Study of Climate Change Issues in the Context of Economics and Energy

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Abstract. The phenomena of climate change are greatly influenced by greenhouse gas emissions, which are mostly caused by high productivity resulting from industrialization and increased household energy consumption, both of which contribute to the overall economic development. The global occurrence of climate change has detrimental effects on the long-term viability of life, particularly the environmental quality. The objective of this study is to examine the impact of the industrial sector's Gross Regional Domestic Product (GRDP), the poverty rate, and the distribution of electrical energy on climate change in Indonesia, as well as to identify and map areas that are vulnerable to the adverse effects of climate change. This study employs panel data, which is a merged dataset consisting of both time series and cross-sectional data. The dataset spans from 2018 to 2022 and encompasses 16 provinces in Indonesia. The analysis method employed is panel data regression, which involves evaluating the chosen panel data model. The Gross Regional Domestic Product (GRDP) of the manufacturing industry sector has a notable and meaningful impact on the occurrence of climate change.

Keywords: Panel data, electrical energy, climate change

1 Introduction

Climate change has a detrimental effect on the sustainability of life and particularly the environmental quality. This phenomenon is universally experienced by all countries worldwide. Climate change refers to significant fluctuations in temperature and precipitation patterns that occur over periods ranging from decades to millions of years. The primary factors contributing to the present situation are the utilization of fossil fuels, deforestation, land conversion, and industrial waste resulting from efforts to promote economic expansion [1].

The problem of climate change has been incorporated into the Sustainable Development Goals in order to address the continuing occurrence and the resulting effects, as outlined in objective 13. The rise in economic growth demonstrates a strong correlation between industrialization, heightened household energy consumption, and the substantial contribution to climate change via the release of greenhouse gases [2] .

Indonesia relies on non-renewable energy sources, which have detrimental effects on the environment, to support economic development. The subsequent data represents the mean temperature of Indonesia, serving as an indicator of climate change .

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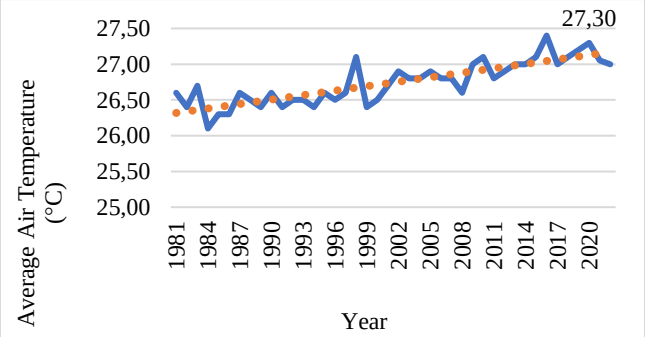

Fig. 1. Graph and Trend of Average Air Temperature in Indonesia.
Source: Meteorology, Climatology, and Geophysics Agency, 2023. Processed Data.

Fig. 1 displays the recorded data of the average temperature trend collected from 91 observation sites across Indonesia. Regarding temperature, 2016 recorded the highest average temperature with an anomaly value of 0.6 degrees Celsius. Following closely after, 2019 and 2020 ranked third and second, respectively, with anomaly values of 0.4 degrees Celsius and 0.5 degrees Celsius for the entire observation period. Climate change in Indonesia is deteriorating due to a 3-degree Celsius rise in global temperatures [3]. The table below displays the mean annual temperature data for each island in Indonesia from 2018 to 2022.

Table 1. Average Annual Temperature (in Celsius)

Island	2018	2019	2020	2021	2022	Avarage
Sumatera	27.07°	27.40°	27.26°	27.43°	27.53°	27.34°
Jawa	26.88°	26.98°	27.01°	27.03°	27.10°	27.00°
Kalimantan	26.67°	26.83°	26.82°	27.98°	27.88°	27.23°
Sulawesi	24.64°	24.63°	24.71°	27.63°	28.04°	25.93°
Bali & Nusa Tenggara	25.23°	25.31°	25.77°	28.07°	27.98°	26.47°
Maluku & Papua	25.42°	25.44°	25.47°	27.18°	27.89°	26.28°

Source: World Bank Climate Change and BMKG Publication, 2023. Data processed.

According to the data in Table 1, the average temperature in Sumatra, Java, and Kalimantan was the highest between 2018 and 2022. The annual forest and land fires in Kalimantan and Sumatra are the result of both natural and human-induced variables, together with the potential influence of climate change, including alterations in rainfall patterns and air temperature . Prasetyo et al. growth and industrial sector in a certain context might directly and indirectly affect the environment, including climate change[4] .

The industrial and transportation sectors typically release greenhouse gases, including carbon dioxide (CO2). Hossain establishes a clear correlation between heightened economic growth and development [5]. Jeshika states that the manufacturing sector has the capacity to substantially enhance production in every region [6]. This is due to its direct correlation with the workforce size in the industry and its potential to generate new economic growth and development. The industrial sector's performance can impact average temperatures due to its utilization of energy-intensive equipment and machinery, which relies on fossil fuels such as oil, gas, and coal.

Another significant factor that clearly influences climate change is the rising population density, particularly among impoverished communities. Widyawati et al. found that as the human population increases, there is a corresponding rise in the energy required for everyday activities and in the production of exhaust gases [7]. The increase in greenhouse gas emissions is also attributed to the growing population within a country, leading to elevated per capita energy consumption and, consequently, to air pollution [8]. There is a misconception that poverty is the primary driver of environmental degradation, as individuals with limited financial resources may lack the expertise to manage the environment effectively [9]. A direct and positive association exists between poverty and environmental harm, with evidence suggesting a causal relationship between the two. Environmental degradation can lead to impoverishment, while poverty can also contribute to environmental degradation. In the subsequent stage, poverty arises due to the environmental degradation caused by poverty in the preceding phase [10].

Energy-related factors are also believed to impact climate change. It is projected that energy demand in Indonesia will rise to 4,425 kWh per capita by 2050, which is five times the 2017 level of 864 kWh per capita. The utilization of electrical energy accounts for the largest proportion of emissions, comprising 35% of the total. This dominance is expected to continue through 2030. The increase in energy demand can be attributed to economic and population growth, as well as the ongoing construction of new power plants that primarily rely on fossil fuels as their energy sources.

2 Literature Review

2.1 Environmental Kuznets Curve (EKC) Theory

The Environmental Kuznets Curve (EKC) is a theoretical framework that examines the relationship between economic growth and environmental degradation. The concept of the EKC originated from the Kuznets curve, which was initially introduced by Simon Kuznets in 1995. The Kuznets curve originally described the relationship between income inequality and economic growth and later gave rise to the Environmental Kuznets Curve (EKC). The EKC suggests that during the initial phases of development (pre-industrial), or what Kuznets referred to as the economic development stage, a country's economy is primarily reliant on natural resources (primary industries) [11]. The environmental degradation occurring at this stage results from the negative effects of economic activities dependent on natural resources. In the subsequent phase, known as the industrial economy, increased economic expansion is accompanied by a corresponding rise in environmental degradation. This phenomenon can be attributed to the shift from the agricultural sector to the industrial sector (the secondary sector), which is responsible for generating significant amounts of waste and pollution [1].

2.2 Climate Change

Climate change refers to significant alterations in the climate cycle, temperature, and rainfall patterns over millions of years. There are several indicators that confirm the occurrence of climate change, one of which is the observed upward trend in average air temperature [9]. Additional indicators include extreme weather events, the melting of polar ice caps, and rising ocean temperatures. This study uses mean air temperature, measured in degrees Celsius, as an indicator of climate change.

3 Research Methods

This study uses panel data, which is a combination of time series and cross-section data. The time series data used is for the 2018-2022 period, covering 16 provinces in Indonesia. The equation in this study refers to the model applied by [12] , so that the equation model is modified to:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln ADHK_{it} + \beta_2 \ln POVE_{it} + \beta_3 \ln ELEC_{it} + \varepsilon_{it} \quad (1)$$

Where:

Y	: Average Air Temperature
ADHK	: GRDP Industrial Sector at Constant Prices
POVE	: Number of Poor People
ELEC	: Distribution of Electrical Energy
β_0	: Constant
β_1, β_2, β_3	: Independent Variable Coefficient
e	: Disturbance Variable / Error Correction Term
i	: Province
t	: Year
ln	: Natural Logarithm Transformation

a. Average Temperature (TEMP)

Average Temperature is the degree or measure of heat of an object using degrees Celsius units. Average Air Temperature acts as one of the indicators of climate change phenomena.

b. Industrial Sector GRDP (ADHK)

Gross Regional Domestic Product (ADHK) of the industrial sector in Indonesia is a product that is created and indicates economic activity in the country.

c. Number of Poor People (POVE)

The Number of Poor People is a group of individuals who have an average monthly expenditure per capita below the poverty line.

d. Distribution of Electrical Energy (ELEC)

Distribution of Electrical Energy is the amount of electrical power distributed to customers in each region, so that it can be represented as the amount of electrical energy that will be used in gigawatt hours.

3.1 Selection of Panel Data Estimation Model

There are three methods that can be used to estimate panel data regression models, namely: Common Effect Model Fixed Effect Model and Random Effect Model. The tests carried out are using the Chow Test, Hausman Test, and Lagrange Multiplier Test.

4 Discussion

Based on the results of panel data regression estimation with the selected model, namely Fixed Effect, the estimation results from the regression equation are as follows:

LNYit = 2.65018549417 + 0.0462374562115*LNADHKit - 0.00963090254301*LNPOVEit + 0.0241903482811*LNELECit

The equation provided shows the numerical values of each coefficient and the impact of the independent variables on the dependent variable. The constant value (C) is 2.65018549417, indicating that if the GRDP of the Industrial Sector at Constant Prices (LNADHK), the Number of Poor People (LNPOVE), and the Distribution of Electricity (LNELEC) are all zero, the Average Air Temperature in 2018-2022 would be 2.65018549417. This is true when all other factors remain unchanged (ceteris paribus). The value 2.65018549417 is derived by taking the natural logarithm. After applying the anti-ln operation, the average air temperature becomes 14.1567.

Table 2. Estimation Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.650185	0.120092	22.06788	0.0000
LNADHK	0.046237	0.012285	3.763825	0.0004
LNPOVE	-0.009631	0.006800	-1.416212	0.1618
LNELEC	0.024190	0.004201	5.758028	0.0000

Based on the estimation results above, the following regression equation has been obtained:

LNYit = 2.65018549417 + 0.0462374562115*LNADHKit - 0.00963090254301*LNPOVEit + 0.0241903482811*LNELECit (3)

The estimation results using the Fixed Effect Model indicate that the GRDP of the industrial sector has a positive and statistically significant impact on climate change, as measured by the average air temperature. The regression coefficient value of 0.046237 suggests that a 1% increase in the industrial sector's GRDP will lead to a 0.0462% increase in the average air temperature, assuming all other variables remain constant (ceteris paribus). The estimation findings demonstrate a positive trend and align with the hypothesis. Figure 3 provides evidence that the GDP of the Industrial Sector has made a substantial contribution to the Indonesian economy, surpassing the national average. This sector outperforms other key economic sectors, such as Agriculture, Forestry, and Fisheries, as well as Wholesale and Retail Trade, particularly in the area of Automobile and Motorcycle Repair.

Several mechanisms explain this correlation. Mariyani et al. found that the industrial sector accounted for 33.53% of carbon emissions and played a significant role in the rise of air

temperature [13]. This phenomenon is due to the use of technology and machinery in industrial activities, which require energy consumption. This energy is predominantly derived from fossil fuels, such as oil, gas, and coal. The use of fossil fuels generates greenhouse gas emissions, including carbon dioxide and methane, which actively contribute to global warming and subsequent climate change. In summary, the process described above elucidates the relationship between the high Gross Regional Domestic Product (GRDP) of the Industrial Sector and its impact on climate change, specifically the rise in average air temperature in provinces located on the islands of Sumatra and Java. The industrial sector's production activities lead to high levels of greenhouse gas emissions, which in turn contribute to the increase in average air temperature in the region.

The Indonesian government has pledged to address the global effects of climate change by setting a target to achieve net zero emissions by 2050. This commitment is reflected in the government's dedication to implementing Low Carbon Development, as outlined in Presidential Regulation Number 18 of 2020 concerning the 2020-2024 Medium-Term Development Plan. One effective method to achieve net zero emissions is the introduction of a Pigouvian tax, designed to incorporate the social costs associated with negative externalities. In the context of net zero emissions, this involves the implementation of a carbon tax.

The approach outlined in Presidential Regulation Number 18 of 2020 involves adopting a carbon pricing mechanism to mitigate the negative externalities associated with carbon emissions and facilitate low carbon development. Research suggests that the purpose of implementing a carbon tax is to incentivize society and industry to transition towards a green economy or activities that promote environmental sustainability and have minimal carbon emissions. Implementing a carbon tax on activities that generate carbon emissions has significant potential for generating state revenue and can effectively reduce carbon emissions from the industrial sector. The minimum carbon tax rate has been set at IDR 30 per kilogram of carbon dioxide equivalent, as stipulated in the Law of the Republic of Indonesia in 2021.

The correlation between the number of impoverished individuals and the occurrence of climate change, as measured by the mean atmospheric temperature, is both weak and statistically insignificant. The estimate demonstrates an inverse relationship and is inconsistent with the hypothesis. The findings align with the study conducted by [10], which concludes that poverty has a non-significant and adverse association with climate change, as measured by air temperature. In his research, he asserts that there is no direct correlation between poverty and climate change, as measured by air temperature. The provided graph displays the correlation between the average poverty rate and air temperature in 16 provinces of Indonesia from 2018 to 2022. Its purpose is to examine the impact of poverty levels on air temperature.S

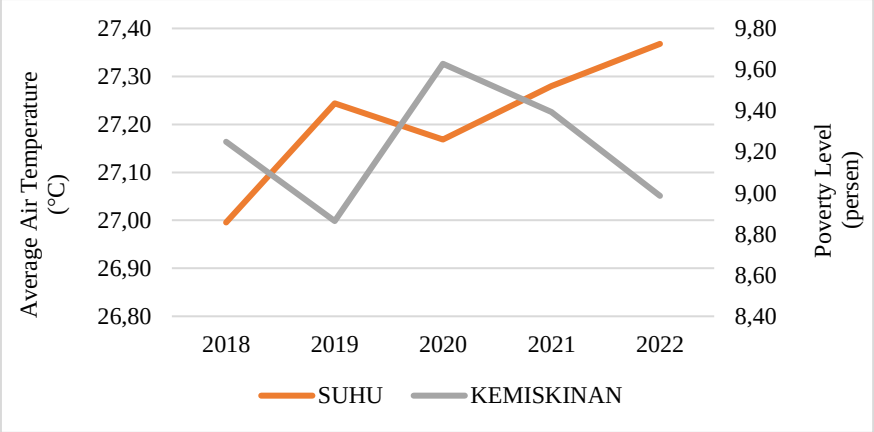

Fig. 2. Average Poverty and Air Temperature from 16 Provinces in Indonesia.
Source: Central Statistics Agency, 2023. Processed data.
Source : BPS, data processed 2024

Figure 2 is a graph illustrating the average correlation between the poverty rate and air temperature across 16 provinces in Indonesia from 2018 to 2022. The graph shows a correlation between annual increases in air temperature and a decrease in the poverty rate, particularly in the years 2020, 2021, and 2022. This trend indicates an inverse relationship between rising air temperatures and declining poverty rates, which aligns with the estimation results.

The correlation between the distribution of electrical energy and climate change is evident in the average air temperature, with a regression coefficient of 0.024190. This coefficient indicates that a 1% increase in the distribution of electrical energy will result in a 0.0241% increase in the average air temperature, assuming all other variables remain constant (ceteris paribus). The estimation findings demonstrate a positive trend and support the hypothesis.

This relationship can be explained as follows: Electricity distribution impacts average air temperature through several mechanisms. One example is the production of greenhouse gases generated by power plants. Fossil fuel power facilities emit carbon dioxide (CO2) and other greenhouse gases, which enhance the greenhouse effect and raise the average atmospheric temperature. As noted by Sakti & Sukartini [14] the current methods of generating electrical energy rely heavily on non-renewable coal, leading to the emission of harmful gases that contribute to rising global temperatures. This, in turn, significantly influences the frequency of extreme climate change events.

These findings highlight the need for measures to anticipate the significant use of electrical energy, which has the potential to jeopardize the sustainability of nature and the environment in Indonesia. Such measures include optimizing the use of smart grids. A smart grid, as defined by the International Energy Agency, is an energy network that employs advanced digital technology to oversee and control the transportation of power from all sources of generation to meet the diverse electricity needs of end users.

Pratama et al. state that the regulations for implementing a carbon tax in Indonesia have only been established at a general level, with no detailed plans for the technical aspects of its implementation, such as determining tax rates based on carbon market prices and the criteria for applying the tax [15]. Consequently, the enforcement of carbon pricing in Indonesia has been delayed due to concerns about global and domestic economic conditions. However, this measure could be an effective means to reduce carbon emissions in Indonesia. According to a study by Rahmayani, et all et al the introduction of a carbon tax in the UK between 2013 and 2015 had a significant impact, successfully reducing carbon emissions by 26% [16].

5 Conclusion

The Gross Regional Domestic Product (GRDP) of the manufacturing industry sector has a substantial and positive impact on the occurrence of climate change phenomena. Conversely, the number of impoverished individuals has a negligible and negative impact on climate change. The distribution of electrical energy has a direct and significant impact on climate change, as evidenced by the analysis of average air temperature in 16 provinces in Indonesia from 2018 to 2022.

6 Recommendation

The government is encouraged to promptly develop appropriate strategies and measures for low-carbon development to achieve net zero emissions by 2050, as stipulated in Presidential Regulation Number 18 of 2020. Low-carbon development can be pursued through green economy initiatives, such as introducing a carbon tax to mitigate the adverse effects of carbon emissions generated by the industrial sector.

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