ISSN: 2338-8412 e-ISSN : 2716-4411

Ekombis Review – Jurnal Ilmiah Ekonomi dan Bisnis
Available online at : https://jurnal.unived.ac.id/index.php/er/index
DOI: https://doi.org/10.37676/ekombis.v11i2

Analysis of the Effect of Economic Growth, Urbanization, Energy Consumption on CO_2 Emissions in G-20 Countries for the Period 1990 – 2020

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How to Cite :
Poetri, I.D., Taufiq, T., Bashir, A., Yulianita, A. (2023). Analysis of the Effect of Economic Growth, Urbanization, Energy Consumption on CO2 Emissions in G-20 Countries for the Period 1990 – 202. EKOMBIS REVIEW: Jurnal Ilmiah Ekonomi Dan Bisnis, 11(2). doi: https://doi.org/10.37676/ekombis.v11i2

ARTICLE HISTORY
Received [15 Mei 2023]
Revised [22 Juli 2023]
Accepted [31 Juli 2023]

KEYWORDS
Economic Growth;
Urbanization;
CO_2 Emissions;
Environmental Kuznet Curve (EKC)

ABSTRACT

This study aims to analyze how economic growth, urbanization, energy consumption influenced to CO_2 Emissions in Countries that are members of the G-20. In this study using time-series data for the period 1990 – 2020; the data utilized are sourced from World Bank database and BP Statistic. The methode uses a quantitative approach that applies the STIRPAT methode with the fixed effect methode panel data regression. The results of the study state that economic growth with GDP per capita has a positive and significant effect, meanwhile GDP per capita squared has a negative and significant on CO_2 Emissions. So that it can prove the EKC hypothesis with an inverted U-Curve relationship between economic growth and CO_2 Emissions. Urbanization and Energy Consumption has a positive and significant effect on CO_2 Emissions.

INTRODUCTION

One of the challenges faced by all countries is balancing the accelerated rate of economic growth with the level of environmental quality that is protected (Hassan et al., 2019). Sustainable Development Goals (SDGs) are one of the challenges that must be achieved with the final target in 2030 being the issue of environmental degradation which is getting worse due to economic activity (Zafar et al., 2019). The Millennium Development Goals (MDGs) are one of the international continuation agendas of the SDGs. The dimensions of sustainable development which include environmental, social and economic are the goals and targets in the SDGs. So that through this SDGs policy, environmental, social and economic aspects can be balanced by each country. Then it produces the Environmental Kuznets Curve (EKC) hypothesis which explains that

economic growth will continuously increase, followed by an increasing decline in environmental quality, but there will be a turning point where policies are implemented that prioritize aspects of environmental preservation so that increasing economic growth is followed by reduction in environmental quality (Todaro & Smith, 2006).

Degradation or decline in environmental quality is a negative impact of a large economy, in the form of water, sound, land and air pollution. The industrialization stage being faced by developing countries has greater environmental degradation or decline in quality compared to developed countries which are already transitioning from industrialization to the service sector. This causes that in developed countries the use of energy that produces pollution will grow at a lower rate compared to economic growth, because policies have been implemented that pay attention to environmental quality (Hayami & Godo, 2005).

Focusing only on profits from development and economic growth without paying attention to the impact on environmental quality will result in environmental damage (Safari et al., 2021). Globally in 2010, compared to 1990, GHG emissions were around 36 billion metric tons, estimated to have increased by 35 percent, namely around 46 billion metric tons. Globally, greenhouse gas (GHG) emissions were around 46 billion metric tons from various activities which resulted in environmental degradation and become a dominant challenge for developing countries (EPA, 2022).

Global warming has the impact of shifting seasons and extreme weather which has become a serious environmental issue globally. This is due to an increase in Green House Gases (GHG) which consist of six components, namely carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and gases containing fluorine (HFCs, PFCs, and SF6). The highest contributor at 75 percent is carbon dioxide (CO2). In the Intergovernmental Panel on Climate Change (IPCC) forum, it was explained that in facing the threat of sustainable development, climate change and poverty alleviation, it is necessary to strengthen the global response, because it has resulted in global warming of 1.5°C above global GHG emission levels and pre-industrial levels.

The rate of world GDP per capita grew positively with an average growth of 1.58 percent. This is in line with the population rate of urbanization which averages 2.19 percent, energy consumption reaches an average of 0.52 percent and CO2 emissions reach 1.62 percent. This shows that the world continues to experience economic growth. In order to analyze the relationship between economic growth and the environment using standard concepts by adopting the Environmental Kuznet Curve (EKC) hypothesis. The Environmental Kuznets Curve (EKC) theory explains that initially an increase in economic growth will be followed by an increase in the level of environmental damage. Initially, countries will only focus on increasing production without paying attention to environmental aspects. This results in environmental damage in the form of pollution of land, water and air due to continuous production. However, when they reach a turning point, society will realize that the need for good environmental quality is very important, so that even though there is an increase in economic growth, it does not reduce environmental quality.

This has a huge impact on society, namely causing various health problems with the continuous increase in CO2. If left unchecked, it will have the effect of reducing the rate of economic growth in the long term. This happens because the level of productivity of natural resources decreases due to environmental damage. So in the end the costs

incurred will be very high and result in GDP per capita of the population decreasing (Todaro, 1998). Ten countries are the largest contributors to CO2 emissions globally, namely China, United State, Russia, Japan, Iran, Indonesia, Saudi Arabia, Germany, South Korea. The ten countries that are the largest contributors to CO2 emissions in the world are members of the G20.

The countries that are members of the G-20 are considered countries with large economic powers. G20 countries are countries that are represented as having more than 60 percent of the world's population, 75 percent of global trade, and more than 80 percent of Gross Domestic Product (GDP). G20 countries have an economic growth rate with an increasing trend from the previous year and have quite high growth with an average growth of 1.33 percent. In line with the urbanization population which shows an increasing trend with an average of 1.89 percent. Increased economic growth followed by increased urbanization and energy consumption also shows an increase in CO2 emissions, plus G20 countries will be the largest contributors to CO2 emissions in the world in 2020. The aim of increasing economic growth is to reduce poverty levels and income inequality. However, on the other hand, this can have a negative impact on the environment by increasing CO2 emissions.

Apart from economic growth and urbanization, consumption of primary energy from fossil sources can also increase CO2 emissions. Based on data from the 2020 BP Statistical Review of World Energy, per capita primary energy consumption in G20 countries tends to increase by an average of 0.15 percent. Meanwhile, the largest contributors to CO2 emissions are members of the G20 countries, namely China, the United States and India. The Paris Agreement was carried out with the aim of creating climate-resilient areas and low emissions without threatening food products through increasing adaptive capacity. Apart from that, funding is also provided for the development of the area. The Paris Agreement is the result of the 21st Conference of Parties (COP) climate negotiations. This agreement has been ratified by 195 countries through the COP 21 conference (Kompasiana, 2022).

In 2017, the twelfth G20 Summit took place in Hamburg, Germany, which succeeded in discussing increasing efforts to prevent climate change, one of which was implementing non-renewable energy efficiency. This was one of the nineteen points resulting from the negotiations. The Hamburg action plan was adopted to present the G20 strategy to achieve strong, sustainable, balanced and inclusive growth. The twelfth G20 Summit in Humburg created a sustainable development agenda by 2030 (Ministry of Foreign Affairs, n.d.)

LITERATURE REVIEW

Research on economic growth and environmental damage has been carried out by several previous researchers. So as a reference the author describes several studies on similar matters. Research of Dar & Asif (2018); Phong et al. (2018); Saud et al. (2018) also conducted similar research on the influence of economic growth, energy consumption, financial development on environmental quality with different results. Dar & Asif (2018) conducted research in Turkey regarding financial development to improve environmental quality by applying an endogenous structural-based cointegration approach. The research results state that energy consumption has a significant positive impact on

carbon emissions, although in the post-breakup period the strength of the relationship appears to be decreasing. These results provide suggestions for limiting fossil fuel subsidies and promoting the consumption of renewable and environmentally friendly energy. In addition, financial development has a negative and significant impact on carbon emissions in Turkey. Real income growth (real GDP) has a positive and significant impact on carbon emissions, but the squared coefficient of income is not negative so this research fails to prove the Kuznets curve for Turkey.

Phong et al. (2018) conducted research in Vietnam which examined the impact of energy consumption and globalization on CO2 emissions which combined GDP per capita, industrialization and urbanization in the period 1985 - 2015. The results of this study stated that energy consumption, industrialization and GDP per capita could increase CO2 emissions while globalization reduced emissions CO2 in the long term. Saud et al. (2018) conducted similar research but with research objects in BRI countries using a sample of 59 countries during the period 1980 - 2016. The research results explained that financial development, foreign direct investment, trade openness had a positive and significant effect on environmental quality. Meanwhile, economic growth and energy consumption have a negative and significant effect on environmental quality.

Azies (2019) conducted research using the geographically weighted regression principal components analysis (GWRPCA) approach. There are two research results through PCA and GWRPCA analysis. The analysis results also show that the best modeling of several regression methods is the GWRPCA model because it has a larger R2 value, namely 85.14 percent. Where the GDP variable has an influence of 85.14 percent on environmental quality, the rest is influenced by other variables. The influence of GDP on environmental quality in Indonesia varies due to differences in geography and demographics in each region.

Febriana *et al*. (2020), Budiwan (2020), Alfisyahri *et al*. (2020) Santi & Sasana (2020) and conduct research using the VECM model method, but differ in the variables. Research result of Febriana *et al.* (2020) shows that almost all variables in the short and long term which include economic development in the industrial, agricultural and transportation sectors show a negative influence on environmental quality, but the impact is very small. Meanwhile, Budiwan's research results (2020) shows that energy consumption has a positive and significant influence on CO¬2 emissions with long-term estimation results. Both studies show the results of causality analysis using the Granger method that there is two-way causality between variables. Research result of Alfisyahri et al. (2020) menunjukkan bahwa di negara-negara G20 antara variabel hydropower energy consumption, GDP, dan emisi CO_2 memiliki kausalitas atau hubungan sebab akibat. Hasil penelitian Santi & Sasana (2020) shows that in the G20 countries the variables hydropower energy consumption, GDP and CO2 emissions have causality or a cause and effect relationship. The research results of Santi & Sasana (2020) show that GDP per capita, population, energy consumption have a significant positive effect on the level of Carbon Footprint. Foreign Direct Investment (FDI) and the 2008 economic crisis had a positive but insignificant effect on the carbon footprint level. GDP per capita squared has a negative and significant effect on the carbon footprint level.

Odugbesan & Rjoub (2020) conducted research in MINT countries (Mexico, Indonesia, Nigeria and Turkey) by analyzing the relationship between economic growth, energy consumption, CO2 emissions and urbanization. Long-term empirical results state that in

Mexico there is a two-way long-term and short-term relationship between economic growth, energy consumption, CO2 emissions and urbanization. Meanwhile, in the short term, two-way causality is found between economic growth and CO2 emissions, but unidirectional causality is found between energy consumption and CO2 emissions. There is a two-way causality between urbanization and energy consumption in Indonesia in the long term. Unidirectional causality between economic growth, CO2 emissions and urbanization. Meanwhile, in the short term, unidirectional causality is found between energy consumption and urbanization. In the case of Nigeria, a unidirectional long-run relationship exists between economic growth and energy consumption, CO2 emissions and energy consumption and urbanization and energy consumption. Meanwhile, a unidirectional short-term relationship was found between economic growth and urbanization, energy consumption and urbanization. In the case of Turkey, long-term relationships were found between GDP and energy consumption, GDP and urbanization, and urbanization and energy consumption. Meanwhile, a unidirectional short-term relationship is found between energy consumption and GDP.

METHODS

This research focuses on the formulation of the problem under study, namely analyzing the relationship between population growth, urbanization and energy consumption on carbon dioxide gas emissions in the G20 countries in 1990 - 2020. This research was conducted in countries that are members of the G-20 (Group of Twenty) namely the United States, European Union, China, Japan, Germany, England, France, India, Italy, Canada, South Korea, Russia, Brazil, Australia, Mexico, Indonesia, Turkey, Saudi Arabia, Argentina and South Africa. The dependent variable used in this research is CO2 emissions, while the independent variables used in this research are urbanization, GDP per capita, GDP per capita squared and energy consumption. This research uses a quantitative approach by examining the influence of economic growth, urbanization and energy consumption on carbon dioxide emissions. This research also analyzes the influence of each variable using the STIRPAT Model analysis technique. The STIRPAT model used in this research is as follows:

$\ln(CO2) = b + b1(\ln URB\text{I,t}) + b2\ln(GDP\text{I,t}) + b3\ln(GDP2\text{i,t}) + b4\ln(EU\ \text{i,t}) + e$

Information:
CO2 = CO2 Emissions; URB = Urbanization; GDP = GDP per capita; GDP2 = GDP per capita squared; EU = Primary Energy Consumption per capita; t = year of analysis; i = country; b0,1,2,3,4 = regression coefficient e = error term; ln = natural logarithm

RESULTS AND DISCUSSIONS

The first test carried out was a descriptive test to collect, present and rank various characteristics of the data so that it could show the character of the sample used in the research. Descriptive analysis of the data taken in this research was 620 data, namely from 1990 to 2020 and as many as 20 countries. The results of descriptive statistical tests include the lowest value, highest value, average and standard deviation of the dependent

variable, namely carbon dioxide gas emissions and the independent variables, namely urbanization (URB), population growth (GDP), and energy consumption (EU).

Table 2. Descriptive Statistical Results

	LNCO2	LNURB	LNGDP	LNEU
LNCO2	1.000000	-	-	-
LNURB	0.627604	1.000000	-	-
LNGDP	-0.060527	-0.377218	1.000000	-
LNEU	0.158994	-0.468142	0.836001	1.000000
Mean	6.473303	18.09945	4.143149	7.838827
Median	6.203373	17.89580	4.275916	8.015695
Maximum	9.346724	20.58030	4.783097	9.233846
Minimum	4.819509	16.33580	2.722234	5.422883
Std. Dev.	0.954964	0.972096	0.481977	0.972096
Observations	620	620	620	620

The first testing procedure is the 1st difference test in determining each stationary and non-stationary variable through the unit root test. The informal stationary test can be seen from the data plot, if the graph shows a tendency for the value to increase as time increases, then it is possible that the data is not stationary. In determining the integration of a variable and correcting the order of higher correlations, it is done by adding in terms of lag differences using the Augmented Dickey Fuller (ADF) test which is a test in unit root testing. The initial stage of testing is to look at the stationarity of the data at the level. If in the test there are variables that are not stationary, then the test needs to be carried out at the first difference to second difference level. At the level level there are several variables that are not stationary so it is necessary to look at these variables at the first difference level. The results obtained are that all variables can be stationary at the first difference level under various conditions.

Table 3. Unit Root Test Results

Variabel	Test	Level		First Diffrences	
		Stat	Prob.	Stat	Prob.
LNCO2	LLC	-2.81555*	0.0024	-7.72352*	0.0000
	IPS	1.67200	0.9527	-17.6108*	0.0000
	ADF	43.9013*	0.3097	326.336*	0.0000
	PP	68.8533*	0.0000	564.763*	0.0000
LNGDP	LLC	-5.32475*	0.0000	-9.33785*	0.0000
	IPS	-1.02033*	0.0000	-16.2089*	0.0000
	ADF	45.0922	0.2674	299.795*	0.0000
	PP	65.0560*	0.0074	465.836*	0.0000
LNURB	LLC	-3.22670*	0.0006	-5.15080*	0.0000
	IPS	0.32147	0.6261	-9.53949*	0.0000
	ADF	55.1840	0.0556	178.358*	0.0000
	PP	230.311*	0.0000	261.695*	0.0000
LNEU	LLC	-1.62930	0.0516	-9.27577*	0.0000
	IPS	3.03463	0.9988	-18.4930*	0.0000
	ADF	35.7455	0.6622	346.324*	0.0000
	PP	72.3894*	0.0013	536.134*	0.0000

*Prob. 0.000

Next, the Common Effect Method, Fix Effect Method and Random Effect Method tests were carried out to select the best method to use. The results of the estimation method can be seen in table 4.

Table 4. CEM, FEM, REM Test Results

Variabel	CEM	FEM	REM
C	-2.0067	-12.1875*	-12.5966*
	(1.0743)	(0.0728)	(0.4757)
LNURB	0.8553*	0.6611*	0.6945*
	(0.0183)	(0.0040)	(0.0248)
LNGDP	-7.2805*	0.1535*	0.1251
	(0.4888)	(0.0238)	(0.2118)
$LNGDP^2$	0.7404*	-0.0524*	-0.0538
	(0.0606)	(0.0026)	(0.0260)
LNEU	1.3116*	0.8893*	0.8824*
	(0.0342)	(0.0045)	(0.0248)
Root MSE	0.3850	0.9990	0.0657
R-squared	0.8371	0.9999	0.9291
Adjusted R-squared	0.8361	0.9999	0.9286
F-statistic	790.5317	1340266.	2015.255
Prob(F-statistic)	0.0000	0.0000	0.0000

*Prob 0.0000,

In selecting the best model, the Chow test, Hausman test and Langrange multipier test were carried out (Widarjono, 2007). The results of the Chow test showed that the probability was smaller than α = 0.05. So it can be concluded that H0 is rejected, so the method chosen is the Fixed Effect Method. The results of the Hausman test showed that the probability was smaller than a = 0.05. So it can be concluded that H0 is rejected so that the method chosen is the Fixed Effect Method. So the model used is the fixed effect method. The results of multiple linear regression (fixed effect method) can be seen in table 5.

Table 5. FEM results

Variabel	Koefisien	Std. Error	t-Statistic	Probabilitas
C	-12.1876	0.0728	-167.3098	0.0000
URB	0.6611	0.0040	164.3196	0.0000
GDP	0.1535	0.0238	6.4476	0.0000
GDP^2	-0.0524	0.0027	-19.5785	0.0000
EU	0.8893	0.0046	194.1427	0.0000
R-squared	0.9999			
Adjusted R-squared	0.8361			
F-Stat	790.5371			

There are four variables, each of which has a different influence and magnitude on CO2 emissions. The urbanization variable obtained a probability result of 0.0000, meaning it is smaller than the significance level α 5% (0.05). So H0 is rejected, which

means that the independent variable urbanization has a significant effect on the dependent variable CO2. The urbanization coefficient is 0.6611, meaning that if there is an increase in the value of the urbanization variable by 1 percent, it will also be accompanied by an increase in the value of the CO2 emissions variable of 0.6611. So, urbanization has a positive and significant effect on CO2 emissions.

The probability that GDP is smaller than α 5% (0.05). So H0 is rejected, which means the independent variable economic growth (GDP) has a significant effect on the dependent variable CO2 emissions. The GDP coefficient is 0.1535, if there is an increase in the value of the GDP variable by 1 percent it will also be accompanied by an increase in the value of the CO2 emissions variable which is 0.1535. So, GDP has a positive and significant effect on CO2 emissions. The probability of GDP2 is smaller than α 5% (0.05). So H0 is rejected, which means that economic growth squared (GDP2) has a significant effect on CO2 emissions. The GDP2 coefficient is -0.0524, meaning that if there is an increase in the value of the GDP2 variable by 1 percent it will be accompanied by a decrease in CO2 emissions of 0.0524. So, quadratic economic growth (GDP2) has a negative and significant effect on CO2 emissions.

The probability of EU is smaller than α 5% (0.05). So H0 is rejected, which means that the independent variable energy consumption has a significant effect on the dependent variable CO2 emissions. The EU coefficient is 0.8893, meaning that if there is an increase in the value of the energy consumption variable by 1 percent, it will also result in an increase in the value of the CO2 emissions variable, which is 0.8893. So, energy consumption has a positive and significant effect on CO2 emissions. The R-Squared result was 0.9999 and Adjs. R-Square is 0.9999, so urbanization, economic growth, squared economic growth and energy consumption on CO2 emissions in 1990 - 2020 are 99 percent and the remainder will be explained by variables that are not in this study.

The Effect of Urbanization on CO2 Emissions

The research results showed that urbanization has a positive and significant influence on CO2 emissions. In accordance with Malthus's theory, this is because as the population increases, food production provided by nature/the environment increases and the ability of nature/the environment to provide food becomes increasingly depleted. This causes the quality of nature/environment to decrease. Based on Malthus' theory that every living human needs food, while the rate of food growth is much slower than the population. The population must be accompanied by a balance in environmental threshold limits, so that the carrying capacity and carrying capacity of the environment is not disturbed and does not become a burden on the environment.

At first the population was still small so the environment was still able to provide quite a lot of food. However, as the population increases day by day, food needs become increasingly difficult to obtain, so humans use tools that were not previously used to make it easier to collect more food. This causes the environment to become increasingly depleted in its ability to provide food. This also causes residents to be forced to move to find a better environment to meet their food needs.

The results of this research are in accordance with the G-20 countries, there are countries with an increase in the proportion of urbanization of more than 50 percent, namely Saudi Arabia, India, Indonesia, China, Turkey, which in accordance with these five countries also have a proportion of increase in CO2 emissions of more than 50 percent.

Therefore, it is best to establish population distribution regulations with environmental insight (green growth) by policy makers. Apart from that, sustainable development can be created by increasing the population's human capital and taking advantage of the demographic bonus.

According to Ischak (2001) Urbanization causes the city population to increase more rapidly, which in the end will cause various kinds of negative impacts on the environment, namely reducing open space because the increasing population will cause an increase in buildings, thereby reducing open areas or empty areas. The more open areas are reduced, the greater the area of groundwater absorption will be. Apart from that, it also causes water and air pollution, namely increasing amounts of industrial and household waste being dumped into rivers, sea or land, resulting in higher levels of water and air pollution. These results are in accordance with Kurniarahma et al. (2020), Imansyah Abida (2017), and PS et al., (2017) which states that urbanization has a positive and significant effect on CO2 emissions. The increasing population in a country will be accompanied by an increase in energy to meet people's daily needs. This is due to the energy mix structure which is still very dependent on fossil energy, thus causing greater CO2 emissions.

The results of other studies show that there is no evidence of a relationship between urbanization and CO2 emissions. This means that the urbanization factor cannot fully predict an increase or decrease in CO2 emissions in a country. The results of this study are not in line with Ramadhani (2021) and Zhou & Liu (2016) which states that urbanization has an insignificant effect on CO2 emissions. This is because urbanization is not a determining factor in the influence of CO2 emissions so that urbanization cannot fully predict increases and decreases in CO2 emissions.

The results of this study are also not in line with Phong et al. (2018); Kristiani & Soetjipto (2019); and Adebayo et al. (2020) who conducted research with the results that urbanization had a negative and significant effect. This is due to modernization, namely changes in the energy structure, causing an increase in the use of low-carbon energy. Urbanization has a negative effect on CO2 emissions, supporting the theory put forward by Gouldson & Murphy (1997) namely ecological modernization. In a phase where the increasing stage of development in a country will reduce the environmental impact. This shows that the increasing use of low-carbon energy or technological progress is causing a decrease in CO2 emissions per capita. Apart from that, this can also be caused by the accumulation of human capital so that the urbanization process will encourage people to create behavior that cares about the environment (Zhang & Lin, 2012).

Research of Gasimli & Haq (2019) in Sri Lanka states that in the short term, urbanization has a positive and significant effect on CO2 emissions, whereas after reaching the highest point in the long term, a turning point occurs, where urbanization will have a negative effect on CO2 emissions. This supports the existence of an inverted-U relationship between urbanization and CO2 emissions.

The Effect of Economic Growth on CO2 Emissions

The research results state that economic growth has a positive and significant effect on carbon dioxide gas emissions. These results are in accordance with (Dar & Asif, 2018); (Destek & Sarkodie, 2019); (Santi & Sasana, 2020) which states that economic growth (GDP per capita) has a positive and significant effect on carbon footprint. In addition, according to research of (Destek & Sarkodie, 2019) that increasing economic growth causes

economic and industrial activity to increase in a country, thereby increasing waste output in the form of CO2 emissions, industrial waste plus an increasing need for absorption land to absorb these waste products. In the end, this will result in an increasing decline in environmental quality.

The research results are in line with the Environmental Kuznets Curve (EKC) hypothesis, which states that the higher a country's economic growth, the higher the environmental quality, in this case carbon dioxide emissions, until it reaches a maximum point. In the early stages of development or the pre-industrial economic phase, a new country will begin to develop its economy so that the country's economic growth increases accompanied by an increasing decline in environmental quality. In this phase, there is massive exploitation of natural resources to support the level of production factors so as to produce large output, plus there is still minimal awareness of the public and government in paying attention to environmental quality. Increased economic growth accompanied by increased environmental damage will reach a maximum peak point, this phase is called the industrial economic phase.

Quadratic economic growth has a negative and significant effect on CO2 emissions. These results are in accordance with Santi & Sasana (2020), which states that GDP per capita squared has a significant negative effect on the level of carbon footprint. The results of this research are in line with the Environmental Kuznets Curve (EKC) hypothesis which states that after massive exploitation occurs, it reaches a turning point at a certain level where economic growth is no longer accompanied by environmental damage. In the test using GDP per capita squared, it occurs in the industrial economics and post-industrial economics phases. Where in these two phases, economic growth increases but the level of environmental damage decreases. This is because the public and government are beginning to have a level of awareness of the importance of the environment so that clean and environmentally friendly economic activities are given top priority. As time goes by, a country will reach the post-industrial economic phase. Where economic growth is increasing but the level of environmental damage is decreasing. In this post-industrial phase, there has been a shift in economic structure, where previously the industrial structure became the majority of the economic structure in the service sector. So it shows that the Environmental Kuznets Curve (EKC) hypothesis is proven or fulfilled in the G-20 Countries.

This research is not in line with Susanti (2018); (Dar & Asif, 2018) ; (Shahbaz dan Sinha, 2019) states that GDP per capita has a positive and significant impact on CO2¬¬ emissions. However, when the GDP coefficient is squared, the results obtained do not have a negative effect, so it fails to prove the Kuznets curve hypothesis. Therefore CO2 emissions do not fall at higher GDP levels. So the results do not support the Environmental Kuznets Curve (EKC) hypothesis. This is based on local pollution, namely sulfur oxide, which follows an inverted U curve, but this does not happen with global pollution. Where CO2 emissions are considered a form of global pollution that can increase and decrease and also takes a long time (Paraskevopoulos, 2009).

Research of (Alfisyahri et al., 2020); (Widyawati et al., 2021) which states that there is one-way and two-way causality in the long term and short term that occurs in the G20 countries. In Mexico and the United States, in the short term, economic growth does not have one-way causality or is not significant, but in the long term it has one-way causality. In the short term, it has two-way causality in India and Japan. In addition, research in

ASEAN countries states that economic growth has a negative and significant effect on CO2 emissions. This is due to high economic growth in a country that is part of the ASEAN countries, but still pays attention to environmental quality which is supported by various sustainable development policies so that it can reduce CO2 emissions and ultimately be able to reduce CO2 emissions.

The Effect of Energy Consumption on CO2 Emissions

There is a very close relationship between energy and life, so that energy is an important thing in the survival and daily activities of all humans. This causes the increasing use of energy, especially primary energy, which will increase CO2 emission levels in the environment if it is not supported by energy efficiency policies, the use of environmentally friendly technology and public awareness in saving energy consumption.

This research shows that energy consumption has a positive and significant effect on CO¬2 emissions. The research results support the research of Budiwan (2020) which states that energy consumption has a positive and significant influence on carbon dioxide gas emissions. This means that the increasing use of primary energy consumption per capita will increase CO2 emissions. This result is in line with data obtained from the World Development Indicator and BP Statistics which shows that there are fluctuations in energy use which have increased from 1990 to 2008 and from 2010 to 2018 have increased. This also occurs in carbon dioxide gas emissions which have increased steadily. fluctuated from 1990 to 2008 and from 2010 to 2018. However, primary energy use per capita decreased in 2009 and 2019, this also happened to carbon dioxide gas emissions which decreased in 2009 and 2019.

This research supports deep theory of Sari *et al*. (2021) which explains that one of the factors causing environmental damage is energy from non-renewable resources. Massive use of primary energy, namely energy originating from fossils, will cause damage to the environment. Apart from that, the availability of fossil energy will decrease and even become scarce in the long term because fossil energy is non-renewable energy. Not only that, if you look at the extraction process which destroys forests and soil which ultimately damages the environment by causing CO2 levels, the earth's temperature will increase and the quality of the soil will decrease.

The results of this study are also in accordance with (Santi & Sasana, 2020); (Dar & Asif, 2018) which states that there is a positive and significant relationship with carbon levels. This proves that the higher population in a country will be accompanied by higher energy consumption, which will indirectly have an impact on reducing environmental quality because of the higher gas output from population activities and industrial waste in that country.

The increase in energy use can be caused by the increase in industry, government policies and an increase in population, resulting in increased energy consumption to meet household needs which will cause an increase in CO2 emission levels. So the results of this study are not in line with Kurniarahma et al. (2020) which states that the energy consumption variable does not significantly influence CO¬2 emissions in Indonesia in the long term. This is due to the existence of policies to reduce energy consumption in the long term, as reported by the American Council for an Energy-Efficient Economy (ACEEE) which supports energy efficiency policies for the twenty-three groups of countries with

the highest energy consumption in the world. Apart from that, there is a theory put forward by Gouldson & Murphy (1997) namely the theory of ecological modernization where the increasing stage of development in a country will be accompanied by a decrease in environmental impacts. This is due to the increasing use of low carbon energy and technological progress in a country with a high level of prosperity, thereby reducing CO2 emissions per capita.

The results of this study are not in line with Harahap (2020) which states that energy consumption has a negative and significant relationship to CO2 emissions in Indonesia. This is because the use of technology is environmentally friendly, accompanied by public awareness which is starting to save on energy consumption, such as using electric transportation or bicycles, so that this can reduce CO2 emissions.

CONCLUSION

Economic growth and CO2 emissions, measured through GDP per capita and caudate or long-term GDP per capita, are in line with the EKC hypothesis or support the inverted U-curve, where GDP per capita has a positive and significant influence on CO2 emissions. On the other hand, GDP per capita squared has a negative and significant influence on CO2 emissions. The implication is that at the beginning of a country's development, economic growth will increase, but this will be accompanied by a decline in environmental quality until it reaches a maximum point and a turning point occurs which causes an increasingly high level of environmental improvement. This can happen if there is a government policy in the form of sustainable development that is clean and environmentally friendly. Of course, using environmentally friendly technologies also requires public awareness of the importance of paying attention to environmental quality when carrying out economic activities.

Urbanization and CO2 emissions have a positive and significant influence in accordance with Malthus' theory. The implication is that the population in a country is getting bigger day by day, so food needs are becoming increasingly difficult to obtain, so humans use tools that were not previously used to make it easier to collect more food. However, increasing urbanization can reduce the level of environmental damage, if people use low-carbon energy and implement technological progress such as the use of motorized vehicles powered by electricity, the use of new renewable energy, the use of public transportation, so that CO2 emissions per capita can be reduced. Apart from that, this can also be caused by the accumulation of human capital so that the urbanization process will encourage people to create behavior that cares about the environment.

Energy consumption and CO2 emissions have a positive and significant influence. This is because the higher energy consumption from a large population will cause greater CO2 emissions to be produced. Therefore, appropriate energy efficiency policies are needed, such as energy conservation policies, so that they support sustainable development with clean and environmentally friendly technology.

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