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Determinants of CO2 Emissions: Evidence from United States

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Abstract

The decline in environmental quality can be marked by an increase in the earth's temperature or what we call global warming. Global warming can be caused by increasing concentrations of greenhouse gas (GHG) emissions on earth, one of the most important components of which is CO2 emissions. This study aims to determine the effect of economic growth, energy consumption, forest areaand urbanization on CO2 emissions in Indonesia in the period 1970-2020. This study uses a Vector Error Correction Model (VECM) analysis model. The results of the study indicate that economic growth, energy consumption, and foreign direct investment have a significant effect on CO2 emissionsin the long term.

Keywords: *CO2 Emission, Economic Growth, Energy Consumption, FDI*

Introduction

The Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change IPCC estimates that global average temperatures will increase by 2 to 4.2 degrees Celsius by 2100. Judging from the reports published by the IPCC, it appears that CO2 emissions are a shock to human survival which will affect human life both in terms of health, food, and the economy (Dila, 2021). Half of global greenhouse gases come from ten countries in the world listed by the World Research Institute (WRI). One of them is United States that produced about 12.7% of global emissions (Pusparisa, 2021).

Economic growth is one measure of a country's economic performance. Economic growth looks at how economic activities affect the income growth of the population of a region in a certain period of time. This economic growth also shows an increase in the standard of living of the community which is marked by an increase in the income of the community as a whole. Economic growth is connected with community economic activities which are also related to the population that continues to increase in every year (Indraswari, 2016).

Economic development to increase economic growth is associated with the exploitation of both natural resources and the environment. If exploitation continues, it is feared that it will result in environmental damage. One of the consequences of environmental damage is climate change due to the influence of greenhouse gases. The greenhouse effect itself comes from CO2, N2O and CH4 emissions. CO2 emissions are gases that trigger an increase in the greenhouse effect, where climate change can occur due to this. In addition, energy use or energy

consumption can also be a cause of climate change because economic development activities are also closely related to energy use (Arista & Amar, 2019).

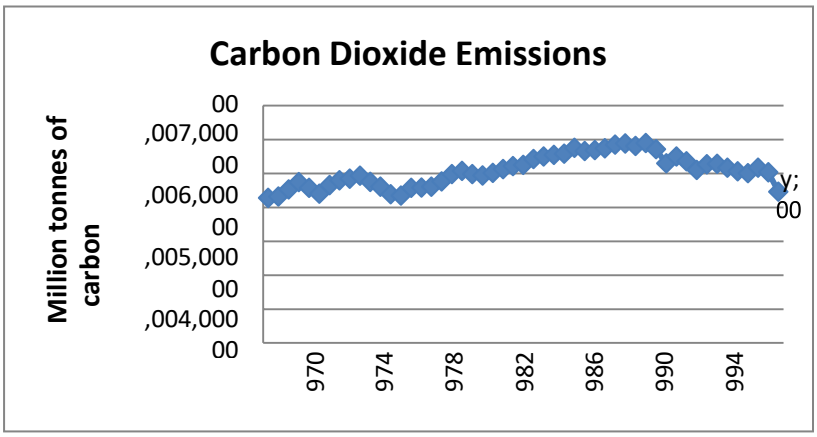

Figure 1. Growth of CO2 Emission US in 1970-2020
Source: British Petroleum

The success of a country can be seen from how the country is able to build its economic growth. To see if the country is experiencing economic growth, it can be seen from whether the country's economic activities are able to affect the income growth of its people in a certain period of time. Sufficient quantities of large goods and services can better meet the needs of households, businesses, and the government, so it can be said that the country is experiencing economic growth (Zuldareva, 2017).

According to Ghosh, (2010) in Candra, (2018) CO2 emissions cause high global temperatures so that they also affect climate change. Industrial growth as a driver of economic growth is the source of the current global warming and environmental quality problems. (Candra, 2018).

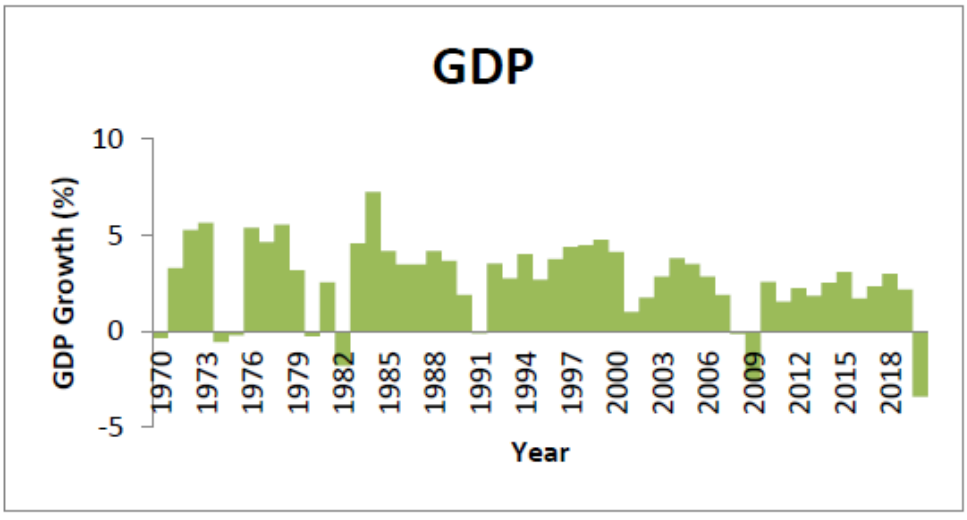

Figure 2 Economic Growth of US in 1970-2020 (%)
Source : *World Bank*

The Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change IPCC estimates that global average temperatures will increase by 2 to 4.2 degrees Celsius by 2100. Judging from the reports published by the IPCC, it appears that CO2 emissions are a shock to human survival which will affect human life both in terms of health, food, and the economy (Dila, 2021). Most experts have linked the root causes of global warming to the rapid global economic growth, the consumption of large amounts of human energy, and the greenhouse effect of the emission of six gases that affect the earth's climate change.

Thus, the contribution of this study is to explore empirically the factors that influence CO2 emissions in the United States, hereinafter referred to as the determinants of CO2 emissions, such as economic growth, energy consumption, and foreign investment using data obtained from the World Bank, British Petroleum and Our World in data in the form of time series data.

Material and Methods

The type of research used in this research is quantitative research. Thetype of investigation used is influence research, where the type of quantitative research aims to determine the influence between variables so that they can perform analysis in the short term to the long term. The subject of this study is a country with a high level of CO2 emission, namely the United States. Time series is the time dimension used in this study which wasconducted in the United States from 1970 to 2020. This study collects related variables in the publication information of the World Bank, British Petroleum, and Our World in Data from 1970 to 2020. Collection techniques the data used is a documentation technique, namely by collecting or conducting data searches, which come from the results of annual survey publications whose collection is carried out periodically by the World Bank, British Petroleum, and Our World in Data. To analyze the causal relationship between economic growth, energy consumption, and foreign investment using the VECM (Vector Error Correction Model) method. Mathematically, the VECM equation is written as follows:

$$\Delta CO2it = \pi 1i + \sum_p \pi 1ip\Delta EGit - p + \sum_p \pi 2ip\Delta ECit - p + \sum_p \pi 3ip\Delta JPit - p + \sum_p \pi 4ip\Delta FDIit - p + \sum_p + \varphi 1iECTit - 1 + \varepsilon 1it$$

$$\Delta EGit = \pi 1i + \sum_p \pi 6ip\Delta CO2it - p + \sum_p \pi 7ip\Delta ECit - p + \sum_p \pi 8ip\Delta JPit - p + \sum_p \pi 9ip\Delta IAit - p + \sum_p + \varphi 2iECTit - 1 + \varepsilon 1it$$

$$\Delta ECit = \pi 1i + \sum_p \pi 11ip\Delta CO2it - p + \sum_p \pi 12ip\Delta EGit - p + \sum_p \pi 13ip\Delta JPit - p + \sum_p \pi 14ip\Delta FDIit - p + \sum_p + \varphi 3iECTit - 1 + \varepsilon 1it$$

$$\Delta FDIit = \pi 1i + \sum_p \pi 21ip\Delta CO2it - p + \sum_p \pi 22ip\Delta EGit - p + \sum_p \pi 23ip\Delta ECit - p + \sum_p \pi 24ip\Delta JPit - p + \sum_p + \varphi 5iECTit - 1 + \varepsilon 1it$$

The ECT model is as follows:

$$ECT_{it} = CO2_{it} - P_I - \beta_{1i}PE_{it} - \beta_{2i}KE_{it} - \beta_{3i}JP_{it} - \beta_{4i}IA_{it}$$

According to Stern (2003) in Zuldareva (2017) CO2 emissions have a clear relationship with gross domestic product. Then, around 1850, about 70% of total energy generation emissions came from North America and Europe with the rest produced by agricultural countries. Developing countries will start doing building construction in the future as a picture of an increasing population and increasing economy. There is a tendency to find that an increase in local wages will affect financial development which will lead to an increase in emissions. The Kuznet curve continues to show that as individual incomes begin to increase, the climate will improve and the utility of small uses will decrease. So, at the same time, energy use causes high CO2 emissions and is driven by financial development caused by energy use.

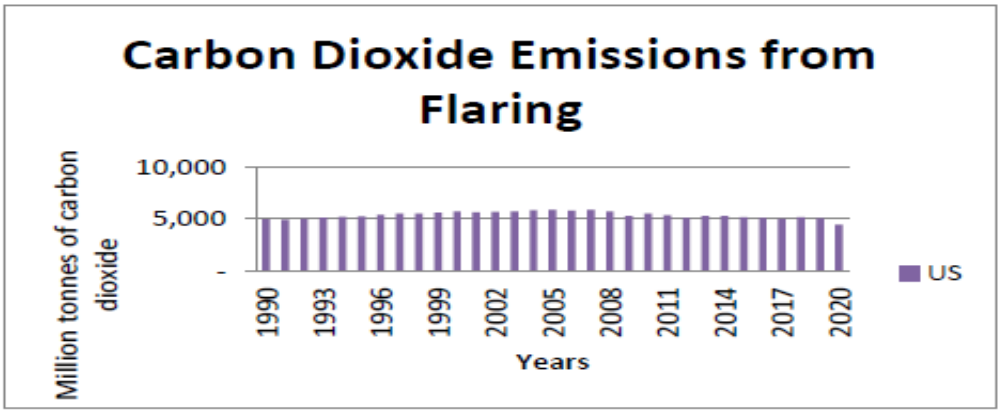

Figure 3 CO2 Emission from US Burning
Source: *British Petroleum*

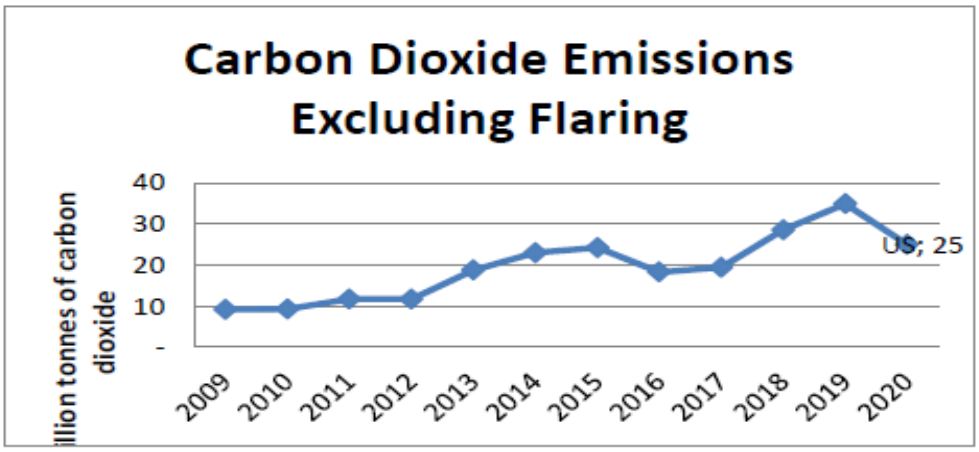

Figure 4 CO2 Emission other than Burning
Source: *British Petroleum*

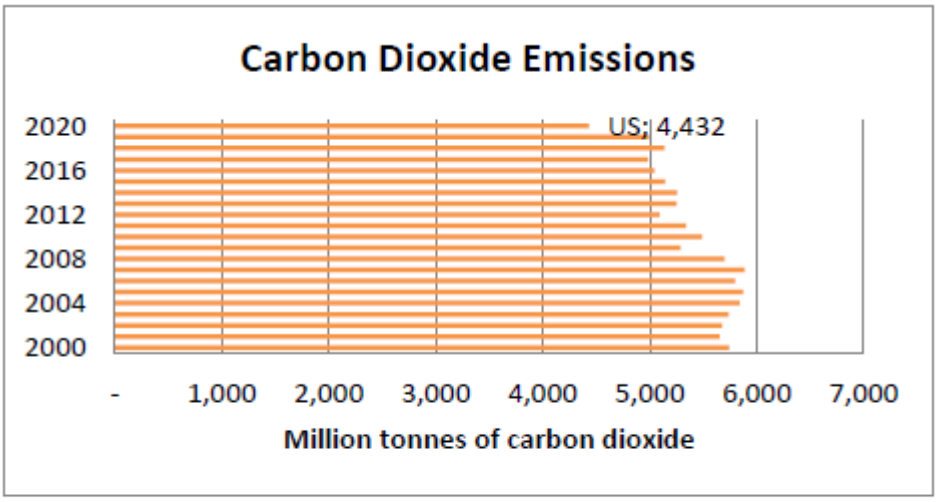

Figure 5 Total of CO2 Emission US
Source: *British Petroleum*

Figure 5 shows the growth of CO2 emissions in the United Statesfluctuating and shows a reduction in emissions from the previous year.

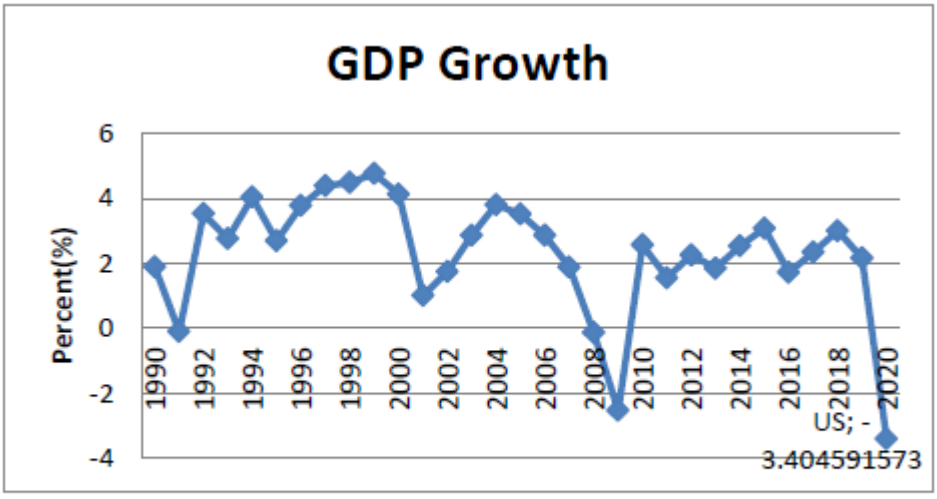

Figure 6 Economic Growth of US
Source: *World Bank*

Monetary developments are indicators of how successful a country is in the economy. Monetary developments look at what financial measures mean for individual salary developments in a country over a period of time. In addition, financial developments also outline how an economy with countless workers and products can more easily address the needs of families, organizations and public authorities (Zuldareva, 2017).

Figure 6 illustrates the economic growth of Indonesia, China, and the United States, where in 1999 the three countries experienced a crisis. In 2009, the three countries experienced poor economic development. The slowdown in economic growth can be caused by various

factors such as sudden economic shocks, excessive debt, excessive inflation, excessive deflation, technological changes, and others.

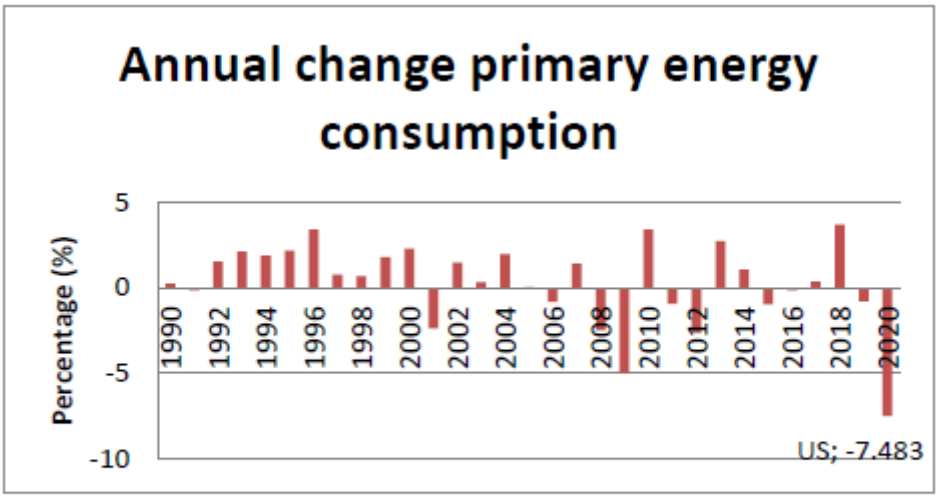

Figure 7 Conumption Energi of US
Source: *Our World in Data*

In 2020, Indonesia, China and the United States will experience a decline in economic growth due to the Covid-19 pandemic, which will not only have an impact on the health crisis but will also affect the economic growth of most countries in the world. even a recession. Only a few countries in the world will survive and develop economically in 2020, including China.

The high energy consumption is caused by the increasing demand for energy. This happens because energy is needed for the operation of the industrial sector as a driver of the economy. Energy is an input resource that supports and enhances other inputs to undergo various processes to produce outputs. As a natural resource, energy must be utilized optimally for the welfare of the community and its management must be based on the principles of sustainable development. Environmentally sound development is the foundation for achieving sustainable development (ZULDAREVA, 2017). One of the causes of the decline in energy consumption is because offices implement the "Work from Home" policy, various industries limit their activities due to falling demand for their products, declining economic activity and increasingly stringent Covid-19 containment policies, resultingin a significant reduction.

There is disagreement as to the reasons for the CO2 expansion, with the most controversial factor being the effect of foreign speculation and monetary developments on CO2. According to Omri, et al., (2014) in Tang, (2017) foreign speculation affects monetary developments and energy utilization. Monetary developments and foreign speculation strongly influence the release of CO2. There is also another assessment by Zhang, C and Zhou, X (2016) in Tang, (2017), that monetary developments and foreign speculation adversely affect CO2 release, and it implies that foreign ventures and financial developments increase CO2 emissions. This assessment is corroborated by their examination, according to the side effects of Zhang, C and Zhou, X (2016) exploration in China from 1995 to 2010, foreign investment added to the reduction of CO2 emissions.

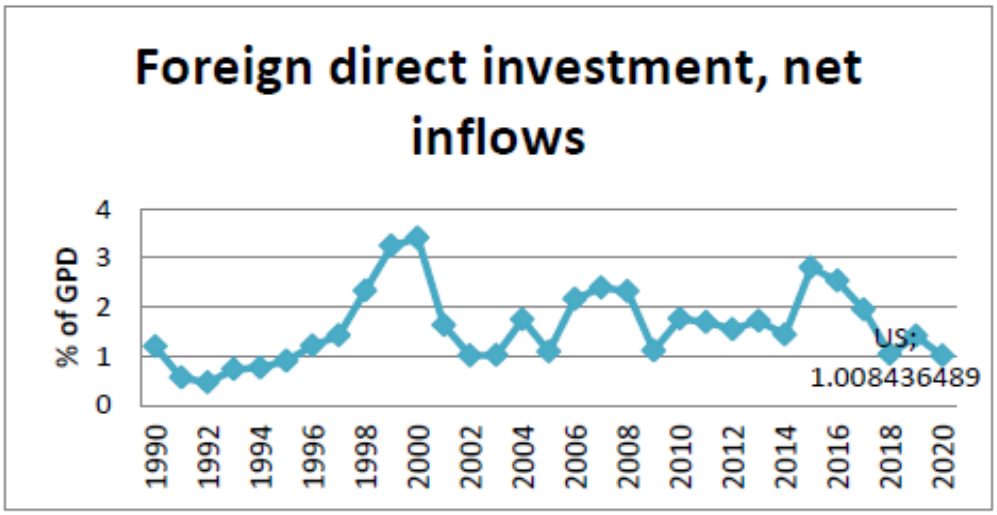

Figure 8 Foreign Direct Investment of US
Source: *World Bank*

Table 1 shows that all mean values in this study are positive, therefore, this study has high variability. It can be seen on the Table that the maximum of emission CO2 in United State is about 5892.21 and the minimum is 4271.52. Then, the maximum of economic growth is 7.2% and the minimum is -3.4%. For the variable of energy consumption have a maximum value about 5.496 and the minimum is -7.483. The last is FDI where the maximum is 3.4% and the minimum is 0.06%.

Table 1 Descriptive Statistic

Variable	*Mean*	*Std. dev*	*Minimum*	*Maximum*
CO2	5074.706593	468.3443744	4271.528132	5892.213432
EG	2.625811603	2.143892681	-3.404591573	7.236633158
EC	0.686627451	2.745460223	-7.483	5.496
FDI	1.153833483	0.848166028	0.066102932	3.405318336

Based on the results of the stationary test seen in Table 2, it shows that the variable CO2 emissions (Y) and foreign investment (X3) are not stationary at the level level because the p value is > from 0.05. Stationary at the level stage occurs in the variables of economic growth (X1) and energy consumption (X2). In order to stabilize all variables, it is necessary to return to the stationary test of the first difference. The results of the first-level difference test for the variable have a p-value <0.05 of the significance value, so it can be concluded that the variables Y, X1, X2, X3 are stationary in the first-deference plane with various conditions.

Table 2 Stationary Test

Variable	Level		Result	1st Difference		Result
	Stat. ADF	*p value*		Stat. ADF	*p value*	
Y	0.99155	0.9949	Not stationary	21.5652	0.0005	stationary
X1	12.6897	0.0003	stationary	42.4959	0.0000	stationary
X2	19.2696	0.0004	stationary	47.2881	0.0000	stationary
X3	14.713	0.0926	Not stationary	33.4324	0.0000	stationary

*Note : ** significance of 5%*

Based on Table 3, it is known that the optimal lag test produces lag with the criteria of FPE, AIC, SC, and HQ. It is recommended that the lag used is lag 4, because seen from the lowest AIC value and the asterisks are mostly in lag 4.

Tabel 3 Lag Optimum Determination

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-530.0025	NA	142346.4	23.21750	23.37651	23.27707
1	-469.4352	107.9677	20572.96	21.27979	22.07485*	21.57763*
2	-451.9899	28.06419	19651.09	21.21695	22.64806	21.75306
3	-437.8419	20.29931	22230.40	21.29747	23.36463	22.07184
4	-416.4778	26.93731*	19140.83*	21.06425*	23.76746	22.07689

Table 4. Cointegration Test

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. ofCe(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.672996	97.17821	47.85613	0.0000
At most 1*	0.478880	46.87798	29.79707	0.0000
At most 2*	0.298335	17.54807	15.49471	0.0000
At most 3	0.035030	1.604609	3.841465	0.2053

Trace test indicates 3 cointegrating eqn (s) at the 0.05 level

*denotes rejection of the hypothesis at the 0.05 level

**MacKinnon on-Hauq-Michelis (1999) p-values

Cointegration test was carried out using the Johansen Cointegration method and obtained a trace statistic value > from the critical value of 5% so that 3 cointegration relationships were obtained, as well as the Max Eigen Statistic value > compared to the critical value of 5%, indicating that there were 3 cointegration relationships. So it can be concluded that there is a stable relationship in the long term between variables. With the cointegration in this equation and the observed variables are stationary at the first difference stage, the next method can use the VECM model.

Table 5 Stability Test of VAR//VECM

Root	Modulus
0.868245	0.868245
-0.125242 - 0.843946i	0.853188
-0.125242 + 0.843946i	0.853188
-0.578540 - 0.577621i	0.815915
-0.578540 + 0.577621i	0.815915
0.386845 – 0.689901i	0.790957
0.386845 + 0.689901i	0.790957
-0.765794 – 0.116760i	0.774644
-0.765794 + 0.116760i	0.774644
0.077958 – 0.742126i	0.746209
0.077958 + 0.742126i	0.746209
-0.431171 – 0.538900i	0.690160
-0.431171 + 0.538900i	0.690160
0.475087 – 0.499140i	0.689092
0.475087 + 0.499140i	0.689092
-0.183214	0.183214

Table 6. Granger Causality Tes

Null Hypothesis:	Obs	F-Statistic	Prob.
X1 does not Granger Cause Y	47	0.25168	0.9068
Y does not Granger Cause X1		0.59536	0.6681
X2 does not Granger Cause Y	47	0.80361	0.5306
Y does not Granger Cause X2		0.69364	0.6010
X3 does not Granger Cause Y	47	0.66511	0.6201
Y does not Granger Cause X3		1.29415	0.2896
X2 does not Granger Cause X1	47	0.60178	0.6637
X1 does not Granger Cause X2		0.21000	0.9313
X3 does not Granger Cause X1	47	0.91422	0.4656
X1 does not Granger Cause X3		0.65279	0.6285
X3 does not Granger Cause X2	47	1.02942	0.4046
X2 does not Granger Cause X3		0.22195	0.9245

From Table 5, it can be seen that the models used are stable because the average value of the modulus is less than one. Therefore, it can be said that the results of further tests on the analysis of IRF (Impluse Response Function) and VDC (Variance Decomposition) can be said to be valid.

Table 6 explain that in the causality test it is known that X1, X2, and X3 are not causally related to CO2 emissions (Y) and vice versa, where the probability value is greater than 0.05 so that the variables do not have a two- way causal relationship.

Table 7. Long-term VECM Test

Variable	Coefficient	t-statistic	t-Table
D(Y(-1))	1.000000		
D(X1(-1))	661.8978	[5.47979]	
D(X2(-1))	752.2284	[5.13944]	2.012896
D(X3(-1))	-484.7790	[-2.83942]	
C	-65.88181		

Table 8. Short-term of VECM Test

Variable	Coefficient	t-Statistik	t-Table
CointEq1	0.160948	[1.36807]	
D(Y(-1),2)	-1.930471	[-2.43778]	
D(Y(-2),2)	-2.19608	[-2.25197]	
D(Y(-3),2)	-0.975247	[0.95537]	
D(Y(-4),2)	-0.221046	[0.33695]	
D(X1(-1),2)	-76.37393	[-1.10186]	
D(X1(-2),2)	-37.49196	[-0.66552]	
D(X1(-3),2)	-6.945064	[0.18382]	
D(X1(-4),2)	0.395015	[0.01869]	2.012896
D(X2(-1),2)	-65.06637	[-0.89806]	
D(X2(-2),2)	-17.01651	[-0.30670]	
D(X2(-3),2)	2.241346	[0.06234]	
D(X2(-4),2)	-13.18977	[-0.67843]	
D(X3(-1),2)	22.73797	[0.31772]	
D(X3(-2),2)	19.38555	[0.34237]	
D(X3(-3),2)	14.17095	[0.27182]	
D(X3(-4),2)	65.1385	[1.41363]	
C	-0.902584	[-0.03556]	

Table 7 shows that the variables X1 and X2 passed the a priori test while the X3 variable did not pass the long-term a priori test. In Table 8 the results of VECM can be seen that economic growth (X1), energy consumption (X2) and foreign investment (X3) have a long-term relationship with CO2 emissions when the t-statistic is greater than the t-table value.

Table 8 shows that the variables X1, X2, and X3 did not pass the short-term a priori test. Based on Table 8, it can be seen that the variables of economic growth (X1), energy consumption (X2), and foreign investment (X3) do not have a short- term relationship to CO2 emissions because the t-Statistic value has a smaller value than the t-Table.

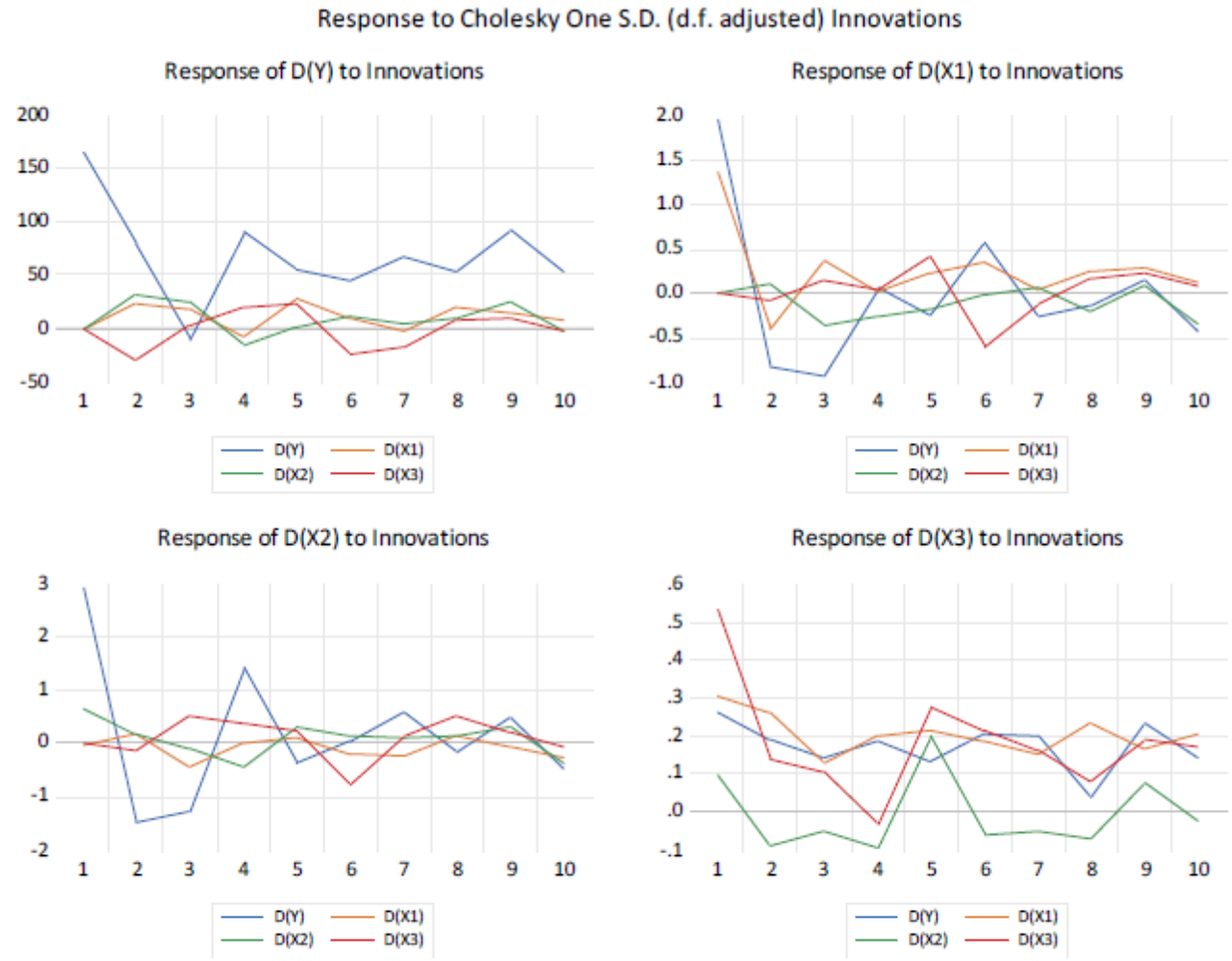

Figure 9 Impulse Response Function (IRF. Test)

Based on Figure 9 the response of the CO2 emission variable is positive from period one to period ten except for the third period. The response of the CO2 emission to economic growth is positive and negative from period one to period ten. The response of the CO2 emission to energy consumption is positive and negative from period one to period ten. The response of the CO2 emission to foreign direct investment is positive and negative from period one to period ten.

Economic growth variable responds positively and negatively from period one to period ten to the CO2 emission variable. The economic growth variable responds positively from period one to period ten to itself except in the second period. Economic growth variable responds positively and negatively to energy consumption variable. The economic growth variable responded positively and negatively from ten periods to the foreign investment variable.

Energy consumption variable responds positively and negatively from ten periods to the CO2 emission variable. The response of the energy consumption variable to economic growth is positive and negative from ten periods. The response of the energy consumption variable to itself is positive and negative from ten periods. The response of the energy consumption variable to foreign investment is positive and negative from period one to period ten.

The foreign investment variable responds positively from period one to period ten to the CO2 emission variable. The foreign investment variable responded positively from period one to period ten to the variable economic growth. The foreign investment variable responds positively and negatively from period one to period ten to the energy consumption variable. The response of the foreign investment variable to itself is positive from period one to period ten except in period four.

Figure 10 shows that in the first period, CO2 (Y) emissions are strongly affected by themselves by 100%. Furthermore, in the first period, the variables of economic growth (X1), energy consumption (X2), and foreign investment (X3) have not affected CO2 emissions (Y). Furthermore, CO2 emissions decreasedin proportion from the first period of 100,0000 to the tenth period to 89,04308.

The second position is foreign investment (X3) which has an increase of 0.000000 in period one to 3.940159 in period ten. The third position is energy consumption (X2) where in period one it is 0.000000 to 3.671380 in period ten.

Then the last position is the economic growth variable (X1) which has a VD value of 0.000000 in period one and then increases to 3.345382 in period ten.

In this study, it was found that economic growth has a long-term relationship and affects CO2 emissions positively and significantly with a t-statistic value of 5.47979, where the t-statistic value is greater than the t- table value, which is 2.022896, so that the long-term economic growth variable affects CO2 emissions are in accordance with the research hypothesis. Although the initial hypothesis or assumption of economic growth does not have a short-term relationship and does not affect CO2 emissions, this is supported by the t-statistic value which is smaller than the t-table value of 2.022896, so that the variable economic growth does not have a short-term impact on CO2 emissions. From this it can be concluded that in the long term there is an influence of the independent variable on the dependent variable. The Environmental Kuznets curve, or EKC theory, which explains that the magnitude of environmental damage will increase with increasing economic growth, but beyond a certain point the amount of environmental damage will decrease as economic growth increases when it has passed a turning point, while in the short term this is not proven in this study in brief. because CO2 emissions are a form of global pollution that is expected to increase or decrease in the long term. The results of this study also show that there is a positive and significant effect of long-term economic growth variables on CO2 emissions. This could be because economic growth has not yet passed the turning point, which occurs because at the initial scale the economy will continue to increase to pursue economic growth targets and increase people's incomes. The results of this study are also in line with research conducted by Baffoe-Bonnie & Mensah, (2018), Vo et al., (2019), Islam et al., (2017), Adhikari, (2021), Thongrawd & Kerdpitak, (2020), Ho, (2018), Arista & Amar, (2019), and Tang, (2017) which state that economic growth has a relationship and positively affects CO2 emissions.

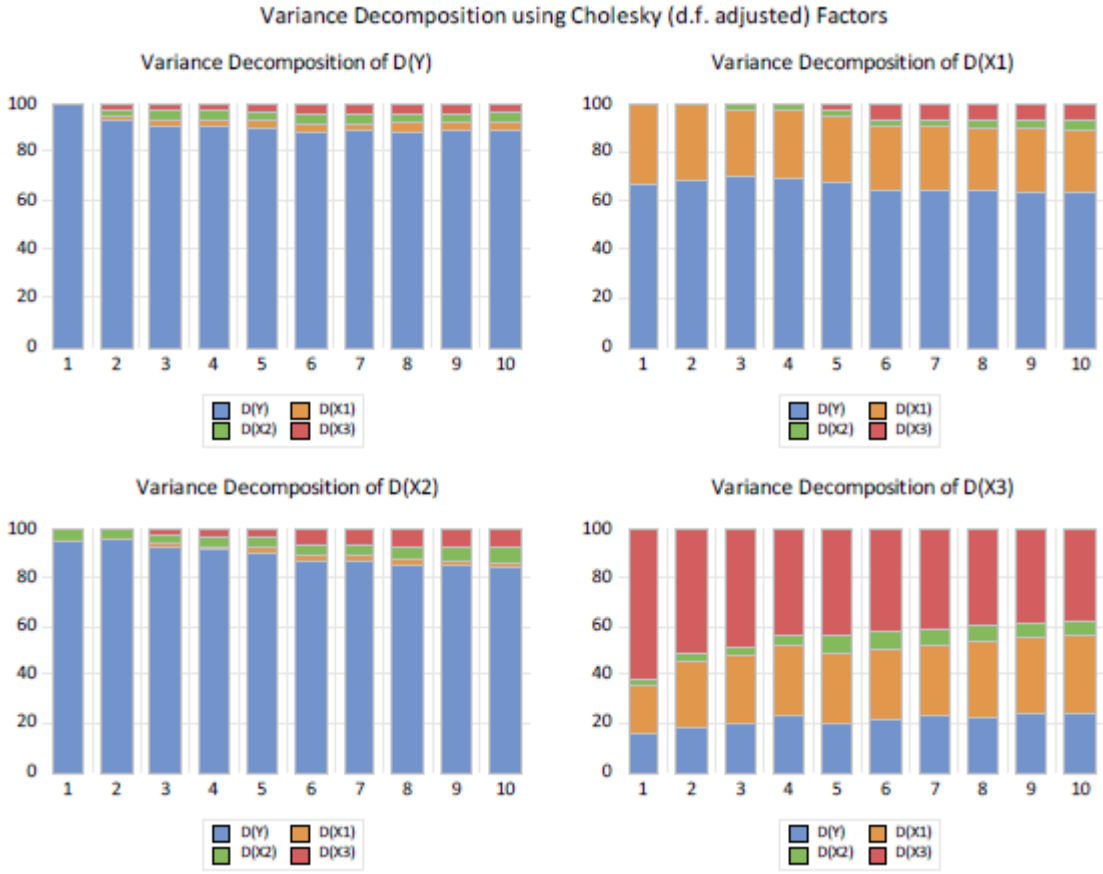

Figure 10. Variance Decomposition Test

The results of this study, found that energy consumption has a long-term relationship and affects CO2 emissions positively and significantly with a t-statistic value of 5.13944, where the t-statistic value is greater than the t-table value, which is 2.022896, so that the variable energy consumption in the long term affect CO2 emissions according to the research hypothesis. Although the initial hypothesis or assumption of economic growth does not have a short-term relationship and does not affect CO2 emissions, this is supported by the t-statistic value which is smaller than the t-table value of 2.022896, so that the energy consumption variable has no short-term impact on CO2 emissions. One part that affects monetary progress is how much energy is widely used, such as the increasing use of energy in the industrialization cycle. The demand for energy in the production industry to run machines must be very high. Then again, support for energy commitments, especially in trade or export receipts and government revenues, which are used in the method of collecting development capital. The results of this study are also in line with research conducted by Baffoe-Bonnie & Mensah, (2018), Vo et al., (2019), Islam et al., (2017), Adhikari, (2021), Thongrawd & Kerdpitak, (2020), Phrakhruopatnontakitti et al., (2020), Husain, (2016), Pao et al., (2012), Kurniarahma et al., (2020), Candra, (2018), ZULDAREVA, (2017), Arista & Amar , (2019), and Tang, (2017) who state that energy consumption has a positive relationship and affects CO2 emissions.

In this study, it was found that there was a long-term relationship indicating that the foreign investment variable had a significant negative effect on carbon emissions with a t-statistic value of -2.83942 which was greater than the t-Table value of 2.012896 in line with the research hypothesis. While the initial hypothesis or assumption of the foreign investment variable on short-term CO2 emissions is not proven, this is evident from the t-

statistic value which is smaller than the t-table value, so that the foreign investment variable has no impact on CO2 emissions in the short term. Long-term results show that foreign investment has a negative and significant effect on CO2 emissions, meaning that if foreign investment increases by 1%, CO2 emissions will decrease by -2.83942 million tons. Foreign investors will basically build an industry based on the up-to-date technology to reduce the level of negative externalities as low as possible for the sustainability of the industry in the long term. The results of this study are also in line with research conducted by Tang, (2017) which states that foreign investment has an effect on CO2 emissions.

Conclusion

Based on the VECM results, the economic growth variable (X1) in the short term is not significant with CO2 emissions, while in the long term the economic growth variable has a significant positive relationship with CO2 emissions so that it is in accordance with the hypothesis. Therefore, economic growth has a significant positive effect on CO2 emissions in the long term. Furthermore, the energy consumption variable has no relationship with CO2 emissions in the short term but has a significant positive effect in the long term. This means that the energy consumption variable is in accordance with the hypothesis. Therefore, there is an effect of energy consumption with CO2 emissions. Furthermore, the foreign investment variable in the short term is not significant to CO2 emissions, but the foreign investment variable has a significant negative relationship to CO2 emissions in the long term. This is in line with the hypothesis made. Therefore, it can be concluded that foreign investment affects CO2 emissions.

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