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Research Paper

Causality of CO2 Emissions, Energy Consumption, Renewable Energy on Economic Growth in Asia Case Studies of 6 Asian Countries

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Abstract.
This research was conducted to examine the relationship and influence between CO2 emission variables, energy consumption, and renewable energy on economic growth in 6 countries in the Asia Pacific region, namely Indonesia, Thailand, Malaysia, Japan, China, and South Korea. These countries have different levels of economic growth. Economic activities carried out in each country produce different externalities. Therefore, this research was conducted to examine the relationship between CO2 emissions, energy consumption, renewable energy, and economic growth in 2014-2020. The data used in this study were obtained from the World Bank and the Statistical Review of World Energy. The research was conducted using the panel data regression method with the fixed effect model (FEM) as the best model. The results of this study indicate that renewable energy, total energy consumption, and CO2 emissions have a significant effect on economic growth. Meanwhile, per capita energy consumption variable has no significant effect on economic growth. From the R-square value, all variables have a correlation of 99% and as much as 1% is explained by variables outside the study. Further suggestions from this research are the government and related agencies regarding environmental sustainability issues due to CO2 emissions which continue to increase energy consumption and is believed to hamper economic growth in 6 Asian countries.

Keywords: consumption of energy, emission CO2, economic growth, panel data regression, renewable energy

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1. Introduction

Economic development carried out by countries in the world has the aim of improving the quality of its people which includes several aspects, namely economic aspects, social aspects, cultural aspects, and technological aspects. However, in the development process it has an impact in the form of positive and negative externalities. One of the external impacts of economic development is the increase in carbon dioxide (CO2)

emissions resulting from various production processes, where carbon dioxide (CO_2) emissions, in the form of greenhouse gases, are the main cause of global warming. Human activities are closely related to the production of CO_2 emissions (anthropogenic activity) (D Labiba, 2018)

Environmental issues have become a global concern in today's world. Concerns about environmental issues arise along with increasing global warming and climate change which is mainly caused by greenhouse gas emissions. Gases consisting of Carbon dioxide (CO_2), Methane (CH_4), Nitrogen (N_2O) and three other gases containing Fluorine accumulate in the atmosphere thereby changing the radiation balance which causes the earth's surface to be warmer (Shazhad, 2015)

Indonesia, Thailand and Malaysia are often identified as developing countries which are at an early stage in developing countries according to the EKC hypothesis. With this in mind, reducing environmental damage, which is difficult to implement, is fueled by the need for economic development and the community's weak environmental awareness. Indonesia, Malaysia and Thailand as developing countries have a tropical climate where developing countries are more likely to bear climate change than developed countries. The object of this study chose 3 developing countries because these three countries have the same economic and regional characteristics. Japan, China, and South Korea, as developed countries, have a lot of concentration in the industrial sector, causing environmental pollution due to industrial waste. China, Japan, and South Korea as industrialized countries which have a serious impact on environmental sustainability, as countries that have high economic growth in developing countries have an impact on environmental degradation.

(Alfonso Carfora, 2019) Energy use is one of the key drivers of economic growth since it promotes industrial development and economic productivity. The modern economy's operational hub, energy also drives household consumption, which is what will ultimately power the economy. On the other hand, the demand for economic expansion has resulted in environmental deterioration, which is frequently a side effect of industrialization and development in both emerging and established nations. A nation's economic development is influenced by a number of variables that can have a negative impact on the environment, including the unsustainable use of natural resources, pollution, and climate change. (Phimphanthavong, 2013)

In the Environmental Kuznets Curve (EKC) theory, the hypothesis suggests that the economic growth that was initially attempted would have an impact on increasing environmental degradation. In line with industrialization in economic growth, environmental damage will increase due to an increase in the use of resources for production.
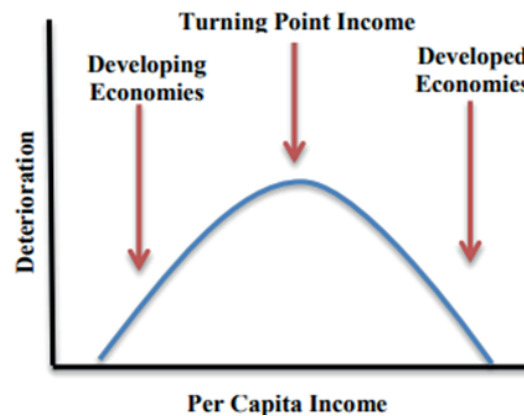
Figure 1: Environmental Kuznets Curve (EKC). Source: (Yandle, 2004).

The EKC hypothesis shows the relationship between various indicators of environmental damage, including air pollutants such as CO_2, SO_2, and water pollutants. and economic development that can be explained by per capita income or Gross Domestic Product (GDP) (Stern, 2004). Southeast Asia is a region with the fastest economic growth in the world, rapid economic development will lead to high energy demand according to the IESR (Institute for Essential Services Reform) forecast that energy demand in the region will increase by up to 70% by 2040, this is not without reason because countries in the Southeast Asia region, especially those who are members of ASEAN, are currently in the process of industrialization. Based on this background, the purpose of this study is to examine the causality of renewable energy (RE), total carbon dioxide emissions (ECT), energy consumption per capita (CPC), energy consumption (CE) on economic growth in 6 Asian member countries.

2. Literature Review

2.1. Gross Domestic Bruto (GDP)

According to Todaro in the journal (Arista & Amar, 2019) this economic growth can be interpreted as an increase in community output or output caused by an increase in the number of production factors used in the community's production process. (Chontanawat et al 2016) in the journal (Arista and Amar 2019) found that energy plays an important role in advancing the economic system on the demand and supply sides. Where they will decide to buy it to maximize its quality. But from the supply side, energy is an important factor in production besides capital, labour and material seem to play the most dominant role in economic and social growth in rural areas. Further research shows that the relationship between energy consumption and growth suggests that

there must be a cause-and-effect relationship that flows from energy consumption to Gross Domestic Product (GDP) (Azam et al., 2015)

2.2. Renewable energy

Because energy comes from sustainable natural processes like wind, air, sunlight, geothermal, and others, renewable energy sources are particularly eco-friendly because they don't generate environmental damage or contribute to climate change or global warming. biofuels. Energy sources are part of natural resources which include oil and natural gas, coal, water, geothermal, peat, biomass, and so on, which can be used directly or indirectly as energy. This renewable energy synergizes with various aspects of sustainable development (Stiglitz, 2006). This is the reason why sustainable development through renewable energy is central to policies around the world. This study demonstrates the worldwide significance of renewable energy in the interaction between national economic conditions. Fuel, electricity, mechanical energy, and heat are just a few of the processes that can be carried out using energy. Anything with the ability to produce is an energy source.

2.3. Carbon Dioxide Emission

Environmental issues have become a global concern in today's world. Concerns about environmental issues arise along with increasing global warming and climate change which is mainly caused by greenhouse gas emissions. Gases consisting of Carbon dioxide (CO_2), Methane (CH_4), Nitrogen (N_2O) and three other gases containing Fluorine accumulate in the atmosphere thereby changing the radiation balance which causes the earth's surface to be warmer (Umair, 2015). (BAPPENAS, 2014), Emission is the release of greenhouse gases (GHG) into the atmosphere, which results in the production of CO_2 or CH_4 gas due to microbial decomposition of organic matter, the process of burning organic matter with CO_2 production, and denitrification, and nitrification. from the denitrification process produces N_2O gas. Southeast Asia is a region with the fastest economic growth in the world, rapid economic development will lead to high energy demand according to the IESR (Institute for Essential Services Reform) forecast that energy demand in the region will increase by up to 70% by 2040, this is not without reason because countries in the Southeast Asia region, especially those who are members of ASEAN, are currently in the process of industrialization. Currently, along with the increasing activity that causes the temperature on earth to increase from year

to year caused by greenhouse gas emissions. Activities that can lead to an increase in greenhouse gas emissions. One of them is carbon dioxide (CO2), the main source of which is the exhaust gas produced when fossil fuels such as coal and oil are burned in power plants and motor engines.

2.4. Consumption Per capita

The development of the industrial sector is accompanied by energy consumption using technology where the technology used is not environmentally friendly, especially in developing countries such as several countries in ASIA. This has increased greenhouse gas emissions, meaning that the continued use of fossil energy will increase the concentration of the house gas carbon dioxide (Co2). Energy is also the key driver of economic growth because it is a necessary component of many industrial and consumption processes. Energy utilization is fundamental to any modern economy since it physically drives economic output and industrial expansion (Saidi & Hammami, 2015). Research (Antonakakis et al., 2017) conducted in 106 countries classified by income group for the period 1971-2011 shows a two-way causality between total economic growth and energy consumption, thus proving the case of the feedback hypothesis.

3. Research methods

This research method and the development of hypotheses used to answer a research problem. The population used in this study were six Asia Pacific countries such as Indonesia, Thailand, Malaysia, South Korea, Japan, and China. The period taken is seven years, namely 2014-2020. The type of data used is secondary data obtained from the BP Statistical Review of World Energy 2021 website. The secondary data is processed using panel data regression analysis techniques with the STATA software application at a rate of 5%. This study uses descriptive quantitative research methods. There are several advantages of using panel data according to (Gujarati, 2004) in the journal (Rosiana & Mahardika, 2017): 1. Provides heterogeneity, 2. Provides more informative, more varied data, smaller collinearity between variables, greater degree of freedom , and more efficient, 3. Better in studying dynamic changes, 4. Better in detecting and measuring effects that simply cannot be observed using pure cross section data or pure time series, 5. Can be used to study complicated behaviour models, and 6. Minimizing bias.

The model used in this study is as follows:

$$GDP_{it} = \beta0 + \beta1 RE_{it} + \beta2 ECT_{it} + \beta3 CPC_{it} + \beta4 CE_{it} + \varepsilon_{it}$$

1. **Equation 1 -- Equation Regress**

Description:

GDPit = Gross Domestic Product

REit = Renewable Energy

ECTit = Energy Consumption Total

CPCit = Consumption per capita

CEit = Carbon dioxide Emissions

β0 = Constant

β1-3 = Coefficient of Each Variable

εit = Error of Country I at year t

Discussion

1. Common Effect Model (CEM)

2. Common Effect Model (CEM) is data that only combines time series data and Cross Section data, this model also ignores time and individual dimensions (Tri Basuki, 2016)

3. Fixed Effect Model (FEM)

4. The Fixed Effect Model assumes that the difference in intercept can accommodate differences between individuals (Tri Basuki, 2016)

5. Random Effect Model

6. The random effect model can estimate panel data in which the disturbance variables are interrelated between time and individuals (Tri Basuki, 2016)

The results of using the common effect model, fixed effect model, and random effect model are as follows:

Based on the results of the tests that have been carried out, the probability of the chi-square cross section is 0.0000 less than = 0.05 or 5%, meaning that the fixed effect model is the best model compared to the Common Effect Model (CEM) and the Random Effect Model.

The regression results in table 1.2 above are written in the following equation:

<div align="center">T_{ABLE} 1: Panel Data Regression Results.</div>

T<small>ABLE</small> 1: Panel Data Regression Results.

Variable	Coefficient Regress		
	CEM	FEM	REM
GDP	(1,03)	(4,68)	(4,68)
Renewable Energy	4,84	4,76	4,76
Carbon Dioxide Emissions	8,28	7,94	7,94
Energy Consumption Per capita	(3,08)	(8,02)	(8,02)
Energy Consumption	2,95	2,15	2,15
Adj R^2	0,9968	0,9935	0,9935
F-Statistic	2854,91	69260,84	1856,33
Prob F-Statistic	0,0000	0,0000	0,0000

Source: Stata 16 . Data Processing

T<small>ABLE</small> 2: Results of Panel Data Regression.

	Model Regress			
	Coefficient	t-statistic	Sig.	Conclusion
C	(-4.68)	2.11	0.043	Significant
RE	4.76	4.90	0.000	Significant
ECT	7.94	(-0.74)	0.466	Not Significant
CPC	(-8.02)	0.29	0.777	Not Significant
CE	2.15	3.21	0.003	Significant
R^2			0.9968	
F significant			0.0000	

Source: Stata-16 (2022), processed data.

GDP = -4.68e+11 + 4.76e+11 + 7.94e+10 + -8.02e+08 + 2.15e+09 + e .... (1). Based on the panel data regression in table 2, the following is the interpretation of the results obtained: The coefficient value (constant) is -4.68e+11, meaning that when renewable energy increases by 1%, GDP increases by 4.76%. The value of the Energy Consumption coefficient is 2.15e+09, meaning that for every 1% increase in the percentage of Energy Consumption, the value of Economic Growth will increase by 2.15%.

3.1. F-test Results (Simultaneous)

Based on the panel data regression analysis that has been carried out, it shows the results that can be seen in table 1, the F-Statistics section can be generated worth 0.0000 where this result is smaller than a = 0.05 which means H0 is rejected and H1 is accepted, so it can be concluded that the Renewable Energy and Consumption variable Energy has a significant effect simultaneously or simultaneously on Economic Growth

3.2. T-test Results (Partial)

Renewable Energy (RE) with a t-statistic of 4.90, has a probability level of 0.000 or less than a = 5% or 0.05 so that Renewable Energy is positively related and has a significant effect on economic growth in 6 ASIA countries. Total Carbon Emissions with a t-statistic of -0.74, has a probability level of 0.466 or more than a=5% (0.05) so Total Carbon Emissions are negatively related and have no significant effect on economic growth in 6 ASIA countries. Energy Consumption Per capita (BPK) with a t-statistic of 0.29 and a probability level of 0.777 or more than a=5% (0.05) so that Energy Consumption Per capita is positively related and has no significant effect on economic growth in 6 ASIA countries. Energy Consumption (CE) with a t-statistic of 3.21, has a probability level of 0.003 or less than a=5% (0.05) so Energy Consumption is positively related and has a significant effect on economic growth in 6 ASIA countries.

3.3. Coefficient of Determination (R2)

Table 1 shows that the coefficient of determination or R-square obtained in this study is 0.9968 or 99.68%. It can be concluded that the dependent variable of Renewable Energy, Total Carbon Emissions, Energy Consumption Per capita, and Energy Consumption can explain its influence on the independent variable, namely Economic Growth in 6 ASIA member countries in 2014 - 2020, namely 99.68%, where the remaining 0.32% explained by other variables outside this study.

4. Interpretation

4.1. The Relationship of Renewable Energy and Economic Growth in 6 Asian Member Countries

The results of the panel data regression analysis carried out for this study indicate that the renewable energy (RE) variable is positively associated and significantly influences economic growth in six Asian nations. This suggests that as the use of renewable energy rises, so does economic growth. The findings of this investigation are based on work by (Yulia Afriyanti, 2020) that increased economic growth will result in a country's ability to invest in renewable energy sources also increasing. Thus, it will encourage the country to increase the consumption of renewable energy. The opinion in this study is also relevant to the Environmental Kuznets Curve (EKC) theory which states (Stren, 2004) that economic growth that continues to improve will be followed by

environmental improvements because people with a better standard of living will have more awareness of the environment so that the emergence of an increase in renewable energy accompanied by increased economic growth.

4.2. Relationship between Total Carbon Dioxide (CO2) Emissions and Economic Growth in 6 Asian Countries

Based on the results of panel data regression analysis that has been carried out in this study. The results show that the variable total carbon dioxide (CO2) emissions have no significant effect on economic growth in 6 Asian countries. This indicates that when carbon dioxide emissions (CO2 decrease, economic growth does not decrease. In the research conducted, the results obtained that total carbon dioxide (CO2) emissions do not have a significant effect on economic growth. This happens because the use of energy that is intended for the mobility of an activity is not always the result of energy that produces carbon dioxide which is not fully utilized for productive things. such as industry, commercial and others that can increase economic growth (Retrinia Nur Alim, 2022). Meanwhile, the results of research conducted by (Retno Febriyastuti Widyawati, 2021) The higher the economic growth of a country, the less carbon dioxide emissions. This happens because a country that has high economic growth can reduce carbon dioxide emissions by still paying attention to the environment, supported by various sustainable development policies so that it will affect the quality of the environment and can reduce carbon dioxide emissions.

4.3. The Relationship Between Energy Consumption Per Capita and Economic Growth in 6 Asian Member Countries

Based on the results of the regression panel data processing that has been done shows that the per capita energy consumption variable (CPC) has no impact on economic expansion. This happens because the use of energy intended for mobility and activity is not always the result of energy that produces carbon dioxide which is not utilized optimally for productive things such as industry, commerce and others that can increase economic growth (Retrinia Nur Alim, 2022) Meanwhile, the results of research conducted by (Retno Febriyastuti Widyawati, 2021) The higher a country's economic growth, the less carbon dioxide gas emissions. This happens because a country that has high economic growth can reduce carbon dioxide emissions by paying attention to the environment, supported by various sustainable development policies that will have an impact on environmental quality and can reduce carbon dioxide emissions.

4.4. The Relationship Between Energy Consumption and Economic Growth in 6 Asian Member Countries

Regression analysis of panel data already has the result that the energy consumption variable is positively related and has a significant effect growth in 6 Asian countries. It can be concluded from this that if the percentage increase in energy consumption is 1%, the value of economic growth will increase by 2.15%. The results obtained are supported by research from (Gozgor et al., 2018) which concludes that energy consumption has a significant positive effect on economic growth. Increasing energy indicates that activities in economic growth are running, such as activities in the industry that are increasingly being pushed forward, this is found in research (Rezki, 2011). Furthermore, there is the opinion of neo-classical economics which states that an increase in energy consumption creates economic growth (Kraft & Kraft, 1978).

5. Conclusion

The findings of this study demonstrate that: (1) Renewable energy and economic growth are positively correlated and have a considerable impact on each other. (2) The impact of overall carbon dioxide (CO_2) emissions on economic growth is adverse and negligible. (3) The amount of energy consumed per person has a favorable and large impact on economic expansion. (4) Energy use and economic growth are favorably correlated and significantly impacted. Therefore, the total carbon dioxide emissions variable and the energy consumption variable in this study do not significantly affect economic growth in six Asian nations. Further suggestions from this research are the government and related agencies regarding environmental sustainability problems caused by CO_2 emissions which continue to increase energy consumption which is believed to hamper economic growth in 6 Asian countries.

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