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DETERMINANTS OF CARBON DIOXIDE EMISSIONS IN INDONESIA

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ABSTRACT: *In the last few decades, sustainable environmental issues have become a major concern in the world due to global warming. Global warming is a serious problem today due to increasing earth surface temperatures. Environmental damage is the impact of the process of increasing per capita economic growth, energy consumption and investment. We analyze the relationship between carbon dioxide emissions, GDP per capita, energy consumption and foreign direct investment during the period 1993 – 2022 using the Vector Error Correction Model (VECM) method. The results of our research show that there is a relationship between GDP per capita, energy consumption, and foreign direct investment on carbon dioxide emissions in Indonesia. This research found that in both the short and long term, the variables per capita economic growth, energy consumption and foreign direct investment have a significant effect on carbon dioxide emissions in Indonesia.In the short term, the GDP per capita variable has a significant positive effect, but in the long term only the GDP per capita variable has a significant negative effect on carbon dioxide emissions. Meanwhile, the energy consumption and foreign direct investment variables have a significant positive effect on carbon dioxide emissions in both the short and long term.*

KEYWORDS):- *Carbondioxide emissions, economic growth percapita, energy consumption, and foreign direct investment, and VECM.*

HEADING

Development economic is a process to increase economic growth in a country. Through development, people can change their standard of living through economic and social aspects, especially in developing countries, to realize equitable community welfare (Leatari et al., 2021). Economic development is based on the concept of sustainable development (Sustainable Development) which involves the condition of natural resources, population with pressure on the process of economic activity which pays attention to long-term impacts, especially environmental degradation. In the last few decades, sustainable environmental issues have become a major concern in the world caused by global warming (Ahmed et al., 2022; Fuady, 2018; Khan et al., 2021).

Based on the Intergovernmental Panel on Climate Change (IPCC) report in 2017, it is estimated that average global temperatures will increase between 1.1 degrees Celsius and 6.4 degrees Celsius in the next century. Even though the intensity of the increase is small, this can cause major changes to natural ecosystems and sea level rise which can threaten 50% of the world's population living in coastal areas (Nguyen et al., 2022; Sharma & Kautish, 2020; Zhang et al. ., 2021). According to data published by The National Aeronautics and Space Administration (NASA, 2016), the earth's surface temperature continues to increase from year to year.

Countries in the world have entered into a series of agreements, such as the climate conference in Paris in 2015 which aims to reduce problems related to climate change by setting the goal of keeping world temperature rise well below 20C (UN, 2022). ASEAN member countries agreed to form the ASEAN Socio-Cultural Community (ASCC) Blueprint 2009-2015 and ASEAN Cooperation on Climate Change. The agreement takes the form of cooperation in dealing with climate change with mutually agreed policies. Apart from that, the United Nations (UN) formed an institution, namely the United Nations Framework Convention on Climate Change (UNFCCC), which was inaugurated on December 12 1997 in Japan. The agreement in the UNFCCC came into effect on 16 February 2005. The UNFCCC produced a document known as the Kyoto Protocol. The Kyoto Protocol is a form of world concern for carbon dioxide emissions (CO2 emissions). Factors that influence the increase in CO2 emissions have different variations in each country, this is due to social, economic, cultural and government policy factors (Chen et al., 2024). The main thing that causes CO2 emissions to increase every year is due to increased consumption of fossil fuels which causes global warming (Lin and Xu, 2020).

Indonesia is one of the developing countries in ASEAN which is in the early stages of development according to the Environmental Kuznets Curve (EKC) hypothesis. Thus, reducing environmental damage is difficult to implement due to the need for economic development and weak public awareness of the environment. Utilization of abundant natural resources if not accompanied by environmental-based management causes the country to be trapped in the Dutch Disease and Resource Curse phenomena (Leal, P.H, et al, 2022). However, there is a paradox when the impacts of climate change are more severely borne by developing countries (Noor and Saputra, 2020).

The development of CO2 emissions in Indonesia from 1993 to 2022 experienced fluctuations. In 1997 the amount of CO2 emissions increased compared to 1996 with a total of 983.16 metric (tons) increasing to 2.75 metric (tons) in 1997. The increase in CO2 emissions was accompanied by the Asian economic crisis, this cannot be separated from the lack of government supervision in law enforcement regarding land transfer, especially in Riau Province. Limited dry land in Riau Province due to land conversion and transmigration activities has caused plantation and industrial plantation forest (HTI) investors to start moving towards wetlands (peat). The fires that occurred in 1997-1998 due to land clearing reached 26,000 ha (Darjono, 2003). The fires in 1997-1998 were also triggered by the worst El Nino phenomenon throughout the year (Nurkholis, et al (2016). Overall, according to the World Resources Institute (WRI) and the Center for International Forestry Research (CIFOR), a combination of climate factors, agricultural practices unsustainable, and ineffective land management policies are the main causes of increasing carbon emissions in Indonesia.

The development of the social sector has a significant role in regulating the level of environmental degradation. Arrangements and regulations to improve welfare are expected to be able to reduce the effects of environmental degradation that arise. So that it can create a thriving economy and minimize the environmental impact it causes. Based on the description and seeing the phenomena that occur, the researchers see that it is important to conduct research related to "DETERMINANTS OF CARBONDIOXIDE EMISSIONS IN INDONESIA".

LITERATUR RIVIEW

1.1.1 Kuznets Theory Of Economic Growth

Kuznet state that economic growth is an increase in capability in the long term in a country concerned to provide economic goods to its population (Todaro, 2000). This capacity increase comes from technological, ideological and institutional advances. Economic growth is one of the essential parameters for successful economic development. Economic growth indicates that economic activities such as goods and services in society are increasing. Economic growth shows an increase in the country's productivity in producing goods and services (Finanda& Toto, 2022). Economic growth is focused on three main aspects, namely long term, process, and output per capita (Boediono, 2012).

1.1.2 Environmental Kuznet Curve

The EnvironmentalKuznetCurve theory has been developed in various environmental studies which depicts an inverted U-like relationship between per capita income and environmental quality (Cahyadin et al., 2021). According to Mekhzoumi et al. (2022) Environmental Kuznet Curve is a hypothesis commonly used in environmental economics literature to study the correlation between income and environmental degradation.

The Environmental Kuznet Curve is divided into three stages, namely the First. Economic development will increase environmental degradation or what is called pre-industrial economics, Second. Economic development has reached a turning point. The economy is transitioning from the industrial sector to the service sector or what is called the third stage, namely post industrial economics (service economy), Third. exploitation of natural resources has decreased, followed by increased public awareness of the environment, so that environmental degradation will also decrease (Noor & Saputra, 2020).

1.1.3 Foreign Direct Investment

Foreign direct investment will affect national productivity, this is due to the transfer of technology, management and expertise brought by the investing country. This increase in productivity will have an impact on increasing output, both for domestic consumption and exports. Apart from that, if FDI can increase, inflation and output growth will also increase.

In the early FDI phase, imports of equipment, machinery, provision of facilities and expertise all contributed to increased imports. This is caused by FDI companies which have a high tendency to import capital goods, intermediate goods and services that are not available in the host country. At later stages of investment, if FDI uses local raw materials and other locally produced inputs, it is unlikely to have a significant adverse impact on imports. However, on the other hand, if it depends on raw materials, human skills and other intangible assets originating from abroad, it will have a detrimental impact, namely increasing imports.

RESEARCH METHODOLOGY

1.1.4 Data Types and Sources

The research used in this research is secondary data, namely time series data for the period 1993-2022 where the data source was obtained from the World Bank and Development Indicators. This research was conducted in Indonesia. This is based on the pre-development trend of economic growth in Indonesia which is increasing every year. Apart from that, there were several phenomena between 1998 and 1999, Indonesia experienced a monetary crisis. Apart from that, Indonesia was also affected by the global financial crisis that occurred in 2008.

1.1.5 Research Model Specifications

This research examines determinant of carbondioxide emission in Indonesia. This model specification was adopted and derived from the research of Kusumawardani (2019) and Waluyo et al (2023), which relates environmental quality to carbon dioxide, which is shown in Equation as follows:

$$CO2 = aGDP^{b}EN^{c}FDI^{d}\varepsilon$$

It is known that CO2 is a representation of carbon dioxide, GDP is economic growthpercapita, EN is energy use, FDI is foreign direct investment. Kemudianditurunkanpada model Vector Error Correction Model (VECM)as follows:

$$CO2 = \Delta(GDP, EN, FDI)$$

So specifically, the above equation is formed in econometric model 3.3 and can be written as follows:

$$\Delta(CO2_t)=\Delta(a)+a\Delta GDP_t+a\Delta EN_t+a\Delta FDI_t + \varepsilon_t$$

1.1.6 Research Analysis Methods

The Vector Error Correction Method (VECM) is a VAR method that establishes a long-term relationship between the dependent variable and independent variables that are mutually cointegrated. In addition, VECM is a method that can determine the existence of short- and long-term relationships between variables and has dynamic and simultaneous properties, capable of detecting shocks caused by endogenous variables (Raehman et al, 2021).

In general, the VECM method for data uses the impulse response function (IRF) and variance decomposition (VD) and is implemented using a probability-based cointegration analysis framework in the vector error correction model (VECM) (Jan et al., 1999). So the equation can be formulated by modifying the equation data as follows:

$$X_t=\beta_o(t)+ \sum_{k}^{p}=1\, \beta_t X_{t-k}+\varepsilon_t$$

Where X_it is the K vector element of endogenous variables in each country, i = 1,..., N when t = 1,..., is a time period. In this research, X_it is a vector of.

Methode CO2 = GDP, EN, FDI

β_oi (t) reflects all deterministic components, namely constants, dummies, while X_(it-k) is the lag value of the endogenous variable and ε_it is K x 1 against uncorrelated disturbances. β_oi A=(t) and β_it as dependent cross section. The influence between variables can be seen from the VECM analysis which is reduced to the following equation:

$$\Delta CO2_t = \alpha_{a0} + \sum_1^m \alpha_1 \Delta CO2_{t-1} + \sum_1^m \alpha_2 \Delta GDP_{t-1} + \sum_1^m \alpha_3 \Delta EN_{t-1} + \sum_t^m \alpha_{4i} \Delta FDI_{t-1} + + \varepsilon_t$$
$$\Delta GDP_t = \alpha_{a0} + \sum_1^m \alpha_1 \Delta CO2_{t-1} + \sum_1^m \alpha_2 \Delta GDP_{t-1} + \sum_1^m \alpha_3 \Delta EN_{t-1} + \sum_t^m \alpha_{4i} \Delta FDI_{t-1} + + \varepsilon_t$$
$$\Delta EN_t = \alpha_{a0} + \sum_1^m \alpha_1 \Delta CO2_{t-1} + \sum_1^m \alpha_2 \Delta GDP_{t-1} + \sum_1^m \alpha_3 \Delta EN_{t-1} + \sum_t^m \alpha_{4i} \Delta FDI_{t-1} + + \varepsilon_t$$
$$\Delta FDI_t = \alpha_{a0} + \sum_1^m \alpha_1 \Delta CO2_{t-1} + \sum_1^m \alpha_2 \Delta GDP_{t-1} + \sum_1^m \alpha_3 \Delta EN_{t-1} + \sum_t^m \alpha_{4i} \Delta FDI_{t-1} + + \varepsilon_t$$

DISCUSSIONS

4.1 Develop General Descriptions

1.1.7 Carbon Dioxide Emissions in Indonesia

Indonesia is a country that occupies the fourth position with the largest population in the world and is the country with the tenth largest economy based on purchasing power parity and is a member of the G-20 (Indonesia Overview, 2022). Dynamic global economic conditions and continuous changes in the economic and political climate cause Indonesia's fundamental macroeconomic conditions to fluctuate in each period. The condition of Indonesia's economic growth in the last seven years is depicted in Figure 4.1 which shows that Indonesia's economic growth experienced fluctuations during that period. In 2009 there was a quite drastic increase in income inequality compared to the previous year. This was caused by the global economic condition which was experiencing pressure due to the crisis in 2008 which confronted the Indonesian economy with several challenges in 2009 which had an impact on the condition of the domestic real sector (Indonesian Economic Report, 2009). The global crisis in 2008 which originated from the American subprime mortgage crisis had a major impact on Indonesia's economic conditions so that in 2009 it resulted in an increase in income inequality. The decline in Indonesian exports to America caused the Indonesian manufacturing sector, especially on the island of Java, to experience a drastic decline, which simultaneously had an impact on income inequality (Tambunan, 2010). Apart from the decline in exports, the decline in Indonesia's GDP caused by the 2008 global crisis was caused by the massive outflow of foreign capital from Indonesia. This condition requires efforts to design solutions to overcome gaps that can continue continuously and sustainably (sustainability) (Klarin, T 2018).

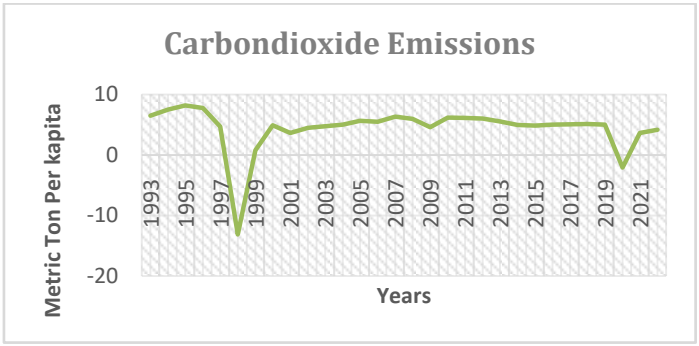

Figure 4.1 Development of Carbon Dioxide Emissions in Indonesia Source: World Bank, processed (2023)

In Figure 4.1, it can be seen that carbon dioxide emissions in Indonesia tend to increase every year. This is caused by industrialization encouraging increased use of fuel as the main ingredient in production which causes an increase in carbon dioxide emissions.

1.2 Model analysis and hypothesis testing

1.2.1 Stationer Test

To test the stationarity of the data in this study, the unit root test is used. Data that is not stationary will cause the regression results to be incorrect or erroneous. This condition can be recognized by the high R2 value, but the t-statistic and F-statistic values are non-standard.Stationarity testing in this study used the Fisher-Augment Dickey Fuller (Fisher-ADF) methods.

Table 1: Unit Root Test

Variabel		**ADF Fisher**	
		Level	**FD**
CO2	Statistic	-4.029696	-5.46581
	(Prob)	0.0043	0.0001
GDP	Statistic	0.575386	-3.965335
	(Prob)	0.9864	0.0051
EN	Statistic	-0.371359	-5.836309
	(Prob)	0.9008	0.0000
FDI	Statistic	1.319915	-6.824364
	(Prob)	0.6066	0.0000

Standard errors in parentheses
***stationary at 5% alpha

The above table reflects the estimated results of the ADF-Fisher unit root tests and shows that there are only 3 variables whose p-value is less than 5% and 1 other variable exceeds the α value or 5% Tests are required. on the first difference level. Next, the unit test results at the first level of difference show that all p-values for all variables are below the α value or 5%, so it can be concluded that the six variables at the first level of difference are stationary.

1.2.2 Optimum Lag Test

The optimal lag test shows the estimation results to determine the time period indicating the presence of variables that have an influence on other variables, which reflects optimal results.

Table 2: Optimum Lag Test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-585.2758	NA	1.06114	43.65006	43.84204	43.70715
1	-521.0397	104.6811*	3.04512*	42.07702	42.03689	41.36244
2	-511.6224	12.55636	5.41312	40.06463*	42.01241*	41.07839*
3	-490.7987	21.59499	4.82512	40.20731	42.70300	40.94941

Standard errors in parentheses
***stationary at 5% alpha
The results of the optimal lag test in the table above, looking at the table in the Akaike Information Criterion (AIC) section, found that the optimum lag is at lag 2. This criterion is because the minimum value in the Akaike Information Criterion (AIC) is at lag 2.

1.2.3 Cointegration Test

The cointegration test is used to determine whether there is a long-term influence on the variables examined. This cointegration test uses the Johansen cointegration test method.

Table 3: Cointegration Test

Hypothesized No.of CE (s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.730970	61.53616	47.85613	0.0016
At most 1 *	0.489752	36.08699	29.79707	0.0261
At most 2 *	0.454022	17.91981	15.49471	0.0474
At most 3 *	0.860267	6.007211	3.841466	0.0319

Standard errors in parentheses
***stationary at 5% alpha
Based on the table above, it can be explained that at the 5% test level (0.05), there are five ranks of variables related to cointegration. This is proven by the trace statistical values 61.53616, 36.08699, 17.91981, 6.007211 which are greater than the Critical Value 0.05, namely 47.85613, 29,79707, 15.49471, 3.841466 which means that H0 is rejected and H1 is accepted or in other words, all the variables are indicated to have

a long-term relationship (cointegration) with each other. Explicitly estimating VECM was further carried out by VECM stability tests.

1.2.4 Causality Test

The causality test is one of the VECM analyses, the purpose of which is to determine the interrelationship between variables, both one-sided and two-sided, by looking at the probability values.

Table 4: Causality Test

Null Hypothesis	**F-statistik**	**Prob.**
GDP does not Granger Cause CO2	1.10820	0.5746
CO2 does not Grange Cause GDP	0.49354	0.7813
EN does not Granger Cause CO2	4.03783	0.1328
CO2 does not Granger Cause EN	2.05283	0.3584
FDI does not Granger Cause CO2	2.10542	0.3490
CO2 does not Granger Cause FDI	0.24389	0.8852
EN does not Granger Cause GDP	1.85129	0.3963
GDP does not Granger Cause EN	7.26687	0.2064
FDI does not Granger Cause GDP	2.60262	0.2722
GDP does not Granger Cause FDI	13.9846	0.2009
FDI does not Grange Cause EN	1.68489	0.4307
EN does not Granger Cause FDI	0.68676	0.5652
EP does not Granger Cause EN	1.07708	0.3692

Standard errors in parentheses

***stationary at 5% alpha

From the table above, the majority of test results fall within the independence causality criteria, or the absence of a causal relationship between variables, as reflected in the probability values in the table above. As can be seen in the table, there are two variables that have a reciprocal causality relationship between the variables and have a one-way relationship or are included in the unidirectional causality criteria from the results of the Parwise-Granger causality test. Variables whose probability value is above an alpha value of 5%, on the other hand, have no causal relationship between the variables.

1.2.5 Vector Error Correction Model (VECM).

In the estimation results of this study using VECM because there is a cointegration relationship.

Tabel 5: VECM Estimation Results

EstimasiJangkaPendek		
Variabel	**Koefisien**	**t-statistik**
CointEq1	0.282718	2.91413
D(CO2(-1),1)	0.561020	2.56680
D(CO2(-2),1)	0.365136	1.25153
D(GDP(-1),1)	0.707634	2.78787
D(GDP(-2),1)	0.005104	1.56211
D(KE(-1),1)	3.009329	2.51598
D(KE(-2),1)	3.867487	2.73349
D(FDI(-1),1)	0.100465	0.88644
D(FDI(-2),1)	0.200117	3.38665
C	0.176434	0.15650
EstimasiJangkaPanjang		
Variabel	**Koefisien**	**t-statistik**
CO2	1.000000	
GDP	-0.022300	-5.30646
KE	7.573021	3.20942
FDI	0.002675	5.64120
C	-5.564407	
R-Squared	0.630581	
Adj. R-Squared	0.566532	

F-statistik	5.094076

Standard errors in parentheses

***stationary at 5% alpha

The estimation results show that theThe estimation results show that the variables per capita economic growth, energy consumption and FDI have a significant effect on carbon dioxide emissions in Indonesia. In the short term, the GDP per capita variable has a significant positive effect on carbon dioxide emissions D(GD(-1)1) of 0.707634. meaning, every increase in GDP per capita by 1 million will increase carbon dioxide emissions by 0.707634 metric tons per capita. Furthermore, the energy consumption variable has a significant positive effect on carbon dioxide emissions with a coefficient value of D(KE(-1),1) of 3.009329. This means that every 1 kWh increase in energy consumption will increase carbon dioxide emissions by 3.009329 metric tons per capita. Energy consumption D(KE(-2),1) also has a significant effect with a coefficient of 3.67487, meaning that when energy consumption increases by 1 kWh it will increase carbon dioxide emissions by 3.867487 metric tons per capita. Then the FDI variable also has a significant positive effect on carbon dioxide emissions with a coefficient D(FDI(-2),1) of 0.200117. This means that every 1 billion increase in FDI will increase carbon dioxide emissions by 0.200117 metric tons per capita.

The relationship between GDP per capita, energy consumption and FDI on carbon dioxide emissions in the long term shows mixed results. The GDP per capita variable shows a significant negative result on carbon dioxide emissions with a GDP coefficient value of -0.022300. This means that every time there is an increase in GDP per capita by 1 million, carbon dioxide emissions will decrease by 0.022300 metric tons per capita. Furthermore, the energy consumption variable has a significant positive relationship with carbon dioxide emissions with a KE(-1) coefficient of 7.573021, meaning that when energy consumption increases by one unit it will increase carbon dioxide emissions by 7.573021 metric tons per capita. Then the FDI variable also has a significant positive effect with a coefficient of 0.002675. This means that every increase in FDI of 1 million will be followed by an increase in carbon dioxide emissions of 0.002675 metric tons per capita.

1.2.6 VECM Model Stability Test

The stability test in this research model was carried out before estimating the VECM model. In addition, the modulus value is used in the stability test to support the results of the impulse response function analysis and variance decomposition.

Tabel 6: Results of the model stability test

1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
-0.095480 - 0.905821i	0.910839
-0.095480 + 0.905821i	0.910839
-0.497134 - 0.260702i	0.561344
-0.497134 + 0.260702i	0.561344
-0.396457	0.396457

Standard errors in parentheses

***stationary at 5% alpha

The table reflects a fairly stable VECM model. This is proven by the total modulus value being less than one, so it can be concluded that the VECM model is valid.

1.2.7 Impulse Respons Function Analysis

Explicitly, the impulse respons function test is part of the VECM analysis, which is able to project shocks onto other variables to predict what contribution each change will make in the system.

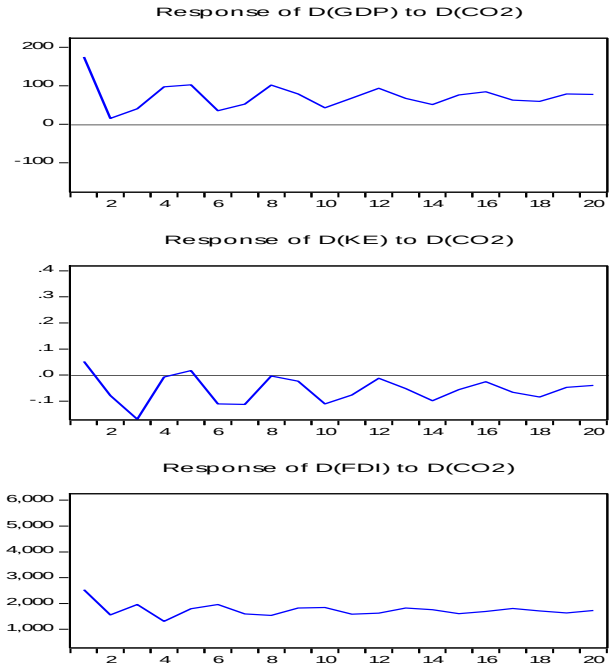

Figure 4.1:Results of Variance Decomposition Analysis of Dependent Variable (CO2)

Based on Figure 4.1, it can be seen from the results of the variance decomposition that the movement of GDP per capita, energy consumption and FDI on Indonesia's carbon dioxide emissions. In the first period, carbon dioxide emissions were influenced by the shock of carbon dioxide (CO2) emissions (100%) even though at that time the shock of GDP per capita (GDP), energy consumption (EN), and Foreign Direct Investment (FDI) still had no effect. Then in the next period, shock movements in the GDP per capita, energy consumption and FDI variables can be seen in the following year. In the GDP per capita variable, the state of shock fluctuates, where in the second period the oil price variable contributes 0.20% to carbon dioxide emissions. Furthermore, from the 3rd and 4th periods there was an increase, namely to 0.88%. Then in the 5th and 6th periods it ranged between 7%. then in the 7th and 11th periods it was 0.92% and 0.90%. Furthermore, in the 8th and 10th periods and the 12th to 20th periods it was relatively stable, ranging from 0.85% - 0.89%. In the energy consumption variable, the state of shock fluctuates. It can be seen that in the 1st period it was not able to have any influence at all. The influence of the energy consumption variable on carbon dioxide emissions was seen in the 2nd period at 0.02%, then increased in the 3rd period, namely 0.03%. Meanwhile, in the 4th and 5th periods there was a decrease, although small, then it increased again in the 6th period by 0.03%. Meanwhile, in the 7th period it was 0.02%, there was a relative decrease until the 20th period was 0.02%. The relative FDI shock variable experienced a decline which was reflected in the 2nd period by 0.04% and in the 20th period by 0.02%.

The biggest contribution to carbon dioxide emissions is the energy consumption variable where the shock movement in the energy consumption variable is relatively stable even though it has decreased. The largest consumption contribution was 2.31%. In the GDP per capita variable, the shock movement also fluctuated and tended to decrease until the end of the period, although it was not large, the highest contribution was in the third period with a contribution of 0.09%. Furthermore, the FDI shock movement tended to decrease until the 20th period where the FDI shock contributed 0.04% to carbon dioxide emissions.

1.2.8 Varians Decomposition

The capacity of the IRF test is to detect whether a shock occurs due to changes in one variable relative to another variable. Furthermore, we will also review the long-term dynamic response and the level of shock effects that occur, reflected in the IRF test graph.

Table 7:Variance Decomposition CO2 response to GDP, energiconsumtion, foreign direct investment.

Period	S.E	D(CO2)	D(GDP)	D(EN)	D(FDI)
1	5.864451	100.0000	0.000000	0.000000	0.000000
2	7.439352	64.72650	2.077570	29.12912	4.066806
3	9.029162	56.11801	8.892367	31.60049	3.389131
4	10.02721	63.11989	8.128099	25.63251	3.119495
5	10.68608	65.87802	7.191196	23.76048	3.170303
6	11.69764	58.64116	7.633209	30.00296	3.722669
7	12.50744	58.33471	9.201416	29.17163	3.292243
8	13.16310	61.95240	8.611988	26.45650	2.979110
9	13.69338	62.10827	8.164142	26.62954	3.098053
10	14.41816	59.32802	8.675151	28.80190	3.194937
11	15.01304	60.22748	9.079342	27.73917	2.954014
12	15.50655	62.09033	8.723973	26.40064	2.785064
13	16.00324	61.58469	8.546599	26.98595	2.882762
14	16.57183	60.53764	8.912957	27.70529	2.844112
15	17.06049	61.48131	8.977091	26.84908	2.692519
16	17.48374	62.37841	8.759642	26.24567	2.616278
17	17.94714	61.84335	8.734371	26.75834	2.663939
18	18.42322	61.57440	8.947035	26.87807	2.600486
19	18.84651	62.30760	8.911092	26.27926	2.502047
20	19.23758	62.67516	8.785376	26.06620	2.473257

Source: Eviews, processed (2024)

The results of the variance decomposition analysis show that after a time interval of 20 periods, it is known that the CO2 variable in the first period was 100% influenced by the CO2 variable in the previous period. In the following period, the CO2 movement is then influenced by other variables that play different roles depending on the size of the coefficient produced. If we look at the results of the variance decomposition analysis over the ten time periods, the variables that contributed the most to CO2 are GDP percapita (GDP). In addition, it can be seen from the above table that the role and effectiveness of the government is the greatest when it comes to CO2. The contribution to government effectiveness varied over ten periods, but was largest overall. Furthermore, the trade openness variable is the second largest contributor after government effectiveness. The variable with the smallest CO2 contribution, namely the GDP variable, is reflected in period 2, which has a contribution of 0.08 percent, and in period 10 this is 0.33 percent.

1.2.9 Classical Assumption Test.

The classical assumption test is used to determine whether the parameter estimates are free from indications of normality, heteroscedasticity and autocorrelation.

Table 8: Classical Assumption Test

Classical Assumption Test	Test	Probability	Explanation
Normality	Jarquebera	0.4430	Normally Distibuted
Heteroskedasticity	White-Heteroscedasticity	0.2833	Heteroskedasticity does not occur
Autocorrelation	LM test	0.2191	Autocorrelation does not occur

Standard errors in parentheses

***stationary at 5% alpha

hows the results of the classical assumptions in this research. The normality test results indicated by the Jaque-Berra probability value are 0.4430. This reflects normally distributed data as the probability value > alpha value is 5%. In addition, the heteroscedasticity test using white heteroscedasticity has a probability value of 0.2833, which means that there are no symptoms of heteroscedasticity. Finally, the autocorrelation

test uses the LM test with a probability result of 0.2191, which is greater than the determined alpha value 5%. It can be concluded that the model is free of autocorrelation problems.

RESULTS AND DISCUSSIONS

1.2.10 The Impact of GDP on Carbondioxide Emission in Indonesia

Based on the short-term VECM estimation results, it shows that GDP per capita has a significant positive effect on carbon dioxide emissions in Indonesia. However, long-term VECM results show that GDP per capita has a negative effect on carbon dioxide emissions in Indonesia. This is because GDP is a benchmark for a country's economy. If GDP increases, production levels will also increase, resulting in an increase in carbon dioxide emissions.

This research validates the Environmental Kuznet Curve (EKC) theory which states that in the short term an increase in GDP per capita will be followed by an increase in carbon emissions (environmental degradation) and in the long term an increase in GDP per capita will reduce carbon dioxide emissions (improving environmental quality). This is because people with low incomes tend not to care about environmental quality because they focus more on improving their quality of life. However, when the quality of life is felt to be sufficient, they will tend to care more about the quality of the environment. The findings in this study are in line with research conducted by Ibrahim et al. (2022); Mahmood et al. (2019); S. A. H. Zaidi et al. (2021)).

1.2.11 The Impact of Energy Consumption on Carbondioxide Emissions in Indonesia

Based on the estimation results, it shows that energy consumption has a significant effect on carbon dioxide emissions in Indonesia in the short term. However, the energy consumption variable does not have a significant effect on carbon dioxide emissions in the long term. This means that when there is an increase in energy consumption, carbon dioxide emissions will increase. The increase in carbon dioxide emissions caused by the increase in energy consumption is in line with the findings made by Ntanos et al. (2015), Sasana & Putri (2017), and Jing Li et al. (2023).

1.2.12 The Impact of Foreign Direct Investment on Carbondioxide Emissions in Indonesia

Based on the estimation results, it shows that FDI has a significant effect on carbon dioxide emissions in Indonesia both in the long and short term. In the short term, FDI has a significant positive effect on carbon dioxide emissions. Meanwhile, in the long term, FDI has a negative effect on carbon dioxide emissions. Therefore, these findings also support the Environmental Kuznet Curve theory. This is because in the short term, incoming investment tends to be used for economic activities without considering the quality of the environment. However, in the long term, incoming FDI tends to be used for production activities carried out with environmental quality in mind. Apart from that, this research is also in line with research conducted by Ghazouani (2021); Tariq et al. (2018). However, in contrast to the findings made by Tamazian & Bhaskara Rao (2010); Tang (2017) states that increasing FDI has an effect on increasing carbon dioxide emissions.

CONCLUSION

Overall, The results of the discussion that have been explained in the form of test estimates using VECM explain the determination of carbon dioxide emissions in Indonesia. In this research, there are several conclusions obtained in this research as follows: 1. Income inequality has a significant effect on carbon dioxide emissions in Indonesia, both in the short and long term.2. GDP per capita has a significant effect on carbon dioxide emissions in Indonesia both in the short and long term.3. Energy consumption has a significant effect in the short term. However, energy consumption does not have a significant effect on carbon dioxide emissions in Indonesia in the long term. 4. FDI has a significant effect on carbon dioxide emissions in Indonesia, both in the short and long term.

Apart from that, this research also validates the Environmental Kuznet Curve (EKC) Hypothesis which states that in the short term people are more likely to prioritize increasing their income rather than caring about environmental quality. Then, in the long term, an increase in people's income is followed by an increase in environmental quality (a decrease in carbon dioxide emissions. However, in this study, energy consumption and FDI, both in the long and short term, have an effect on increasing carbon dioxide

emissions. This means that people in Indonesia have not yet switched to using energy renewables and the use of FDI is often used for production activities that produce carbon dioxide emissions.

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