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Research Article

The Relationship Between Environmental Degradation and Per Capita Income in ASEAN Countries

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Abstract.

This study aims to analyze the relationship between environmental degradation, namely carbon dioxide (CO_2) and methane (CH_4) emissions, and the per capita income in ASEAN countries. The data used is secondary data in the form of panel data for 1993–2020 originating from the World Bank and Our World in Data. The method used is quantitative descriptive analysis with the Granger Causality Test. The results of the study indicate that there is a one-way relationship that flows from environmental degradation in the form of CO_2 and CH_4 emissions to per capita income in ASEAN countries, but the reverse does not apply.

Keywords: environmental degradation, carbon dioxide emissions, methane emissions, per capita income

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1. Introduction

Each country competes with each other in terms of developing its own country, especially in terms of economic development which plays an important role in encouraging economic growth and social welfare. Technology is one of the factors that influences economic growth and contributes to the development and modernization of production methods [1].

In the last few decades, many types of new technologies have appeared, both through invention and innovation processes [2]. The addition of capital and labor which is a conventional factor of production is no longer the only basis for a country's economic growth, now progress in science and technology (IPTEK) also affects the economy. Technological developments shift the way humans process resources to produce goods in various business sectors [3].

The economic sector that has a major role in the country's economy is the industrial sector. According to [4] every country is at different stages of industrial development, but all countries consider industry as important to boost the economy. Industry is an

economic activity in the form of managing raw materials, raw materials, or semi-finished goods into finished goods that have added value. The existence of the right technology to support the growing growth of the industrial sector. In terms of economic activity, technology can cut costs and speed up processes, making life easier for people in every aspect [5].

Apart from technology, the role of energy cannot be separated in activities that add value. Energy plays an important role in the production process [6]. Energy can be a key factor in increasing economic growth and living standards and increasing energy use is the impact of economic growth. Energy use leads to economic productivity and industrial growth and is central to the functioning of every modern economy [7]. In [8] energy is also used in agricultural processes, mining, services, including the transportation and information technology sectors. For more than 150 years fossil energy has driven the economy and until now supplies around 80 percent of the world's energy [9].

Southeast Asia or the ASEAN region is one of the most populous regions with the fastest economic growth in the world. The ASEAN region which has many developing countries is increasingly aggressive in efforts to improve the economy. According to *the Asian Development Bank* (ADB), economic growth in Southeast Asia will reach 5.5 percent in 2022. ASEAN countries are becoming more open to international trade after gradually removing inter-regional and intra-regional trade and investment barriers [10].

Then ASEAN countries have agreed to carry out comprehensive economic cooperation by accelerating industrial activities to improve the economy [11]. The impact of this collaboration is that energy demand in ASEAN countries also increases rapidly. ASEAN countries still use fossil energy as the main component in running the economy [12]. Based on this, the ASEAN economy is growing as the world strives to reduce greenhouse gas emissions.

Figure 1 shows the trend of an increase in the total gross domestic product per capita (GDP per capita) of ASEAN countries from 1993 to 2020. One of the reasons for this positive trend is the rapid pace of industrial activity as a driving force for ASEAN economic activity. The tourism industry plays an important role in developing the economy and indirectly has *a multiplier effect* . Tourism has comprehensive links with many other industries. The tourism industry has made a significant contribution over the years to the economic development of Southeast Asian countries [13]. Not only the tourism industry, Southeast Asia's economy has also been driven by the manufacturing industry for decades [14].

However, behind technological advances and the rise of industrial activity in efforts to grow the economy of ASEAN countries, there is an important problem, namely, how

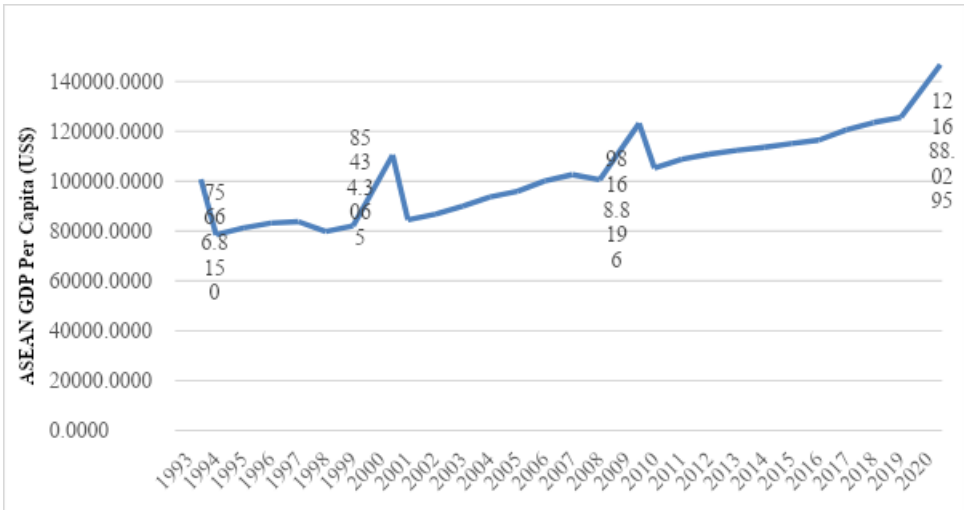

Figure 1: Development of ASEAN GDP Per Capita, 1993 – 2020. Source: World Bank Open Data, processed data (2022).

to face *the trade-off* between development and environmental conservation efforts [15]. The cost that must be incurred for economic improvement is environmental degradation.

Environmental degradation or decline in the quality of the environment has become an important problem in all regions of the world. Nature and humans are the two main contributors to environmental degradation. Humans cannot predict or completely eliminate the natural causes that contribute to environmental degradation. Earthquakes, volcanic eruptions, tsunamis, storms, disease outbreaks, droughts, and fires are just a few examples of these natural events. Meanwhile, human efforts to regulate their behavior, including in regulating the environment, are the only thing that can stop human factors from contributing to environmental degradation [16].

Climate change is one of the impacts of environmental degradation caused by human factors. Natural climate variability and the materials that make up the Earth's atmosphere can be affected by climate change. The ingredients that make up the earth's atmosphere are greenhouse gases (GHG). Emissions of carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) all contribute to GHG effects. The biggest gas that causes greenhouse gas impacts is CO_2 emissions [17].

Research conducted by [18] states that the ASEAN region has extraordinary growth potential. While it may not happen immediately, a rapidly growing population will increase the need for food and water use, place undue pressure on the environment, and ultimately result in environmental exploitation. The amount of CO_2 in ASEAN over a period of 27 years has fluctuated. Based on the [19] report, apart from improving the economy in the ASEAN region, the clearing of large areas of agricultural land and resource extraction are the main causes of deforestation and forest degradation. At the

end of the 90s there was a sharp increase in CO_2 emissions, namely in 1997 which was caused by very severe forest and land fires (karhutla) in Indonesia. The impact of forest and land fires can be felt in neighboring countries, causing disruption to public health [20].

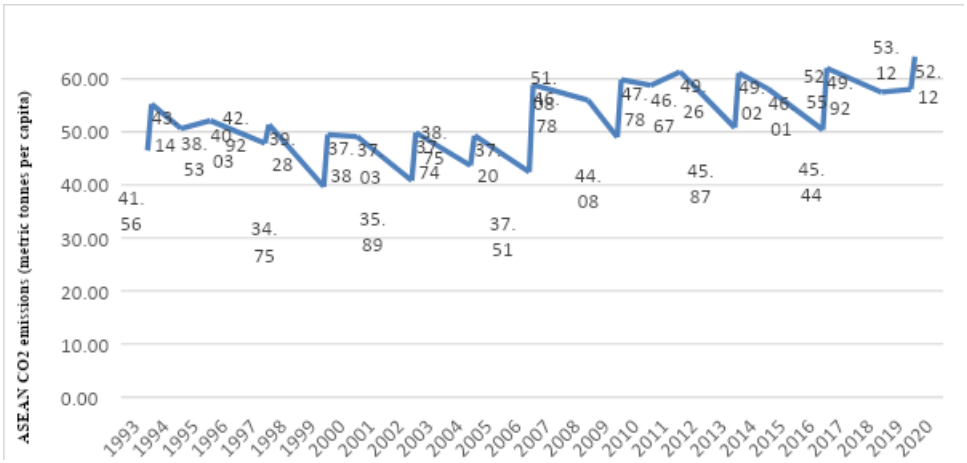

Figure 2: Development of ASEAN CO_2 Emissions, 1993 – 2020. Source: Our World in Data, data processed (2022).

Furthermore, entering the year 2000, the amount of CO_2 emissions was still fluctuating. In the [21], ten ASEAN countries in 2016 contributed 7.35% of the total CO_2 emissions produced by all countries in the world. In 2019, CO_2 emissions increased by 9.04 metric tons per capita compared to a decade earlier. The total CO_2 emissions in 2019 were 53.12 metric tons per capita. This increase in emissions is caused by the rise in industrial activities that require fuel that produces CO_2 gas. According to [22] demands for economic growth, high economic activity and a fairly rapid population increase are burdening the quality of the ASEAN environment. In addition, another factor that contributes to environmental damage is increasing energy use, which increases demand for resources and causes significant pollution [23].

Figure 3 shows the ten ASEAN member countries, five of which play a major role in supplying CO_2 emissions , namely Brunei Darussalam in second place is Singapore then Malaysia, Thailand and Indonesia. Brunei Darussalam is famous for its oil and gas reserves which make it a significant oil and gas producer. These oil and gas reserves have powered its economy for the last 85 years and more [24]. This was the driving factor for Brunei Darussalam to become the supplier of the highest CO_2 emissions in ASEAN during the research period.

Then the main source of Singapore's CO_2 emissions is the result of burning fossil fuels which are used as an energy source in the industrial, building, household and

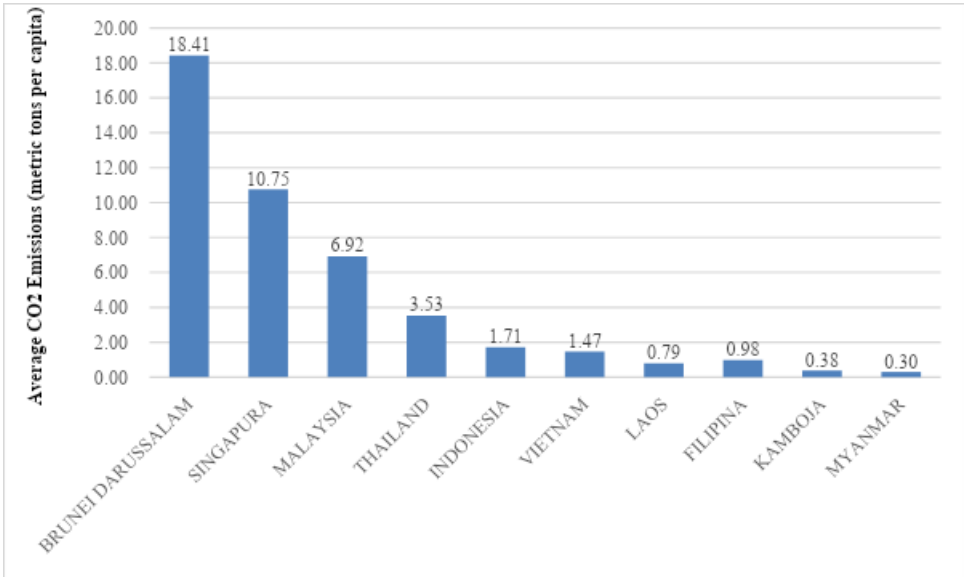

Figure 3: Average CO_2 Emissions of ASEAN Countries, 1993 – 2020. Source: Our World in Data, data processed (2022).

transportation sectors. [25]. In Malaysia, Thailand and Indonesia, economic activities that use a lot of energy cause an increase in CO_2 emissions in these three countries.

It can be seen that the problem of environmental degradation cannot be separated from economic activities, especially the industrial sector. The rate of economic growth in ASEAN is relatively high and has tended to increase since last year. It seems that economic growth is in line with the worsening environmental degradation explained by the amount of CO_2 emissions.

Given the detrimental consequences of CO_2 emissions, previous studies have studied the various determinants of environmental pollution and degradation by combining one or two independent variables. Various findings emerge from many studies examining the relationship between CO2 emissions and economic growth. Like the research conducted by [26, 17] concluded that there is a two-way causality between economic growth and the amount of CO_2 emissions. Meanwhile there are other results which state that there is no relationship between the two variables [27, 28].

This study aims to continue research that has been done before by adding a variable determining environmental degradation, namely methane gas (CH_4). Methane emission is a much more potent greenhouse gas than CO_2 in terms of its ability to increase the earth's temperature, therefore CH_4 emissions are included in this study as an environmental degradation variable. So far there has been no research discussing the relationship between carbon dioxide (CO_2) emissions, methane (CH_4) emissions, and per capita income in ASEAN countries.

2. Theory, Literature Review, and Hypothesis

The theory of the Environmental Kuznets Curve (EKC) is used in this study to describe the relationship between environmental degradation and income per capita [29]. The EKC curve depicts the stages in the development of a country . In the early stages of a country's economic growth, Kuznets calls it the *pre-industrial economies stage* , the level of environmental damage will be at a high level. Then at the next stage people will begin to realize that the need for good environmental quality is becoming more important. At this stage there will be a turning *point* where economic growth will no longer result in environmental damage.

In [30] *new* growth theory or endogenous growth theory underscores the importance of investing in the creation of new knowledge to sustain growth. The new growth theory incorporates a wider range of factors that can contribute to economic growth, including human capital and technology. In the new growth theory, investment in human capital and technology is an important part of a country's economic growth. Human capital is in the form of knowledge and skills while technology is in the form of innovations carried out by companies as a result of knowledge spillover *to* trigger productivity growth. Then the production of goods by the factors of production of science will grow rapidly [31]. These two things are endogenous factors in the new growth theory model.

Several previous studies have discussed the relationship between environmental degradation and per capita income. [32] conducted research on the relationship between energy consumption and economic growth and carbon dioxide (CO_2) emissions from four selected Asian countries, namely Indonesia, Malaysia, the Philippines and Thailand between 1971 and 2017 using the Granger Causality Test. The results of the study show that in Indonesia, Malaysia and Thailand economic growth and CO_2 emissions do not have a different relationship in the Philippines. The same test was used by [33] in Tunisia, [34] in five member countries of the Southern Common Market & [35] in the BRICS countries. The result is that GDP per capita has a unidirectional relationship to CO_2 emissions, while in the study by [36] who used panel data found the opposite finding, namely that the economic growth variable has a negative and significant effect on CO_2 emissions in ASEAN. In the research of S, [37] it was found that the CO_2 variable had causality with the GDP variable in Indonesia from 1981 to 2017. The same test was used by [38] who found that in the short term there one-way relationship from CO_2 emissions to economic growth.

The causality between CH_4 emissions, economic growth, agricultural land use, and electricity consumption in Argentina was investigated by [39] using ARDL, the Granger

VECM Causality Test. In conclusion, economic growth affects CH_4, electricity consumption and agricultural land use affect economic growth. [40] conducted research with the same variables in Central African countries and found that there is a two-way causality between CH_4 emissions and economic growth. Different results were found in [41] which discussed the causality of climate change in the form of CH_4 emissions with tourism sector income, namely CH_4 emissions had one-way causality on tourism sector income. Based on the theoretical basis and framework of thought, the hypothesis in this study is formulated as follows: it is suspected that environmental degradation as a proxy for CO_2 emissions and CH_4 emissions has a two-way relationship to income per capita.

3. Research Methods

This research is a descriptive quantitative study that aims to examine the causal relationship between environmental degradation and per capita income in five ASEAN countries, namely Brunei Darussalam, Singapore, Malaysia, Thailand and Indonesia. These five ASEAN countries were chosen as research objects because they are ASEAN countries that have the highest CO2 emission contributions. The observation data used covers the period 1993 – 2020. The variables used include CO_2 emissions and CH_4 emissions as indicators of environmental degradation and GDP per capita as a proxy for the level of social welfare. The data used in this study is secondary data obtained from several agency publications. Data on GDP per capita were obtained from the World Bank, while data on total CO_2 and CH_4 emissions were obtained from the publication Our World in Data.

This research applies the Granger Causality Test. In general, the Granger Causality test model in panel data can be expressed in the following form:

$$Y_{it}Y_{it} = \alpha_1 Y_{it-1}\alpha_1 Y_{it-1} + \beta_1 X_{it}\beta_1 X_{it} + u_{1it}u_{1it}$$
$$X_{it}X_{it} = \alpha_2 X_{it-1}\alpha_2 X_{it-1} + \beta_2 X_{it}\beta_2 X_{it} + u_{2it}u_{2it}$$

Then, based on the model above, the model used in this research was formed as follows:

$$CO2_{it} = \alpha_1 CO2_{it-1} + \beta_1 PDB_{it} + u_{1it}$$

$$PDB_{it} = \alpha_2 PDB_{it-1} + \beta_2 CO2_{it} + u_{2it}$$

$$CH4_{it} = \alpha_1 CH4_{it-1} + \beta_1 PDB_{it} + u_{1it}$$

$$PDB_{it} = \alpha_2 PDB_{it-1} + \beta_2 CH4_{it} + u_{2it}$$

where $CO2_{it}$is the total carbon dioxide emissions of country i and year t, $CO2_{it-1}$is the lagged value of the CO $_{2\ variable}$ at time (t-1) and individual i, α_1, α_2, β_1, $\beta_2$is the coefficient of the Granger Causality model, $u_{1it}$and u_{2it} is the term error of each variable at time t and individual i.

4. Results and Discussion

From the results listed in Table 1, it can be observed that all variables, including CO2 emissions $_{, CH4}$ emissions and GDP per capita, have reached stationarity at the first difference level with a predetermined critical value of 5% or a probability of less than 5%.

TABLE 1: Unit Root Test Results.

Variables	Levels		1st *difference*	
	T-stat	Prob.	T-stat	Prob.
CO2 _	6.95930	0.7293	75.5567	0.0000
CH $_4$	4.77645	0.9056	42.3990	0.0000
GDP	1.55748	0.9987	45.4010	0.0000

Based on the information listed in Table 2, it can be concluded that lag 3 is the most optimal lag for the CO2 Emission variable $_{with}$ Per Capita Income.

TABLE 2: Optimal Lag Test Results for CO2 Emission Variables with Per Capita Income.

lag	Testing Models					
	LogL	L.R	FPE	AIC	S.C	HQ
0	-1,431,734	NA	9,73e+09	28.67468	28.72678	28.69576
1	-1,016,147	806.238	2590150,	20.44294	20.59925*	20.50621
2	-1,009,176	13.2461	2441015,	20.38351	20.64403	20.48895
3	-1,002,324	12.74401	2306367,*	20.32648*	20.6912	20.47409*
4	-999.3235	5.460867	2354155,	20.34647	20.8154	20.53625
5	-998.5954	1.296033	2515397,	20.41191	20.98505	20.64387
6	-997.3722	2.128368	2662162,	20.46744	21.14479	20.74158
7	-9,939,675	5.787929	2698369,	20.47935	21.2609	20.79566
8	-982.9793	18.24045*	2351346,	20.33959	21.22534	20.69807

Based on the information listed in Table 3, it can be concluded that lag 5 is the most optimal lag for the CH $_{4\ Emission\ Variable}$ with Per Capita Income.

Table 3: Optimal Lag Test Results for CH4 Emission Variables with Per Capita Income.

lag	Testing Models					
	LogL	L.R	FPE	AIC	S.C	HQ
0	-1,442,095	NA	1.20E+10	28.88191	28.93401	28.903
1	-9,231,576	1,006,740	403298,9	18.58315	18.73946	18.64641
2	-9,138,823	17.62292	362964,2	18.47765	18.73816*	18.58308
3	-9,063,241	14.05837	338130,1	18.40648	18.77121	18.55409*
4	-905.0461	2.325979	357233,1	18.46092	18.92985	18.65071
5	-897.5547	13.33456*	333410,0*	18.39109*	18.96423	18.62305
6	-8,954,392	3.680965	346622,0	18.42878	19.10613	18.70292
7	-893.5347	3.23766	362037,2	18.47069	19.25225	18.787
8	-8,910,016	4.205013	373601,3	18.50003	19.38579	18.85851

Based on the results listed in Table 4, it can be concluded that there is a one-way relationship between the environmental degradation variable, which is represented by CO_2 emissions and CH_4 emissions to per capita income. The environmental degradation variable in the form of CO_2 emissions statistically influences the per capita income (GDP) variable with a probability value of 0.0009, which is smaller than the significance level of 0.05. Therefore, the null hypothesis is rejected. However, the GDP variable accepts the null hypothesis with a probability value of 0.4161, which is greater than the significance level of 0.005, so it can be concluded that the GDP variable does not affect the CO_2 variable.

Table 4: Granger Causality Test Results.

Hypothesis	F-Statistics	Prob.
CO2 does not affect GDP	5.87478	0.0009
GDP does not affect $_{CO2}$	0.9559	0.4161
CH $_4$ does not affect PDB	4.97404	0.0004
PDB does not affect CH $_4$	0.47666	0.7929

The environmental degradation variable in the form of CH_4 emissions statistically influences the per capita income (GDP) variable with a probability value of 0.0004, which is smaller than the significance level of 0.05. Therefore, the null hypothesis is rejected. However, the GDP variable accepts the null hypothesis with a probability value of 0.7929, which is greater than the 0.005 significance level, so it can be concluded that the GDP variable does not affect the CH_4 variable.

The results of the Granger Causality Test in Table 4 show that there is a one-way relationship moving from CO_2 emissions to per capita income in the five ASEAN

countries. This is proven by the probability value, namely 0.0009 < alpha value 0.05. The results of this research are supported by research by IS, [37] and [38] which found that there is a one-way causality from CO_2 emissions to per capita income.

CO_2 emissions can affect people's health and welfare through air pollution. This happens because CO2 emissions can interact with other chemicals in the air and form pollutants such as sulfuric acid, nitrogen oxides, and fine particulate matter. These pollutants can enter the human respiratory tract and cause various health problems such as irritation to the eyes and throat, headaches, nausea, coughing, shortness of breath, and can exacerbate conditions in people with asthma and heart disease which can lead to health costs that must be borne. government or society. The average CO2 emission $_{in}$ the ASEAN region is experiencing an increasing trend. This increase has a significant impact on human life. High $_{CO2}$ emissions in the air have an impact on human health, including the emergence of disease and even death, which will ultimately increase spending in the health sector [42].

In addition, an increase in CO2 emissions $_{can}$ also have an impact on the environment and the ecosystem as a whole. Climate change can affect climate and weather, which can impact water availability, food resources and biodiversity, all of which impact the overall well-being of society.

However, at higher income levels, there is a shift in the form of technological progress and increased energy efficiency, society and government can adopt cleaner and more sustainable technologies, reducing CO_2 emissions per unit of production. Then the increase in per capita income, people have greater resources to allocate some of their income for a better environment. This can involve investment in renewable energy, use of environmentally friendly technologies, development of sustainable transportation and other environmental protection policies. Thus, the level of CO2 emissions $_{can}$ decrease along with the increase in people's welfare.

The results of the Granger Causality Test in Table 4 show that there is a one-way relationship moving from CH_4 emissions to per capita income in the five ASEAN countries, as evidenced by the probability value, namely 0.0004 < alpha value 0.05. The results of this research are supported by research [40] which found that there is a one-way causality from CH_4 emissions to tourism sector income.

CH_4 emissions are closely related to the agricultural, industrial and waste management sectors. CH_4 emissions occur as a result of activities such as the production and use of fertilizers, the production and management of organic wastes, and the production and distribution of natural gas. Methane has greater global warming potential than CO_2 in the short term, and can accelerate global climate change. Unforeseen

climate changes, such as extreme temperature increases, floods or droughts, can disrupt tourism destinations and reduce tourist attractiveness. This has a domino effect on the local economy, business closures, loss of employment in the tourism sector which can affect people's income. CH_4 emissions can also affect the welfare of society at large, including through impacts on the availability of clean water because CH_4 emissions from agricultural waste can contaminate water sources and soil, affect food production, and human health. At high levels, exposure to CH_4 can cause headaches, fatigue, nausea, and irritation of the eyes, nose, throat to irritation of the respiratory tract and interfere with lung function. Air pollution caused by greenhouse gases spurs increased health spending [42].

The results of this research are also supported by the Environmental Kuznets Curve Theory. CH_4 emissions tend to be associated with a growing agricultural sector, intensive agriculture can increase CH_4 emissions. Along with economic growth, more intensive agricultural activities increase CH_4 emissions. However, as countries achieve higher levels of per capita income and better technological progress, they can adopt more efficient and environmentally friendly agricultural practices, such as better waste management, reduced methane gas leaks, or the implementation of more sustainable agricultural systems. This can cause a decrease in CH_4 emissions.

5. Finding and Conclusion

The conclusion that can be reached is that there is a one-way relationship moving from environmental degradation in the form of CO_2 and CH_4 emissions to per capita income based on findings from studies using Granger Causality Test panel data analysis. CO_2 and CH_4 emissions are dangerous for public health and the environment. However, as income levels increase, societies and governments become more environmentally conscious and will prefer to take action to reduce CO_2 and CH_4 emissions. This involves living a greener lifestyle, choosing renewable energy sources, and supporting strict environmental regulations.

Future researchers are encouraged to use other variables and analysis techniques related to this research and increase the research period to make it more relevant. The community is expected to raise awareness of the importance of protecting the environment and natural resources by reducing the use of private vehicles, unnecessary use of electricity derived from fossil energy, use of plastic, use of pesticides and chemical fertilizers as well as participating in environmental programs provided by policy makers.

6. Implications, Limitations, and Suggestions

The main drawback in this study is that the results of the long-term and short-term relationship of environmental degradation in the form of carbon dioxide (CO_2) and methane (CH_4) emissions on per capita income are unknown. By analyzing long-term relationships, the authors can identify whether there is a causal relationship that occurs over a longer period of time, which may indicate a more fundamental or structural causal relationship. Looking at short-term relationships helps you understand how the variables respond to one another over a shorter period of time. This can include relationships that are more reactive to changes or fluctuations that occur over a shorter timeframe. Other analytical techniques can be added in this study to see the relationship in that time period.

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