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Causality of the Industrial Sector on Carbon Emissions (Co2) and Government Commitment in ASEAN-5

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Abstract From the standpoint of the green economy, the aim of this study is to ascertain the causal relationship between GDP, energy consumption, and industry on carbon emissions. The industrialization sector has developed as a result of changes in the economic structure. The economy of the nation is impacted by this shift in two ways: first, through economic growth, and second, by externalities resulting from industrialization. The environmental issues are not yet favourable for this ASEAN-5 emerging nation, which is in a pre-industrialization stage when economic growth is focused on raising income and employment. Stricter rules in the environmental sector are necessary since, as per the EKC hypothesis, a green economy can only be realized when ecological consciousness is reached at a specific income level. Empirically, the VECM approach is applied to yearly secondary data from five ASEAN countries between 2011 and 2020. The study's findings indicate that two variables—the GDP variable and the two-way relationship between CO2 and the test—have a causal relationship based on the Granger causality test results. On the other hand, there is a one-way relationship between the industrial variable and energy usage. According to the findings of the PVECM calculation, all factors—namely, the manufacturing sector, energy use, and economic expansion—decrease carbon emissions. This scenario demonstrates how an environmentally friendly economy, defined by a reduction in carbon emissions, can be accelerated by the employment of technological innovation in the macroeconomic mix to accelerate economic expansion.

Keywords Carbon Emissions, Energy Consumption, Manufacturing Industry, VECM Panels

1. Introduction

In the globalization, economic expansion is the main key to successful economic development. In particular, intensive use of resources supports the economy, but in the long term, with uncertain climate anomalies and the Resource Curse phenomenon, very prominent changes occur in the economy that are reflected by the difficulty of achieving economic balance. It comes into the increase in production output is proportional to the increase in pollution produced [1].

The increase in production results reflects the rapid activity of the manufacturing industry. The series of industrial improvements is part of the positive impact of Industrial Revolution 4.0. On the other hand, this industrial value chain has a double effect on the economy, in the form of economic expansion and an increase in the impact of externalities resulting from production in the form of pollution [2] The industrial sector is one of the main sources of increasing energy consumption. Indirectly, manufacturing activities depend on energy as the driving force of the economy. Manufacturing industrial production that is not accompanied by technological innovation for renewable energy in the long term has an impact on environmental quality [3].

The manufacturing industry is believed to be an instrument of the national economy and the foundation of a country in driving the economy. Building an independent and complete industrial system will produce great added value. However, as an energy-intensive industry, it is highly dependent on energy consumption, as the scale expands and the need for energy consumption increases rapidly, ultimately the manufacturing industry is the largest contributor to carbon emissions [4].

Kuznet, in his theory, explains that environmental degradation occurs due to changes in economic structure. Where the phase of change in economic structure from agriculture to industry has a double impact on the economy. Kuznet hypothesis describes the relationship between economic growth and pollution from carbon emissions in an inverted U shape. Referring to the Kuznet hypothesis, higher income reflects increased economic growth in the long term and can achieve environmental quality characterized by low carbon emissions [1].

Empirical evidence supporting the Kuznets Theory states that increasing economic growth contributes to increasing carbon emissions [5], it is in line with the research by [6] that stated the main factor increasing global warming is increasing carbon emissions. Different from research [7]

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based on the results of the Granger causality test for the short and long term, asymmetric industrialization reduces carbon emissions.

Several studies have proven that the main contributor to carbon emissions is not only economic growth from the added value of industrialization but also other factors from the countries affected by the Industrial Revolution 4.0, namely ASEAN-5 countries including Indonesia, Malaysia, Thailand, the Philippines and Vietnam. Industrialization has historically been associated with creating wealth and improving living standards, on the other hand, it has harmed the economy. This contributes to environmental pollution, reflected in increasing energy consumption which results in a massive increase in carbon emissions [8].

From the description above, the objective of this research is explicitly to determine the causal relationship between the industrial sector which is proxied by the variable energy consumption, manufacturing industry and environmental carbon emissions in ASEAN-5 countries, both short and long term.

2. Literature Review

2.1. Environment Kuznet Kurve (EKC)

Simon Kuznet pioneered the Environmental Kuznet Curve (EKC) hypothesis, an inverted U theory that explains the long-term relationship between economic growth and environmental quality, where development or economic growth itself causes environmental damage in future generations. Successful economic development is synonymous with increased economic growth. This increase in economic growth will also cause increased environmental degradation, up to a certain critical point.

The Environmental Kuznets Curve (EKC) diagram has previously categorized the relationship between changes in economic structure and economic growth of a country into three stages; First, environmental damage. With the development of industrial processes from small-scale industry to large-scale industry, natural resources can be utilized better. Second, in the industrial-level economy, there is a shift in the economic structure from the agricultural sector to the industrial sector due to the increase in domestic industry. Third, changes in the economic structure of the post-industrial economy are continuing, with a shift from the industrial sector to the service sector, where information and technology are becoming more efficient and sophisticated. This change in economic structure causes reduced environmental degradation and increased income, which in turn causes an increase in environmental and air pollution due to the need for economic activities to increase production.

2.2. Endogen-Solow Growth Theory

According to Solow, (Solow Neoclassical growth model) what influences economic growth is the level of capital accumulation, population growth rate, and level of technological development (Sukirno, 2013: 437). The Solow growth model according to Aghion, and Howitt, 2003; Helpman, 2004; Schiliro, 1986 is an exogenous variable consisting of saving levels, population growth and technical progress growth. There are changes in production factors, capital and labour due to changes in population growth and investment, which are assumed to be in a perfectly competitive market.

$$Y = F(K, L) \tag{2.1}$$

This formula describes the production function to determine the occurrence of technology. Y is output in the form of national income. K and L reflect capital and labour.

$$dK/dt \equiv K \equiv (t) \tag{2.2}$$

The Solow model is categorized in the law of motion in the capital stock. The capital is obtained from the accumulation of commodities and the amount of additional capital stock dK/dt is called net investment I(t).

$$s(t) = I(t) = sY(\text{t}) \tag{2.3}$$

The above formula is a function of saving and investment derived from total income Y(t).

$$K = sF(K, L) \tag{2.4}$$

The formula above is obtained from equation (2.1) into equation (2.3)

$$L(t) = Loe^{nt} \tag{2.5}$$

The above formula is the result of exogenous population growth, labour (n) that increases relatively constantly. Solow differs from Harrod-Domar who assumes that there is no technological change.

Equation (2.4) L shows the total number of workers, while (2.5) L shows the supply of labour.

$$K = sF(K, Loe^{nt}) \tag{2.6}$$

The above equation is obtained from the equation (2.5) into equation (2.4). Equation (2.6) describes the growth movement by analyzing capital accumulation and the growth rate of labour.

$$K = Loe^{nt} + nrLoe^{nt} \tag{2.7}$$

Equation (2.7) above is a differentiation related to time.

$$(r = nr)L_0 e^{nt} = \text{s}L_o e^{nt} F(K/L_o e^{nt}, 1) \tag{2.8}$$

Equation (2.8) above is obtained by substituting equation (2.7) into equation (2.6) so that a constant return to scale is formed.

$$r = sF(r, 1) - nr \tag{2.9}$$

Equation (2.9) reflects changes in the capital and labour ratio.

Robert Solow is one of the economists in the Neo-Classical group. According to Neo-Classics, economic growth is based on an increase in the supply of production factors (accumulation of capital, population and labour) as well as the level of technological progress (Hasmarini, 2003). Where this theory has developed since the 1950s, Neo-classics view the economy based on the assumptions that underlie its analysis. That the economy will experience (full employment) or full use of labour levels as well as the use of capital in the form of equipment capacity used throughout the period.

2.3. Sustainable Development

Sustainable development which was first introduced by the World Commission on Environment and Development (WCED) stated in Our Common Future or the Brundtland report, is still a matter of debate for environmental experts. This gives rise to various definitions of sustainable development. According to (Emil Salim, 1990), sustainable development aims to improve community welfare to meet human needs. Sustainable development essentially aims to achieve equitable development between current and future generations. According to the Ministry of the Environment, economic-oriented development that takes into account the principles of sustainability must meet three criteria: (1) wasteful use of natural resources, (2) pollution and other environmental factors (3) must increase the availability or fungibility of resources in activities (Jaya, 2004).

According to [9] there are three reasons why economic development must be based on the principle of sustainability. Firstly, moral reasons, the current generation enjoys goods and services produced from natural resources and the environment so it is morally necessary to pay attention to the availability of these natural resources for future generations or this moral obligation includes extracting resources. natural resources that can damage the environment, which can eliminate the opportunity for future generations to enjoy the same thing. Second, technological reasons, for example, the high economic value of biodiversity, therefore economic activity should not lead to activities utilizing natural resources and the environment alone ultimately threatens ecological functions. Third, economic reasons, reasons from the economic side are still being debated because it is not yet known whether economic activities so far have or have not even met the sustainability criteria, as we know that the economic dimensions of sustainability are quite diverse, but often the sustainability aspects from the economic side are only limited to measuring intergenerational welfare.

3. Research Methodology

3.1. Design and Data Source

This research uses panel data which combines time series data with cross section data. Time series data, namely carbon dioxide, GDP, energy consumption, and industrial sector with a period of 2011 to 2020 and source obtained from the World Bank. The cross-section data, namely Indonesia, Malaysia, Thailand, Vietnam and the Philippines, is the research object used, taken from several countries in the Southeast Asia region. In this research, the background for choosing the 2011-2020 period is because it is directly related to economic and methodological issues.

3.2. Research Design Specification

This research examines GDP, Energy Consumption and Number of Manufacturing Industries on Carbon Emissions in ASEAN-5. This model specification was adopted and derived from research by Jian, J et al, 2019 which proxies carbon emissions from a green economy perspective which is written in equation 3.1

$$EK = aGDP^{b}KE^{C}IM^{d}\varepsilon \quad (3.1)$$

it is stated that EK is a representation of a green economy which is proxied from carbon emissions, GDP is economic growth, KE is energy consumption, IM is the number of manufacturing industries written in equation 3.2

$$\Delta EK = \Delta(GDP, KE, IM) \quad (3.2)$$

By that, the above equation is formed into 3.3 econometric as follows;

$$\Delta(EK_{i,t} = \Delta(a) + a\Delta GDP_{i,t} + a\Delta KE_{i,t} + a\Delta IM_{i,t} + \varepsilon_{i,t} \quad (3.3)$$

3.3. Research Analysis Methods

In general, this research uses the VECM method on panel data and uses IRF and VD which implement a likelihood-based framework for co-integration analysis in the VECM year. So, the PVECM equation can be formulated by modifying the equation using panel data as follows:

$$X_{it} = \beta_{oi}\ (t) + \sum_{k}^{p} = 1\beta_{it}X_{it-k} + \varepsilon_{it}$$

X_{it} is a vector element from endogen variable in every country. i= 1,..., N, meanwhile t=1 ,..., is a period of time. In this research, X_{it} act as a vector of:

EK – GDP, KE, IM Model

$\beta_{oi}\ (t)$ describes all deterministic components, namely constants, and dummy. X_{it-k} is the lag value of the endogenous variable and ε_{it} is K x 1 for uncorrelated disturbances, and $\beta_{oi}\ A = (t)$ and β_{it} as a dependent cross-section. The influence between variables can be observed from the PVECM analysis which is reduced to the following equation:

$$\Delta EK_{it} = \alpha_{a0} + \sum_{i=1}^{m}\alpha_{1i}\Delta EK_{it-1} + \sum_{i-1}^{m}\alpha_{2i}\,\Delta GDP_{it-1} + \sum_{i-1}^{m}\alpha_{3i}\Delta KE_{it-1} + \sum_{i=1}^{m}\alpha_{3i}\Delta IM_{it-1} + \alpha_{4}ECT_{t-1} + \varepsilon_{it}$$

$$\Delta GDP_{it} = \theta_{a0} + \sum_{i=1}^{m}\theta_{1i}\Delta GDP_{it-1} + \sum_{i-1}^{m}\theta_{2i}\,\Delta EK_{it-1} + \sum_{i-1}^{m}\theta_{3i}\Delta KE_{it-1} + \sum_{i=1}^{m}\theta_{3i}\Delta IM_{it-1} + \theta_{4}ECT_{t-1} + \varepsilon_{it}$$

$$\Delta KE_{it} = \mu_{a0} + \sum_{i=1}^{m}\mu_{1i}\Delta KE_{it-1} + \sum_{i-1}^{m}\mu_{2i}\,\Delta EK_{it-1} + \sum_{i-1}^{m}\mu_{3i}\Delta GDP_{it-1} + \sum_{i=1}^{m}\mu_{3i}\Delta IM_{it-1} + \mu_{4}ECT_{t-1} + \varepsilon_{it}$$

$$\Delta IM_{it} = \beta_{a0} + \sum_{i=1}^{m}\beta_{1i}\Delta IM_{it-1} + \sum_{i-1}^{m}\beta_{2i}\,\Delta EK_{it-1} + \sum_{i-1}^{m}\beta_{3i}\Delta GDP_{it-1} + \sum_{i=1}^{m}\beta_{3i}\Delta KE_{it-1} + \beta_{4}ECT_{t-1} + \varepsilon_{it}$$

4. Discussion

4.1. Development of Carbon Emissions in ASEAN-5

One of the most dangerous compounds contributing to the environment is carbon dioxide, where this compound can harm nature and human health. The company's activities continue to be carried out to meet increasing human needs, resulting in air pollution which will pollute the environment and cause global warming and uncertain climate anomalies. The data used is carbon dioxide data from 2011 to 2020 as follows.

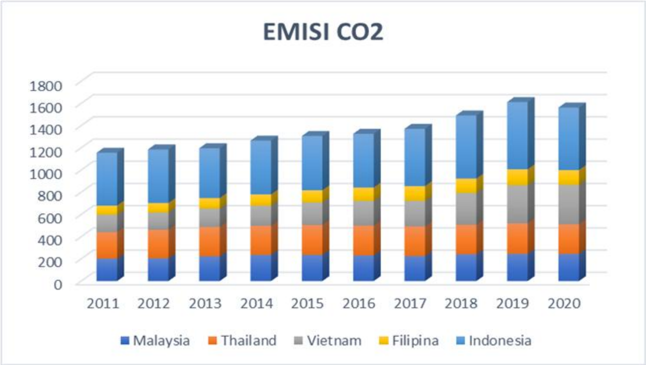

Figure 4.1. Development of Carbon Emissions in ASEAN-5 Source: Word Bank, 2020

Based on Figure 4.1, shows that in 2020 the highest amount of carbon dioxide gas emissions occurred in Indonesia, namely 563,1973. Historically, Indonesia's economic structure has changed from the agricultural sector to the manufacturing sector. Where the industrial sector is directly proportional to energy consumption as the driving force of the economy. In line with the high demand for consumption. If the growth of the industrial sector is not accompanied by the use of technology, it will indirectly produce external impacts on the environment, namely carbon emissions [10]. Apart from that, the industrial sector is one of the contributors to Indonesia's GDP (Word Bank, 2020). The relationship between the industrial sector is directly proportional to economic growth, this understanding is in line with the Kuznets theory (EKC) where the industrial sector is in the economic phase, namely in the long term will reduce carbon emissions due to technological innovation so that environmental orientation is the main agenda [11].

Referring to Malaysia is the third contributing country to carbon emissions in ASEAN-5. One of the biggest contributors to carbon emissions in Malaysia is electricity generation. Apart from that, the increasing demand for electricity generation causes excessive dependence on fossil fuels. The fact is that the government is unable to diversify fuels to meet the needs for providing electricity generation. In the end, assuming that it chooses an energy source that is easier and cheaper, it does not think about the availability of natural resources. Apart from that, excessive use of fossil fuels has resulted in the average temperature in Malaysia increasing due to the provision of power plants using fossil fuels [12].

Furthermore, Thailand. It is known that Thailand is an ASEAN-5 country that contributes to the 2nd largest contributor to carbon emissions. Concretely, Thailand is known as a developed tourist destination, where the Thai tourism sector drives the Thai economy (Word Bank, 2020). The pace of the tourism sector is related to the high demand for energy for transportation, services and facilities, where all needs in the tourism sector contribute to increasing carbon emissions in Thailand [13].

The 4th contributing country in the ASEAN-5 section is Vietnam. looking at the Vietnamese economy, massive economic expansion is reflected in the increase in energy as a support for the economic scheme. The Vietnamese government's policy is to balance economic expansion by setting a carbon price to realize environmentally friendly economic development [14].

Furthermore, the Philippines is the country with the lowest carbon emissions in Asean-5. It is known that the Philippines is a developing country that is sensitive to climate change. The Philippines' economic growth rate is in line with the energy used. The sector contributing to carbon emissions in the Philippines is transportation. All means of transportation are inadequate, so many people use private vehicles which ultimately causes traffic jams and increased demand for fuel [15].

4.2. Research Results with PVECM

4.2.1. Stationarity Test

Table 1. Stationarity Test

Variables	ADF t-Statistik	Prob	Detail	Rating
Carbon dioxide	14.2703	0.1610	Not Stationary	Level
	25.1149	0.0041	Stationary	1st difference
GDP	11.6395	0.3099	Not Stationary	Level
	31.7247	0.0004	Stationary	1st difference
Energy Consumption	11.1841	0.3434	Not Stationary	Level
	2136.304	0.0187	Stationary	1st difference
Industry	17.3562	0.0668	Not Stationary	Level
	31.6481	0.0005	Stationary	1st different

Table 2. Optimum Lag Test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-123.703	NA	9.82e+30	82.71355	82.90038	82.77332
1	-1225.843	18.09980	1.40e+31	83.05623	8399036	83.35506
2	-1194.713	43.58289*	5.44e+30*	82.04752	83.72895	82.58542*
3	-1176.704	20.40944	5.64e+30	**81.91363***	84.34237	82.69060

Based on the graphic image above, it is known that unit root testing uses ADF at the level of all variables, the probability value is greater than the p-value, namely 5%. Next, a unit root test is carried out at the first different level, it is known that all variables pass at the first different level, reflected by a probability value of less than 5%.

4.2.2. Optimum Lag Test

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

The results of the feasibility test for the optimum lag length in Table 2 above show that the optimum lag for the AIC criteria is at lag 3, marked by the highest number of stars with a value of 81.91363* or information based on AIC which has the smallest value, namely at lag 3. When the optimal lag length is found, then further testing can be carried out, namely the cointegration test.

4.2.3. Cointegration Test

The cointegration test is used to detect whether or not there is a long-term influence on the variables studied. Determining variables in the cointegration model if the trace statistic value is greater than the critical value or the probability value is below 5%.

Table 3. Cointegration Test

Hypothesized		**Trace**	**0.05**	
No. Of CE (s)	Eigenvalue	Statistic	Critical Value	Prob.**
None*	0.970302	206.2439	47.85613	0.0000
At most 1*	0.921058	118.3272	29.79707	0.0000
At most 2*	0.680857	54.85130	15.49171	0.0000
At most 3*	**0.650739**	**26.29840**	**3.841466**	**0.0000**

The results of the cointegration test show that there are four similarities between the observed variables that are cointegrated. This is proven by the trace statistical value being greater than the critical value with a value of 5%. So it is said that H0 is rejected and H1 is accepted or in other words, the variables used with each other are co-integrated in the long term. With the integration in this equation and the observed variables being stationary, the next method uses VECM (Vector Error Correction Model).

4.2.4. Causality Test

The causality test is one of the PVECM analyses whose aim is to determine the reciprocal relationship between variables, both one-way and two-way, by looking at probability values. The following are the results of the Granger causality test.

Table 4. Granger Causakity Test

Null Hypothesis	Obs	F-ststistic	Prob
GDP does not Granger Cause Co2	35	5.54759	0.0041
Co2 does not Granger Cause GDP		5.97340	0.0028
K_Energy does not Granger Cause Co2	35	1.20708	0.3254
Co2 doe, not Granger Cause K_Energy		0.99842	0.4081
The industry does not Granger Cause Co2	35	1.04192	0.3893
Co2 does not Granger Cause Industry		2.54697	0.0761
K_Energy does not Granger Cause GDP	35	0.28415	0.8364
GDP does not Granger Cause K_Energy		3.66765	0.0240
The industry does not Granger Cause GDP	35	2.38441	0.0904
GDP does not Granger Cause Industry		0.36904	0.7759
The industry does not Granger Cause K_Energy	35	2.75398	0.0611
K_Energy does not Granger Cause Industry		0.36181	0.7810

Based on the table above, it can be explained that those which have a causal relationship are variables with probability values smaller than 0.05, namely GDP which is the leading indicator for CO2 with a probability of 0.0041, and CO2 which is the leading indicator for GDP with a probability of 0.0028, so that It is concluded that the CO2 and GDP variables have two-way causality. This condition shows that increasing economic growth is accompanied by increasing carbon emissions or increasing carbon emissions as a result of increasing economic growth. and the GDP variable on energy consumption in this condition reflects the existence of a reciprocal relationship between variables and has a one-way relationship.

4.2.5. VECM Panel Estimation Results

The estimation results show that in the short term, the CO2 variable in the 1st lag has an insignificant negative effect of -0.55 percent. So it is stated that if there is an increase of 1 percent in the previous year, it will reduce carbon dioxide emissions in the current year by -0.55 percent with a t-statistic value of -4.41130. then the 2nd lag has a t-statistic value of -7.02 and the 3rd lag has a value of -1.88 and <t-table 2.0128, in conclusion this comparison states that the

independent variable does not have a significant effect on the dependent variable as seen from the lag 1, 2 and 3 t-statistic values are less than the t-table then the dependent variable or hypothesis H0 is accepted and H1 is rejected.

Table 5. PVECM Estimation Result

Variabel	Estimasi Jangka Pendek	t-Statistik
	Koefisien	
Cointegrating Eq	-0.314707	-2.93480
D(CO2(-1))	-0.556939	-4.41130
D(CO2(-2))	-0.341467	-7.02740
D(CO2(-3))	-0.145544	-1.88419
D(GDP(-1))	-1.072440	-1.86060
D(GDP(-2))	-0.454787	-1.05698
D(GDP(-3))	0.317102	-1.02798
D(K_ENERGY (-1))	-84.39173	-1.63706
D(K_ENERGY (-2))	-45.40123	-0.96566
D(K_ENERGY (-3))	-21.24140	-0.65689
D(INDUSTRY(-1))	-2.081743	-3.38149
D(INDUSTRY(-2))	-1.783590	-3.35405
D(INDUSTRY(-3))	-0.853023	-2.66660
C	-7500.840	-1.56685
Variable	Long Term estimation	t-statistic
	Coefficient	
CO2(-1)	1.000000	-10.7688
GDP(-1)	-4.540462	-4.01291
K-ENERGY (-1)	-179.8521	-15.9354
INDUSTRY(-1)	-5.717472	
C	79700.09	
R-Squared		
Adj. R-Squared	0.941850	
F-statistic	30.90219	

Furthermore, the results of the short-term VECM estimation of the GDP variable in the 1st lag show a negative coefficient value of -1.072 percent so that the effect is negative or insignificant, so if there is a 1 percent increase in GDP in the previous year it will reduce carbon dioxide emissions by -1.072 percent in the current year, while the 2nd lag GDP variable has a t-statistic value of -1.056 < t-table 2.0128, a negative coefficient value of -0.45487 percent, meaning that if there is an increase of 1 percent GDP will reduce Co2 in the second year. Meanwhile, the 3rd lag shows a t-statistic value of 1.07298 and a coefficient of 0.317104, meaning that in the 3rd lag of GDP, a 1 percent increase in GDP will increase Co2 in the following year. Meanwhile, in the long term, the GDP variable harms Co2, this reflects the success of the government's role in increasing economic growth and reducing the impact of externalities from production waste.

Next, the short-term VECM estimation results for the Energy Consumption variable at lag 1 show a negative coefficient value of -84.39 percent so that it has a negative or insignificant effect, so if there is a 1 percent increase in the Energy consumption variable in the previous year it will reduce carbon dioxide emissions. amounting to -84.39 percent in the current year. then the 2nd lag has a t-statistic value of -0.96 and the 3rd lag has a value of -0.65 and <t-table 2.0128, so it is stated that it has no significant effect on CO2. Meanwhile, the energy consumption variable in the long term has a negative coefficient value of -179.8 percent, meaning that if there is a 1 percent increase in GDP in the previous year, it will reduce carbon dioxide emissions in the current year. Long-term estimates can be seen from the negative t-statistic coefficient value -4.0129<2.0128, meaning that in the long term, a 1 percent increase in GDP will reduce carbon dioxide emissions and the hypothesis can be concluded simultaneously that H1 is accepted and H0 is rejected.

Thus, the estimation results for the manufacturing industry variable in the short and long term have a negative effect on carbon emissions. This means that when there is an increase in the number of manufacturing industries by one percent, both long-term and short-term, it can reduce carbon emissions. This happens because the economic expansion that occurs is marked by an increase in the number of industries plus the government's policy in sorting investments so that industries are built using renewable, environmentally friendly energy and sophisticated technology, as a result of which the production output increases, the waste produced very minimal. So it can be concluded that there is a reciprocal relationship between the increasing number of industries and carbon emissions, meaning that H0 is simultaneously accepted and H0 is rejected.

Finally, the estimation results for the Energy Consumption variable show that in the short and long term, it has a negative influence on carbon emissions. The results of this research prove that an increase in energy consumption coupled with appropriate use can accelerate economic expansion. Transparent management practices and the use of environmentally friendly technology are ultimately able to support an economy that is characterized by a rapid economy that is directly proportional to low carbon emissions (Co^2).

4.2.6. PVECM Model Stability Test

The stability test in this research model was carried out before estimating the PVECM model. Furthermore, the mode value in the stability test is used to support the results of the Impulse Response Function analysis and variance decomposition. The following are the results of the stability test;

Table 6. Uji Stabilitas Model

Root	Modulus
-0.119114 – 0.698162i	0.708251
-0.119114+ 0.0,698152i	0.708251
-0.498579	0.498579
0.195552-0.377519i	0.425160
0.195552+ 0.377519i	0.425160
-0.310090-0.265926i	0.408500
-0.310090+0.265926i	0.408500
-0.189256	0.189256

Based on table 6, shows that the PVECM model is quite stable. This is proven by the overall mode value being less than one, so it can be concluded that the PVECM model is valid.

4.2.7. IRF Test

Impulse Response Function (IRF) is used to describe variable behaviour in shock rates. The results of the Impulse Response Function (IRF) can be observed through the following image.

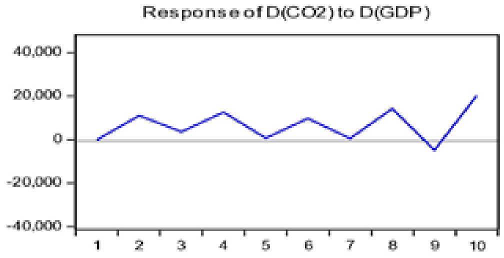

Figure 4.2. IRF GDP test for carbon emissions

From the graphic image, it can be explained that the carbon dioxide response to the GDP shock from the first period to the fourth period increased and showed a positive response. However, in the fourth period to the fifth period, it decreased and showed a negative response, then from the fifth to the eighth period it experienced an increase so that it showed positive results and there was a decrease from the eighth to the ninth period, it experienced a decrease and experienced an increase again until the tenth period. This is said to be a fluctuating response of carbon dioxide to a GDP shock by showing a balanced response above the horizontal line or the balance line. Economic growth and carbon dioxide emissions in ASEAN-5 are still in a reasonable condition, this is because the government plays a big role in determining state policies to strengthen green economic growth policies by determining sustainability-oriented outcome targets [16].

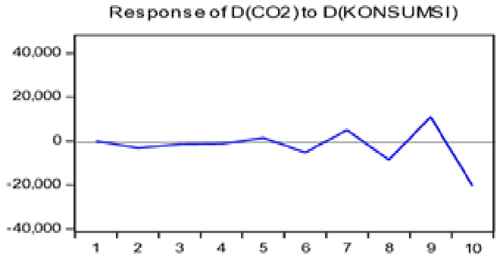

Figure 4.3. IRF Consumption Test on Carbon Emissions

From this figure it can be explained that the response of carbon dioxide to the energy consumption shock from the first period to the second period decreased and showed a negative response. However, in the second period to the third period there was an increase above the horizontal line and showed a positive response, then in the third period to the fifth period there was a decline above the horizontal line for a long period so that it showed a negative response and in the fifth to seventh period it experienced a decline again, then from the period eight experienced a long increase until the tenth period. In other words, carbon dioxide to energy consumption in ASEAN-5 is in a balanced state and is shown to always be in a horizontal line. This is due to the government policy of ASEAN-5 countries which still maintains energy consumption. If left unchecked, there will be an increase in energy consumption (fuel oil or gas), causing the carbon dioxide emissions released to also increase.

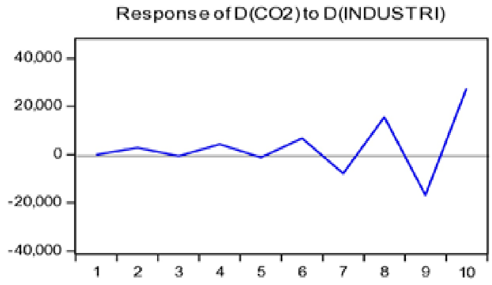

Figure 4.4. IRF Industry Test for Carbon Emissions

Based on the graphic image above, reflects the graphic response of the manufacturing industry to carbon emissions from the beginning of the period to the tenth, experiencing shocks as seen in the fluctuating movement of the graph. This happens because the increase in the number of industries is not accompanied by technological innovation, where the technological stimulus has a double effect on production, namely increasing the output of goods or services and increasing the amount of waste. Concretely, in the long term, economic dynamics will be created when the economy is able to transfer technology and the government can stimulate the economy by suppressing production output and not ignoring the impact of externalities, so the economy can be stable. This condition is reflected in the reciprocal relationship between increasing the number of manufacturing industries and emissions carbon.

4.2.8. Variance Decomposition

The Variance Decomposition (VD) test analysis is focused on looking at the influence of the GDP, Energy consumption and Industry variables on the independent variable, namely CO2 so that the Variance Decomposition analysis is used to explain changes in one variable that are influenced by changes in other variables. Following are the results of the Variance Decomposition test:

Table 7. Classic Assumption Test

Classic Assumption Test	Test	Probabilities	Details
Normality	Jarubera	0.2139	Normally distributed
Heteroskedasticity	White-heteroscedasticity	0.2320	Non-heteroskedasticity
Autocorrelation	LM test	0.1420	Non-autocorrelation

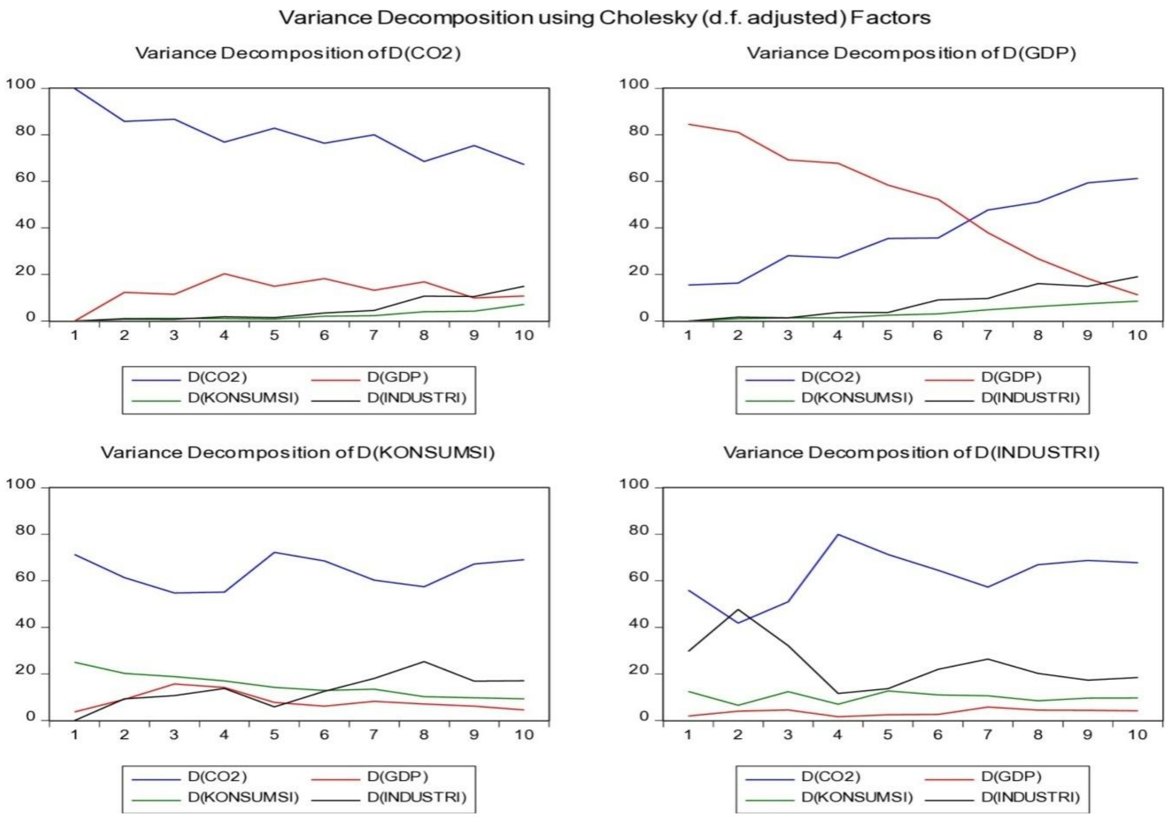

Figure 4.5. Variance Decomposition

In the first period, carbon dioxide was greatly influenced by the carbon dioxide shock variable with a normal condition of 100 percent. Meanwhile, in the first period, GDP, energy consumption and industry did not influence CO2. Then the CO2 shock has a gradually decreasing proportion of influence on CO2 itself from period one to period ten with a shock size of 70.90 percent. Furthermore, the GDP variable for the second period contributed 4.6 percent and in the third period there was a GDP shock to CO2 so that it experienced an increase with a shock size of 8.05 percent. in the third to tenth period, the GDP shock contribution to CO2 increased with a shock contribution of 5.4 percent. then the second period Energy consumption variable contributed 1.48 percent and experienced an increase in the tenth period giving an increase in the shock contribution of Energy consumption to CO2 with a shock of 5.8 percent. Lastly, the variable Industry in the second period contributed 0.09 percent, experiencing a continuous increase until the tenth period with a large shock of 17 percent.

4.2.9. Classic Assumption Test Results

Table 7 shows the results of the classic assumptions in this research. The normality test results are shown by a probability value of 0.2139. This reflects normally distributed data because the probability value > alpha value is 5%. Furthermore, the heteroscedasticity test using white heteroscedasticity has a probability value of 0.2320, meaning that heteroscedasticity does not occur. Finally, the autocorrelation test uses the LM test with a probability result of 0.1420 > 5% alpha value, so it can be concluded that there is no autocorrelation.

4.3. Result and Discussion

4.3.1. Co^2 Causality and Economic Growth

The Granger causality test shows that the probability value of economic growth can influence carbon-dioxide emissions and carbon dioxide emissions can influence economic growth. Thus, it can be concluded that the two variables have a two-way causal relationship between carbon dioxide and economic growth (Feedback or Bilateral Causality). This two-way relationship between economic growth and carbon dioxide is one of the main reasons ASEAN-5 countries are still classified as developing countries. So the lack of attention from the government and technology that is still relatively less advanced causes carbon emissions to increase. In contrast to developed countries, economic growth is increasing and carbon dioxide emissions can be controlled. So the main scope of dominant developing countries is only pursuing economic growth without thinking about the effects of carbon dioxide emissions and this confirms the existence of the EKC hypothesis. The research results are under theory and the results of previous research including [17] an increase in GDP per capita by 10 percent will result in an increase in CO2 emissions by 1.4 percent. So the role of GDP per capita greatly influences CO2 emissions and if CO2 emissions continue not to be controlled it will be very dangerous for the long-term sustainability of living things.

Furthermore, this is confirmed by other research [18] in countries that are less prosperous or can be said to be developing countries that still focus on GDP per capita growth so that there is less pressure on CO2 emissions. This is different from developed countries, economic growth is more closely accompanied by reducing CO2 emissions by using the latest and better technology. In general, countries with economies that are still developing at the ASEAN-5 level still focus on the production sector, so the main task of paying attention to the impact of externalities from economic activities, namely environmental quality, is still neglected. Other research confirms this situation [19] that CO2 per capita in Indonesia increased from 1977-2014, so that the U curve almost resembles an inverted U. This indicates that when GDP per capita increases, CO2 emissions will increase.

4.3.2. Co^2 Causality and Energy Consumption

The Granger causality test shows that the probability value of energy consumption cannot affect carbon dioxide emissions and carbon dioxide emissions cannot affect energy consumption. Thus, it is concluded that there is no two-way or one-way causal relationship between carbon dioxide and energy consumption. In the cases in China, [20] stated that Chinese state policymakers have been careful to implement strict and disciplined pollution regulations. When setting a target for reducing carbon emissions by 20–40% by 2050. This can be seen from the fact that GDP has a long-term relationship with fossil fuel consumption; however, this does not appear to have an impact on CO2 emissions.

Non-renewable energy consumption in the five ASEAN-5 countries as developing countries has not caused environmental degradation because government policy in the use of energy consumption is still said to be controllable so that it has no impact on carbon dioxide emissions. This is strengthened by research by [21] that finds out there is no causal relationship between CO2 emissions from energy consumption on economic growth in Malaysia. also in Singapore, it shows that there is no reciprocal relationship between economic growth and energy consumption. This proves that Singapore can maintain economic growth without causing environmental damage. Meanwhile, the environmental Kuznets Curve in Malaysia shows that it has not yet passed the turning point, but Singapore has passed the critical point and is already in a state of environmental improvement while continuing to carry out economic development with the disciplined policies of the government of their respective countries.

4.3.3. Co^2 Causality and Manufacture Industry

The probability value in the Granger causality test shows that the Industry Variable doesn’t affect the CO2 emission and vice versa. It concludes that the two variables do not have both one-way and two-way relationships. However, some provisions must be known regarding the impact of carbon dioxide emissions that must be accepted. When an industry is established, if it exceeds the threshold, it will be very detrimental to living things. An interesting thing was found in research by [22], he stated that Government policies related to the implementation of green industry in encouraging the use of lower carbon technology will result in a negative influence on GDP in the Industrial sector and can reduce CO2 emissions in Indonesia. So industrialization has a significant negative effect on CO2 emissions, making industry an added value for economic growth in ASEAN-5 countries.

The impact of government policies related to the green industrial revolution in ASEAN-5 creates jobs, while on the other hand, it also reduces global warming, and climate change and moves the wheels of a country's economy. This is in line with the research by [23], The state has an important role in achieving sustainable development goals, by controlling industrial companies in implementing green industry. Environmentally friendly innovation methods have a very important impact on climate conditions. reducing CO2 emissions and reducing the intensity of CO2 emissions, however, there are large costs that must be borne, for example in procuring environmentally friendly technological innovations within the company. The good thing is that in the long term it is very beneficial for the survival of living things.

4.3.4. Government Commitment to Achieving SDGs in ASEAN-5

Based on the SDGs score table for ASEAN-5, it can be concluded that the government is committed to achieving a green economy by combining institutions and partnerships. Where the government's commitment is reflected in bureaucratic governance, namely institutional regulations supported by politics both vertically and horizontally regarding policy application. Apart from that, the bureaucratic environment can absorb community participation in the implementation of the green economy [24].

Table 8. ASEAN-5 Government Commitment to Achieving SDGs

SDGs Effort	**Country**	**SDGs Effort**		**SDGs Coordination**	**SDGs Pathways**	**Multilateralism**
Rank	Rank	Score	Rating	Rating	Rating	Rating
7	Indonesia	77,3	High Enterprise	Very High Enterprise	Low Enterprise	High Enterprise
26	Thailand	66,8	Medium Enterprise	High Enterprise	Low Enterprise	High Enterprise
35	Philippines	63,1	High Enterprise	High Enterprise	Very Low Enterprise	High Enterprise
37	Malaysia	62,8	Medium Enterprise	High Enterprise	Low Enterprise	High Enterprise
61	Vietnam	51,5	Medium Enterprise	Medium Enterprise	Low Enterprise	High Enterprise

The Indonesian government's commitment to achieving a green economy by implementing a carbon tax and carbon reduction as support for the renewable energy transition and suppressing downstream technology to achieve the implementation of a green economy *green economy* [25]. Meanwhile, the Malaysian government is implementing a diversification policy from fossil fuels to renewable energy, namely solar panel energy (Thaddeus J, et al, 2020). In contrast to Malaysia, the Vietnamese government is implementing a policy of switching to a low-carbon development model, reflected in rapid technological progress, substantial research and innovation toward sustainable development [14]. Meanwhile, the Thai government is committed to a green economy by increasing investment partnerships as a support for the economy by prioritizing the impact of externalities to achieve sustainable development [26]. For the Philippines, the government's commitment to achieving a green economy focuses on resource reallocation and climate change action in mitigating the impact of global warming (Pham N M, et al, 2020). The following is the government's commitment to achieve the SDGs scores:

Table 9. Capaian Skor SDGs Asean-5

No	State Member	Score Achievement
1	Thailand	74,13 of 100
2	Vietnam	72,76 of 100
3	Malaysia	70,38 of 100
4	Indonesia	69,16 of 100
5	Philippines	66,66 of 100

5. Conclusions

From the standpoint of the green economy, the purpose of this study is to ascertain the causal relationship between GDP, energy consumption, and industry on carbon emissions. The results of the discussion that have been explained are in the form of test estimates using PVECM regarding the causality relationship between Industry and carbon emissions in ASEAN-5 where Industry is proxied by the variables, Manufacturing Industry, Energy Consumption, and GDP. In this research, there are several conclusions obtained in this research as follows: Based on the results of the Granger causality test, there are 2 variables that have a causal relationship, namely the GDP variable to Co2 which has a two-way relationship, while the Industry variable to Energy Consumption has a one-way relationship. Based on the PVECM estimation results, all variables, namely manufacturing industry, energy consumption and economic growth, have a negative effect on carbon emissions. This condition shows that the macroeconomic mix to accelerate economic expansion in line with the use of technological innovation can accelerate an environmentally friendly economy marked by the reduction of carbon emissions.

6. Policy Recommendations

Achieving a green economy is marked by decarbonization, saving natural resources and social interaction. To achieve decarbonization there are 6 variations as a substitute source of energy, namely by utilizing geothermal heat, wind, water, seawater waves, solar heat and bioenergy. On the other hand, a policy mix is needed as a green economic instrument, namely stabilizing the macro economy and finances supported by the government. The government's instrument is to support the world carbon transaction system to bridge the entry of green investment. Concretely, every ASEAN-5 country must change their production and consumption systems with a sustainable scheme so that the implementation of green economics is achieved, namely resource efficiency, reduced poverty, and a protected environment.

REFERENCES

[1] P. H. Leal and A. C. Marques, “The evolution of the environmental Kuznets curve hypothesis assessment: A literature review under a critical analysis perspective,” *Heliyon*, vol. 8, no. 11, 2022, doi: 10.1016/j.heliyon.2022.e11521.

[2] N. Patel and D. Mehta, “The asymmetry effect of industrialization, financial development and globalization on CO2 emissions in India,” *Int. J. Thermofluids*, vol. 20, no. June, p. 100397, 2023, doi: 10.1016/j.ijft.2023.100397.

[3] L. Wang and J. You, “An integrated perspective on the spatial–temporal characteristics of China’s manufacturing carbon emissions at the regional and industry levels,” *Energy Reports*, vol. 10, pp. 1688–1701, 2023, doi: 10.1016/j.egyr.2023.08.034.

[4] C. W. Boqiang Lin, “does industrial relocation affect regional carbon intensity? evidence from china’s secondary industry energr,” *Energy Policy,173, 113339*, 2023.

[5] H. Mahmood, “CO2 Emissions, Financial Development, Trade, and Income in North America: A Spatial Panel Data Approach,” *SAGE Open*, vol. 10, no. 4, 2020, doi: 10.1177/2158244020968085.

[6] S. Viphindrarti, H. C. Diartho, and S. Aisah, “Effect of foreign direct investment and economic growth on CO2 emmision in Indonesia,” *Int. J. Sci. Technol. Res.*, vol. 9, no. 3, pp. 6427–6432, 2020.

[7] A. Saleem, M. H. Sial, and A. R. Cheema, *Does an asymmetric nexus exist between exports and economic growth in Pakistan? Recent evidence from a nonlinear ARDL approach*, vol. 56, no. 1. Springer US, 2023. doi: 10.1007/s10644-022-09426-z.

[8] S. Mehmood, K. Zaman, S. Khan, Z. Ali, and H. ur R. Khan, “The role of green industrial transformation in mitigating carbon emissions: Exploring the channels of technological innovation and environmental regulation,” *Energy Built Environ.*, vol. 5, no. 3, pp. 464–479, 2024, doi: 10.1016/j.enbenv.2023.03.001.

[9] Fauzi. A, *Ekonomi Sumber Daya Alam dan Lingkungan, Teori dan Aplikasi*. Gramedia Pustaka Utama, 2004.

[10] S. E. Prastiyo, "How agriculture, manufacture, and urbanization induced carbon emission? The case of Indonesia. Environmental Science and Pollution Research," *Environ. Sci. Pollut. Res. 27(33), 42092-42103.*, 2020.

[11] G. Spilker, "International political economy and the environment," *Oxford Res. Encycl. Polit.*, 2017.

[12] M. S. A. Latif, M. Fahmy-Abdullah, and L. W. Sieng, "Determinants factor of technical efficiency in machinery manufacturing industry in Malaysia," *Int. J. Supply Chain Manag.*, vol. 8, no. 6, pp. 917–928, 2019.

[13] A. Raihan, "The dynamic nexus between economic growth, renewable energy use, urbanization, industrialization, tourism, agricultural productivity, forest area, and carbon dioxide emissions in the Philippines," *Energy Nexus*, vol. 9, no. February, p. 100180, 2023, doi: 10.1016/j.nexus.2023.100180.

[14] M. M. Tun, D. Juchelkova, M. M. Win, A. M. Thu, and T. Puchor, "Biomass energy: An overview of biomass sources, energy potential, and management in Southeast Asian countries," *Resources*, vol. 8, no. 2, 2019, doi: 10.3390/resources8020081.

[15] L. Tõnisson *et al.*, "From transfer to knowledge co-production: A transdisciplinary research approach to reduce black carbon emissions in metro manila, philippines," *Sustain.*, vol. 12, no. 23, pp. 1–19, 2020, doi: 10.3390/su122310043.

[16] M. Anwar, "Ekonomi Dan Multilateral," *Inspektorat Jenderal Kementeri. Keuang.*, pp. 343–356, 2022.

[17] K. M. Inumula and K. Deeppa, "Cointegration between Energy Consumption, CO 2 Emissions, and GDP in India," *Jindal J. Bus. Res.*, vol. 6, no. 1, pp. 1–13, 2017, doi: 10.1177/2278682116684268.

[18] R. York and J. A. McGee, "Does Renewable Energy Development Decouple Economic Growth from CO2 Emissions?," *Socius*, vol. 3, 2017, doi: 10.1177/2378023116689098.

[19] F. Kartiasih and A. Setiawan, "Aplikasi Error Correction Mechanism Dalam Analisis Dampak Pertumbuhan Ekonomi, Konsumsi Energi Dan Perdagangan Internasional Terhadap Emisi Co2 Di Indonesia," *Media Stat.*, vol. 13, no. 1, pp. 104–115, 2020, doi: 10.14710/medstat.13.1.104-115.

[20] R. Shahani and A. Bansal, " An Econometric Investigation of Dynamic Linkages Between CO 2 Emissions, Energy Consumption, and Economic Growth: A Case of India and China," *Jindal J. Bus. Res.*, vol. 10, no. 1, pp. 107–127, 2021, doi: 10.1177/22786821211002252.

[21] Zaini Miftach, "Analisis Kausalitas Emisi Co2, Konsumsi Energi, Pertumbuhan Ekonomi, Dan Modal Manusia Di Asean," *J. Kaji. Ekon. dan Pembang.*, pp. 53–54, 2018.

[22] A. Pratama, "Pengaruh Industrialisasi Terhadap Emisi CO2 Di Indonesia," *J. Ecodemica J. Ekon. Manaj. dan Bisnis*, vol. 6, no. 1, pp. 98–110, 2022, doi: 10.31294/eco.v6i1.11726.

[23] T. C. Phan, "Impact of green investments, green economic growth and renewable energy consumption on environmental, social, and governance practices to achieve the sustainable development goals: A sectoral analysis in the ASEAN economies," *Int. J. Eng. Bus. Manag.*, vol. 16, 2024, doi: 10.1177/18479790241231725.

[24] J. Guha and B. Chakrabarti, "Achieving the Sustainable Development Goals (SDGs) through decentralisation and the role of local governments: a systematic review," *Commonw. J. Local Gov.*, pp. 1–21, 2019, doi: 10.5130/cjlg.v0i22.6855.

[25] S. E. Prastiyo, Irham, S. Hardyastuti, and Jamhari, "How agriculture, manufacture, and urbanization induced carbon emission? The case of Indonesia," *Environ. Sci. Pollut. Res.*, vol. 27, no. 33, pp. 42092–42103, 2020, doi: 10.1007/s11356-020-10148-w.

[26] M. L. T. Nguyen and T. N. Bui, "Trade openness and economic growth: A study on asean-6," *Economies*, vol. 9, no. 3, 2021, doi: 10.3390/economies9030113.