{k=0}^{p}\beta_{6k}TO_t + \theta_1 lnCO2_{t-1} \\ & + \theta_2 lnGDP_{t-1} + \theta_3 lnGDPSQ_{t-1} + \theta_4 lnURB_{t-1} \\ & + \theta_5 FDI_{t-1} + \theta_6 TO_{t-1} + \varepsilon_t \end{aligned} \quad (3)$$

Where Δ is denoted as the difference operator, the sign Σ is the number of lags used for each variable. The coefficients β_1-β_6 are in the short-term while θ_1-θ_6 are the long-term coefficients. ϵ_t as an error term. ARDL cointegration testing uses the Bound test approach by Pesaran et al. (2001). Pesaran et al. (2001) used bound computation in large samples from 500 to 1400. However, the

results will be biased when the research sample is small (Shahbaz, 2012). Therefore, researchers use an alternative, Narayan (2005), where bound computation is used for small samples ranging from 30 to 80. The F-test approach is used to test the long-term relationship in equation (3). H_0: $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \theta_6 = 0$ and alternative H_1: $\theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq \theta_6 \neq 0$. To strengthen the ARDL estimation, several classical assumption tests and model stability are included. The research framework's flowchart is presented in Figure 1.

4. EMPIRICAL RESULTS AND DISCUSSION

Table 2 displays descriptive statistics of the research data in average, maximum, minimum, and standard deviation. The average carbon emissions are 1518 tons per capita, per capita income is 1990.62 dollars, urbanization is 105 million people, FDI is 1.25%, and open trade is 53.47%. The standard deviation of FDI shows no major fluctuations (1.374), such as open trade (11.95).

The initial stage of analysis is to conduct a stationarity test. This is necessary to avoid errors in regression and methodology. Researchers use Phillips-Perron (PP) to test the stationarity of variables. Table 3 explains that two variables reject the null hypothesis at the level, namely CO_2 and URB. The rest, namely GDP, FDI, and TO, accept the null hypothesis at this level. The first difference level shows that all three variables have rejected the null hypothesis, which means they are stationary. So, the conclusion is that there is mixed integration in the study. Based on the ARDL framework, this stage has met the requirements.

Figure 1: Framework research

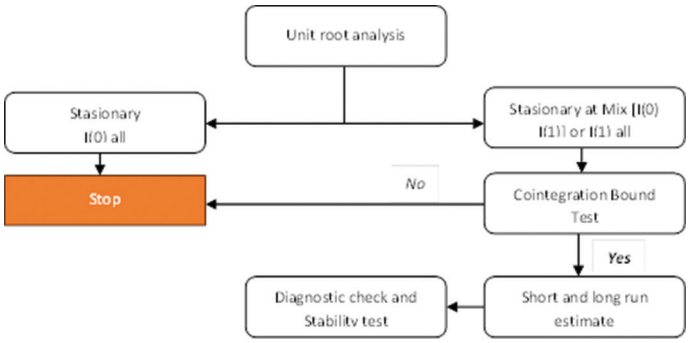


Table 2: Descriptive statistics

Variable	Mean	Maximum	Minimum	SD
CO_2	1.518	2.245	0.814	0.390
GDP	1990.622	4151.228	459.191	1323.47
URB	1.05E+08	1.54E+08	55,711,776	30,009,895
FDI	1.252	2.916	−2.757	1.374
TO	53.474	96.186	32.972	11.995

FDI: Foreign direct investment, TO: Trade openness, CO_2: Carbon emissions, SD: Standard deviation

Table 3: Testing for the stationery

Variable	Level	First diffierence	Conclusion
CO_2	−14.179***		I (0)
GDP	−0.829	−5.473***	I (1)
URB	−14.179***		I (0)
FDI	−2.333	−5.332***	I (1)
TO	−2.430	−8.508***	I (1)

***Mean level of significance 1%. Source: Author calculation. FDI: Foreign direct investment, TO: Trade openness, CO_2: Carbon emissions

Next, the detailed results of the Bound ARDL cointegration test are shown in Table 4. The *F*-stat calculation value was found to be 22,436. This calculation figure is compared with the lower band *(I (0))* and upper band *(I (1))*. According to Pesaran et al. (2001), if the *F*-stat number is greater than the lower and upper bands, the null hypothesis is rejected, and vice versa. If it is below the lower band and upper band or between, then the null hypothesis is accepted namely there is no cointegration. The lower and upper band values use the Narayan (2005) approach. Table 4 shows cointegration, meaning a long-term relationship exists between CO_2, GDP, GDPSQ, URB, TO, and FO in Indonesia from 1990 to 2020.

The next step is to estimate the long-term and short-term relationships of the research variables on carbon emissions. The estimation results are presented in Table 5. The long-term estimation results found that GDP and GDSQ have positive and negative relationships. The GDP coefficient is −2.554, and the GDPSQ is 0.163. This illustrates the existence of U-curve shape where the initial stage of GDP suppresses carbon emissions, but in the second stage, carbon emissions increase (Dinda, 2004). This suggests to lack of environmental regulations or enforcement in promoting the entrance of FDI and international trade worsen the situation. This finding is in line with Ertugrul et al. (2016) and Haseeb et al. (2018) but differs from Ikhsan and Amri (2024) in the ASEAN-6 region,Mngumi et al. (2023) in the case of BRICS economies and Haug and Ucal (2019) in the case of Turkey.

The impact of URB on carbon emissions was found to have a positive and elastic effect. Statistically, this effect is significant at the 1% level. If URB increases by 1%, CO2 increases by

Table 4: Cointegration test

Model	F-statistic	I (0)	I (1)	Conclusion
CO_2=*f (gdp, gdpsq, urb, to, fdi)*	22.436***	4.132	5.761	Cointegrated

*Mean level of significance 1%. Lower and Upper band values by Narayan (2005) are also 1%. Source: Author calculation

Table 5: Short-run and long-run estimated results

Variable	Coefficient	SE	t-statistic	P-value
Long-run				
GDP	−2.554***	0.522	−4.889	0.000
GDPSQ	0.163***	0.032	4.997	0.000
URB	2.229***	0.166	13.393	0.000
FDI	0.024*	0.012	1.906	0.085
TO	0.003***	0.001	3.699	0.004
Constant	−32.079***	1.624	−19.746	0.000
Short-run				
ΔGDP	−0.792***	0.235	−3.362	0.007
ΔGDPSQ	0.006***	0.015	3.901	0.003
ΔURB	38.383***	2.816	13.629	0.000
ΔFDI	0.025**	0.008	3.043	0.012
ΔTO	0.002	0.001	1.413	0.187
ECT	−1.254***	0.079	−15.852	0.000

*, **, *** mean level of significance 10%, 5%, and 1%. Source: Author calculation. FDI: Foreign direct investment, TO: Trade openness, CO_2: Carbon emissions, SE: Standard error

2.229%, assuming ceteris paribus. This finding is in line with studies conducted by Dauda et al. (2021), Mahmood et al. (2020), and Afridi et al. (2019) but different from Nathaniel et al. (2019). Urbanization occurs because needs and jobs are sufficiently available in urban areas. This is natural in developing countries with low to middle incomes (Afridi et al., 2019). Along with increasing population mobilization in the city, land and infrastructure expansion is necessary. This results in deforestation being carried out on a large scale.

FDI was found to have a positive sign on CO_2 and is significant at the 1% level. CO_2 increases by 0.024% when FDI increases by 10%, assuming ceteris paribus. This finding is in line with Omri et al. (2014) and Bakhsh et al. (2017) but contrasts findings such as Marques and Caetano (2022), Saqib and Dinca (2023), and Hoa et al. (2023). FDI is seen as an important investment in building an economy. Investments entering a country will be used for certain things (Muhammad and Khan (2019). Saqib and Dinca (2023) and Hoa et al. (2023) explain that incoming FDI is used to develop environmentally friendly technology. Technology is an expensive commodity that requires a long time of research. If FDI is directed more towards economic expansion, the economic scale will experience a fairly rapid increase (Pao and Tsai, 2011). When economic expansion occurs without technological development, carbon emissions increase much more.

TO has a positive sign on CO_2. Statistically, it has a significant effect at the 1% level. If TO increases by 1%, CO_2 will increase by 0.003%, assuming ceteris paribus. The TO coefficient tends to be inelastic compared to other variables. This finding is in line with the research conducted by Shahbaz et al. (2017) and Ertugrul et al. (2016) but is different from the findings of Dauda et al. (2021), Wang and Zhang (2021), and Derindag et al. (2023). Open trade plays an important role in countries' export and import sectors. Most trade activities are carried out in developing countries such as Indonesia, which are limited by technology and resources.

The short-term estimation results in Table 5 show that the EKC curve shows a U relationship in the short term. URB has a positive and significant sign on CO_2, where a 1% increase in URB in the short term causes CO_2 to increase by 38.38%. FDI was found to have a positive and significant sign with a coefficient of 0.025. This explains why a 1% increase in FDI causes CO_2 to increase by 0.025%. Meanwhile, TO was found to have no significant effect on CO_2 in the short term.

As stated in the framework section, several diagnoses are needed at the end of the estimation to strengthen the results and ensure that the estimates obtained are efficient and reliable. Researchers follow several diagnostics Ikhsan and Amri (2023) used in the form of normality, autocorrelation, heteroscedasticity, and model specification miss (RESET). Table 6 shows that all tests accepted H0 with no violations ($P > 0.05$). In addition, the results of the model stability in Figures 2 and 3 show that the (blue) estimation line is within the 5% significance value (red line). This indicates that the long-term estimation results are stable. Thus, the estimation in the study is efficient and reliable.

Table 6: Testing for the OLS assumptions

Testing	Chi-statistic	P
Normalitas	1.732	0.420
Serial correlation	2.509	0.285
Heteroskedasticity	21.580	0.305
RESET	0.114	0.730

Source: Author calculation

Figure 2: The CUSUM stability test

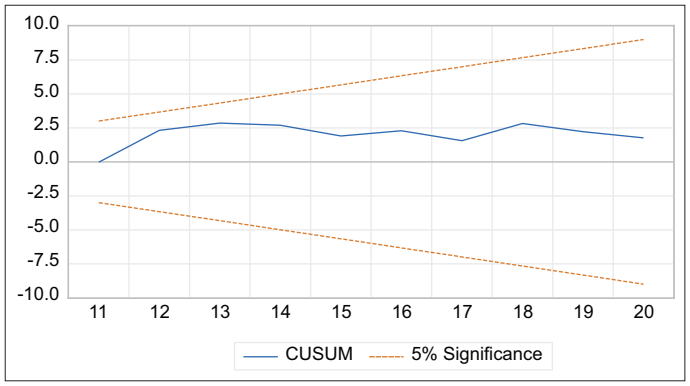
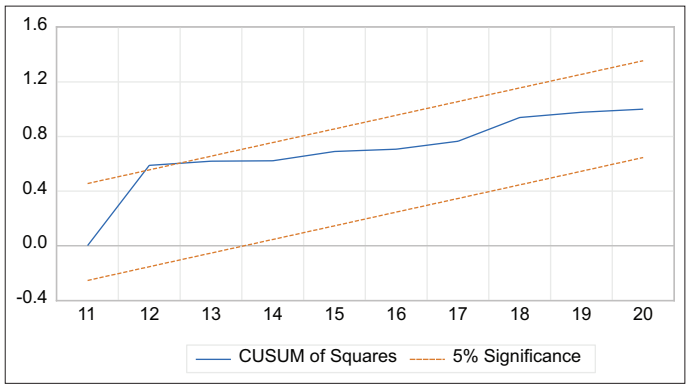


Figure 3: The CUSUMSQ Stability Test



5. CONCLUSION AND RECOMMENDATION

Foreign direct investment and open trade are important components in boosting economic growth towards a higher direction, especially for developing countries like Indonesia. However, both of them provide new activities that increase carbon emissions. This study analyzes the impact of foreign direct investment, open trade, economic growth, and urbanization on carbon emissions. Researchers use the ARDL method. Several tests have been applied in the study, including stationarity, to find stationary variables at different levels. The cointegration test results found that the research variables have a long-term relationship. The estimation results found no assumption violations and were stable in the long term.

Based on the analysis results from 1990 to 2020, the existence of the environmental Kuznets curve was found to explain the relationship between GDP and CO_2 has a U-shaped relationship, which means that an increase in the scale of per capita income has a positive effect on CO_2. The U pattern occurs in the short and long term. Next, URB has a positive impact on increasing CO_2. The impact is greater than the others, namely 2.229%. An important finding of this study explains that FDI has a significant positive effect on

CO_2 in the short and long term. Meanwhile, TO found a significant positive relationship and only had an effect in the long term.

Therefore, some policies must be included. First, investment is an important capital in improving the economy. However, foreign investment is expected to be invested in green technology development so that carbon emissions can be reduced. This is proven by several studies of countries that invest in green technology to create a good climate without reducing the economy. Second, the government needs to take a policy approach in using environmental friendly goods in promoting trade. Third, increasing economic growth accompanied by per capita income needs to be directed towards the consumption of environmental friendly goods to achieve a green economy and reduce carbon emissions. Fourth, the government needs to reduce the rate of urbanization and develop rural areas. For urban areas, the use of environmentally friendly energy is needed.

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