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Analysis of Factors Influencing Energy Intensity in G20 Countries

Cynthia Dikna Sari [a*], Toto Gunarto [a++], Tiara Nirmala [a++], Marselina [a++] and Neli Aida [a++]

[a] *Faculty of Economics and Business, University of Lampung, Lampung, Indonesia.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The purpose of this study is to analyze the impact of Gross Domestic Product (GDP), Industry Value Added (IVA), Urban Population (UP), Trade, and Foreign Direct Investment (FDI) on Energy Intensity in G20 countries.
Study Design: This research used a quantitative descriptive method using panel data analysis.
Place and Duration of Study: The scope of this research extends to G20 member countries such as Argentina, Brazil, Canada, China, Germany, European Union, France, United Kingdom, Indonesia, India, Italy, Japan, Korea, Mexico, Rusia, Saudi Arabia, Turki, United States, and South Africa, between 1990-2021.
Methodology: This research uses descriptive method combined with panel data analysis, analyze determine of GDP, IVA, UP, Trade, and FDI on Energy Intensity in G20 countries. Furthermore, the data uses is secondary data that has a regression model on panel data from 1990-2021.
Results: The result of this research show that IVA has a positive relationship and has a significant effect on increasing energy intensity in G20 countries. GDP, Trade and UP variables have a negative relationship and have a significant effect on Energy Intensity in G20 countries. Meanwhile, the FDI variable has no significant effect on Energy Intensity in G20 countries.

[++] *Senior Lecture;*
**Corresponding author: E-mail: cynthiadiknasari@gmail.com;*

Conclusion: Based on research result, Energy Intensity in G20 countries is influenced by various factors, The IVA factor has a positive and significant relationship with energy intensity, can be utilized to increase productivity and economic growth, but need to be balanced with effort to increase energy efficiency.
While the GDP, Trade and Urban Population factors have a negative and significant relationship to energy intensity. However, FDI does not have a significant effect on energy intensity in G20 countries. The government should consider policies to reduce dependence on intensive energy, especially in sector that have a negative relation with energy intensity such as GDP, trade and urban population.

Keywords: Energy intensity; GDP; industry value added; urban population; trade; foreign direct investment; panel data analyst.

1. INTRODUCTION

G20 countries account for approximately 75 percent of global energy demand, 80% of global greenhouse gas emissions and 60% of the world's population. Therefore, G20 countries have a great responsibility and strategic role in encouraging the use of clean energy [1].

Stimulate economic growth and development by using natural resources sustainably and efficiently, using clean resources, minimizing pollution and environmental impact, and fighting natural disasters. Based on energy intensity data from 2000 to 2019, energy intensity conditions in G20 countries showed a decreasing trend during 2000-2019.

The relationship between energy and sustainable growth is closely linked to energy efficiency. The more effectively a country manages its energy, the more efficient it is. Energy efficiency is also an indicator of the Sustainable Development Goals (SDGs) [2]. Improving energy efficiency is an important development task. A suitable solution that can be implemented due to limited resources and the growing need to use energy efficiently [3].

The trend of urbanization and rising living standards will lead to very high energy demand in cities. By 2050, 55% of the world's population is expected to live in urban areas [1]. Cities account for nearly two-thirds of global energy demand, generate up to 50% of solid waste and are responsible for 70% of greenhouse gas emissions. Globally, at the urban level, material consumption is expected to increase from 40 billion tons in 2010 to 90 billion tons in 2050, mainly driven by demand for construction materials in developing countries. development. Thus, cities will play a key role in the transition from a linear economy to a circular economy.

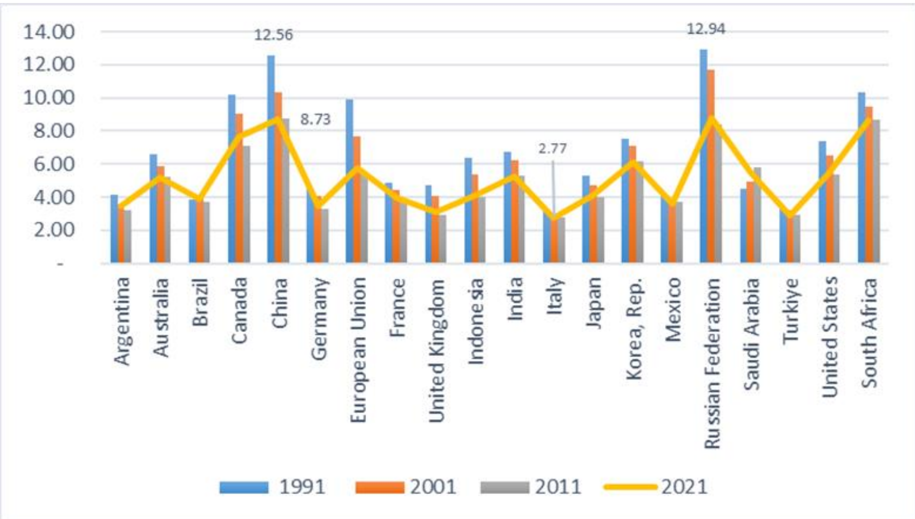

Fig.1. Energy Intensity from G20 Countries
Source: World Bank, 2023

Environmental problems that were previously ignored due to factors such as increasing economic growth, industrialization and trade, are now having an impact that can threaten the world's environmental conditions. Trade policy can be designed to accomodate changes in environmentally friendly energy policies [4].

The study [5] discusses energy economics and climate policy as well as the complexities of energy sector regulation. The development and progress of a country depends on energy, every country needs energy as capital for development. Investment and energy efficiency are necessary if a country wants to produce a sustainable energy supplies.

Studies on the determinants of energy intensity, both in Indonesia and other countries, have been conducted using a variety of methods, but no one has yet measured the determinants using panel data in G20 countries. G20 countries are currently focusing on the clean energy transition and playing a strategic role. Therefore, the influence of energy intensity on economic growth, industrial value added, population, trade and investment must be studied in G20 countries. This study contributes to measuring the variables that influence energy intensity in G20 countries.

2. METHODOLOGY

This research uses quantitative method for analysis using panel data regression, to see how Gross Domestic Product (GDP), industrial added value, urban population, trade and foreign direct investment influence energy intensity in G20 countries. The scope of this research is G20 member countries such as Argentina, Brazil, Canada, China, Germany, European Union, France, United Kingdom, Indonesia, India, Italy, Japan, Korea, Mexico, Russia, Saudi Arabia, Turkey, United States, and South Africa, using the 2000-2019 period. The data used is combined data between cross-sectional and time series data is also known as panel data. This research uses secondary data sourced from World Bank data. The following Table 1 describes the variables and units in this research.

This study uses the following research model:

$$EI_{it} = \beta_0 + \beta_1 LogGDP + \beta_2 IVA_{it} + \beta_3 UP_{it} + \beta_4 TRD_{it} + \beta_5 FDI_{it} + \varepsilon_{it}$$

Explanation
β_0 = Constant
β_1 = Coefficients
EI_{it} = Energy Intensity
GDP_{it} = Gross Domestic Product
IVA_{it} = Industry Value Added
UP_{it} = Urban Population
TRD_{it} = Trade
FDI_{it} = Foreign Direct Investment
E = Residual (error term)
i = Member of G20 Countries
t = Time
Log = Logarithmic transformation

When estimating panel data, there are three approaches to selecting the best model, specifically the common effects model, fixed effects model, and random effects model. To determine the best model of the three, Chow test, hausman test and lagrange multiplier test was executed.

Table 1. Variables, symbols, units, and data sources

Variables	Symbols	Units	Data Sources
Energy Intensity	EI	Mega Joules Per Kapita	World Bank Data
Gross Domestic Product	GDP	Trillion (Constant US$)	World Bank Data
Industry Value Added	IVA	Persentase (%)	World Bank Data
Urban Population	UP	Persentase (%)	World Bank Data
Trade	TRD	Persentase (%)	World Bank Data
Foreign Direct Investment	FDI	Persentase (%)	World Bank Data

3. RESULTS AND DISCUSSION

3.1 Results

a) Chow Test: The Chow test in panel data is a statistical method used to test for significant differences between linear regression models and panel data in two different groups. In the Chow test, a comparison is made between the Common Effect Model and the Fixed Effect Model by looking at the probability (p-value). Following are the results of the chow test.

Table 2. Chow test

Effect Test	Statistic	d.f.	Prob
Cross Section F	400.508238	(19,615)	0.0000

Based on the results of the Chow test, the p-value between the Common Effect Model and the Fixed Effect Model at the 5% real level (0.05) is 0.0000. The p-value results are smaller than the 5% real level (0.05), so it can be concluded that the Fixed Effect Model is more appropriate to use than the Common Effect Model from data in G-20 countries based on the Chow test.

b) Hausman test: Based on the results of the Hausman test, the p-value between the Random Effect Model and the Fixed Effect Model at the 5% real level (0.05) is 0.0091. The p-value results are smaller than the 5% real level (0.05), so it can be concluded that the Fixed Effect Model is more appropriate to use to analyze research models than the Random Effect Model from data in G-20 countries based on the Hausman test.

c) Lagrange multiplier test: Based on the results of the Lagrange multiplier test, the Breusch-Pagan probability between the Common Effect Model and the Randon Effect Model at the 5% real level (0.05) is 0.0000. The results of the p-value are smaller than the 5% real level (0.05), it can be concluded that the Random Effect Model is more appropriate to use to analyze research models than the Common Effect Model from data in G-20 countries based on the Lagrange multiplier test.

Based on the test results, it was found that the Fixed Effect Model was the best model used in this research and had passed classical assumption testing. The estimation results are as follows in the Table 5.

Based on the estimation result in Tabel, the regression equation can be written as follows:

$$\boldsymbol{EI_{it} = 60.13 - 1.971(LogGDP) + 0.078(IVA_{it}) - 0.274\ (UP_{it}) - 0.06(TRD_{it}) - 0.001\ (FDI_{it}) + \varepsilon_{it}}$$

Table 3. Hausman test

Effect Test	Statistic	d.f.	Prob
Cross section random	15.303654	5	0.0091

Table 4. Langrange multiplier test

Effect Test	Cross-section	Time	Both
Breusch-Pagan	6881.424 (0.0000)	4.653474 (0.0310)	6886.078 (0.0000)

Table 5. Panel data estimation results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Log_PDB	-1.971.111	0.102230	-1.928.118	0.0000
IVA	0.078264	0.008618	9.081.384	0.0000
TRD	-0.006117	0.002650	-2.308.317	0.0213
UPOP	-0.274241	0.055034	-4.983.124	0.0000
FDI	-0.001632	0.016081	-0.101508	0.9192
C	60.13155	2.983686	20.15344	0.0000
R-squared	0.933231	Mean dependent var		5.557597
Adjusted R-squared	0.930625	S.D. dependent var		2.383.479
S.E. of regression	0.627787	Akaike info criterion		1.945.049
F-statistic	3.581.593	Durbin-Watson stat		0.192076
Prob(F-statistic)	0.000000			

3.2 Discussion

Based on the regression results, it was found that Gross Domestic Product (GDP), urban population and trade in G20 member countries have a negative and significant influence on energy intensity. Meanwhile, Industrial Value Added has a significant positive impact on energy intensity. In this case, if there is an increase in GDP of 1%, it will cause a decrease in energy intensity in G20 countries of – 1,971 with ceteris paribus assumptions.

Based on research [6] stating that GDP has a negative relationship with energy intensity according to the Kuznets curve hypothesis, there is a non-linear (quadratic) relationship between energy intensity and GDP per capita. These results are supported by findings from various countries such as in the European Union in the study [7] that GDP has a significant negative impact on energy intensity. Income reflects the level of economic development which is closely related to increasing energy efficiency. This result is similar to the study [8] he negative relationship shows that increasing GDP can reduce energy intensity in China. When GDP increases, people are aware of environmental benefits, saving energy and reducing energy intensity.

The regression results for the urban population variable give significant negative results, if there is an increase in urban population of 1% it will cause a decrease in energy intensity in G20 countries of -0.274 with ceteris paribus assumptions. The results of research [9] show that the population migration situation to urban areas has a negative impact on energy intensity. The impact of urbanization is U-shaped on energy intensity, due to the increasing difference in energy intensity demand during the urbanization process. The intensity of energy requirements varies with stages of urbanization, and major stages of urbanization depend on large amounts of energy as a support source. When urbanization reaches a certain level, energy demand will decrease. Propose the implementation of policies that take into account energy efficiency in the process of urbanization and development.

The trade variable shows significantly negative result, when there increases in trade of 1%, it will cause a decrease in energy intensity in G20 countries by –0.006 with ceteris paribus assumptions. This result is also in accordance with research [10] that trade as a driving factor for entry into countries reduces energy intensity, encourages local companies and industries to be more energy efficient. The negative relationship between energy intensity and trade is in line with research [11]. This finding is in line with the principles of firm heterogeneity theory in international trade, showing that greater exports and imports in GDP cause a decrease in energy intensity. However, contrary to the Kuznets curve environmental theory, trade has no impact on energy consumption in India and abroad.

Industrial value added has a positive influence on increasing energy intensity in G20 countries. If there is an increase in industrial value added by 1%, it will cause an increase in energy intensity in G20 countries by 0.078 with ceteris paribus assumptions. Based on [2] and [12] industry has a positive impact on energy intensity. This could be an indication that the country is focusing on developing the industrial sector so that it is still intensive in energy use. Based on research [12], primary, secondary and tertiary industries encourage energy use.

The regression coefficient on Foreign Direct Investment (FDI) is negative but not significant. The same as research [13] that FDI has an insignificant impact on energy intensity in developing countries. Another finding from research [6] is an increase energy efficiency in developing countries through FDI does not happen automatically occur and without climate or energy policy.

To reduce energy dependence, the government must consider policies aimed at reducing high energy dependence, especially in sectors that have a negative relationship with energy intensity, such as GDP, trade and urban population. To increase industrial added value, it is important to optimize energy use during production. By reducing energy intensity, industry can increase efficiency, technological innovation and competitiveness, which in turn can provide higher added value and more sustainable economic growth.

The study regarding the determinants of energy intensity in this research has limitations. In other research, there are still many variables that may have an influence on energy intensity, such as technology. Future research can add technological factors to see their effect on energy intensity.

4. CONCLUSION

Based on research result, Energy Intensity in G20 countries is influenced by various factors, The IVA factor has a positive and significant relationship with energy intensity, can be utilized to increase productivity and economic growth, but need to be balanced with effort to increase energy efficiency.

While the GDP, Trade and Urban Population factors have a negative and significant relationship to energy intensity. However, FDI does not have a significant effect on energy intensity in G20 countries. The government should consider policies to reduce dependence on intensive energy, especially in sector that have a negative relation with energy intensity such as GDP, trade and urban population.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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