Article Type: Research Paper

Analysis of the Existence of Environmental Kuznets Curve (EKC) Hypothesis on CO2 Emission, Energy Consumption, and Economic Growth in Indonesia

Silvia Tri Rahayuningrum

Abstract: This research explains environmental issues, in the context of Kuznets' theory that links economic growth, energy consumption and CO2 emissions. The focus of the research is to test the Kuznets Environment Curve (EKC) hypothesis in Indonesia in the period 1990-2019 using time series analysis Vector Error Correction Model (VECM). Research findings show that, both in the long and short term, CO2 emissions and energy consumption have a significant impact, while economic growth has no significant impact. These results indicate that the ECC hypothesis is not supported in Indonesia. Emerging policy implications include the transition to clean energy, sustainable farming and forestry management, waste and pollution control, and increased environmental awareness and education. Faced with the complexity of environmental challenges, the implementation of this policy has become crucial toining a balance between environmental sustainability and economic growth.

Keywords: EKC; CO2 Emissions; Energy Consumption; Economic Growth
JEL Classification: O4; O13; Q5

AFFILIATION:
Faculty of Economics and Business, Universitas Gadjah Mada, Special Region of Yogyakarta, Indonesia

***CORRESPONDENCE:**
silviatrirahayuningrum@mail.ugm.ac.id

THIS ARTICLE IS AVAILABLE IN:
http://journal.umy.ac.id/index.php/jerss

DOI: 10.18196/jerss.v8i1.19310

CITATION:
Rahayuningrum, S. T. (2024). Analysis of the Existence of Environmental Kuznets Curve (EKC) Hypothesis on CO2 Emission, Energy Consumption, and Economic Growth in Indonesia. *Journal of Economics Research and Social Sciences*, *8*(1), 38-52.

Introduction

Issues about the environment will be an issue that is always hot to talk about and will be an interesting conversation among various circles. Environmental issues are one of the pillars beside the economic, social and legal & governance pillars in the SDGs, which are global goals adopted by the United Nations in 2015 to ensure that all people around the world can enjoy peace and prosperity without exception by 2030 (UNDP, 2023).

Air pollution, global warming, and climate change are global threats that are always discussed, according to the 2007 Intergovernmental Panel on Climate Change (IPPC) predicting there will be an increase in global temperatures and sea level rise from 1.1o to 6.4 and 16.5 cm to 53.8 cm in 2100 (Iskandar, 2019). Indonesia is the fourth most populous country in the world, with a population of 273.8 million in 2021 (World Bank, 2023). It is also included in the country with the largest economy. It is proven that Indonesia is a member of the G20, and in particular, Indonesia has the opportunity to host the G20 meeting in 2022. However, being a country whose economy continues to grow, this is in line with increasing energy consumption and CO2 emissions.

There are several factors that affect the high level of CO2 emissions, including economic development, population growth, technological change, natural resources, institutional structure, transportation models, lifestyles, and international trade (Robalino-López et al., 2015). Economic growth has a direct impact on a country's CO2 emissions. Much literature states that there is a relationship between economic growth and CO2 emissions through energy use which is influenced by energy efficiency, promotion of renewable energy, and productive sectoral structures (Robalino-López et al., 2015).

Kuznets theory is an economic theory put forward by Simon Kuznets in 1955 (Kuznets, 1955). This theory explains the relationship between economic growth and income inequality. He observes that economic inequality tends to be high in the early stages of industrialization, but after reaching a certain point, it tends to decrease. However, in the 90s, the classic theory of the Kuznets curve was again being debated. This time, the theory states that increased environmental degradation occurs during the early stages of economic growth, but after reaching a certain threshold level in the evolution of economic growth, such degradation begins to decline. The development of this theory became known as the Environmental Kuznets Curve (EKC), which was introduced by Panayotou (Azomahou et al., 2006).

An explanation of the possibility of an inverted U-shaped relationship between economic growth and environmental pollution is based on three effects, namely: scale effects, compositional effects and engineering effects (Grossman & Krueger, 1991). The scale effect shows that economic growth has a negative impact on the environment. With the same assumption, increased production will increase pollution and environmental degradation. The compositional effect explains that there is a positive effect on the environment. During economic development, the economic structure changes as in the previous stage pollution will increase in line with changes in the economic structure of a country, this usually occurs in countries with an agricultural sector basis towards a more resource-intensive heavy manufacturing industry sector and at later stages of development, pollution will decrease along with a shift in structure towards light manufacturing service industries. The last effect is the effect of technology, showing that old technology will be replaced by new, more modern technology that will result in an increase in environmental quality and reduced pollution (Azwar, 2019).

The research question in this paper is to test whether the Environment Kuznet Curve hypothesis actually occurs in Indonesia or not. This research is structured as follows: Section 2 provides an overview of Indonesia, section 3 presents an overview of the literature, section 4 introduces data specifications and models, and methodologies, section 5 discusses the empirical results, and finally, section 6 provides conclusions and policy implications.

Indonesian context

Indonesia is a country that is in the top 20 GDP category; like other countries around the world, Indonesia was also affected by the crisis caused by the covid 19 pandemic, where economic growth in 2020 reached -2.1%, but Indonesia is trying to revive again in 2021

with economic growth of 3.7%, and in 2022 it will increase to 5.3%. Energy consumption in Indonesia tends to increase along with economic growth and population growth.

Primary energy production in Indonesia shows that the largest energy source comes from coal, with total production in 2019 of 15,527,106 terajoules, in 2020 of 14,248,071 terajoules and in 2021 of 15,372,660 terajoules. The next largest sources of energy are natural gas (2,453,147 terajoules) and crude oil and condensate (1,611,136 terajoules) in 2021. Energy consumption in 2021 will reach 4,768,794 terajoules which have decreased by 2.97% compared to 2020, while the highest percentage of energy consumption is in the Industry, Construction and Mining Non-Oil sector with a percentage of 46.0 1% in 2019, 43.92% in 2020 and 42.08% in 2021 (Badan Pusat Statistik, 2021).

On the other hand, behind Indonesia's large GDP, the emissions produced by Indonesia are no less large. Indonesia is the fifth largest emitting country after the United States, China, Russia and Brazil in 2021, namely 102.562 Gt CO2. (Badan Pusat Statistik, 2021). Indonesia's carbon emissions are currently one of the largest in Southeast Asia and a source of serious environmental problems. Therefore, countries in the world, including Indonesia, are developing renewable energy. Renewable energy development is especially important after the 2015 SDGs to reduce carbon emissions, implement a green economy and reduce poverty which will lead to sustainable development (Nurlaila & Yuianto, 2019).

Indonesia is a developing country with rapid economic growth. Therefore, it is important to conduct EKC research in Indonesia to be able to provide information about the relationship between economic growth and environmental degradation in developing countries. Indonesia also has abundant natural resources but is also experiencing serious environmental problems such as air and water pollution, deforestation and climate change. Therefore, EKC research in Indonesia can provide information about the impact of economic activities on the environment.

EKC's research in Indonesia can provide information about the effectiveness of environmental policies that have been implemented in Indonesia, as well as provide better policy recommendations to reduce the negative impact of economic growth on the environment.

Literature review

The following literature review is relevant to our study, specifically delving into the correlations among economic growth, energy use, and greenhouse gas emissions. We will examine previous studies in order to gain a deeper knowledge of how these aspects are interconnected and the implications this has for our comprehension of the subject.

Table 1 Collection of Past Research

Author	Country	Period	Methodology	Outcomes
(Xie & Jamaani, 2022)	G-7 economies: Kanada, Prancis, Jerman, Italia, Jepang, AS, Inggris	1990 to 2020	Panel Causality	REC,GI, ERT-> -CO2 GDP -> +CO2
(Anser et al., 2021)	South Asian countries such as Bangladesh, India, Maldives, Pakistan, and Sri Lanka	1985 to 2019	Causal Association EKC Analysis	GDP,NREN,GLOB -> CO2
(Saboori & Sulaiman, 2013b)	Malaysia	1980–2009	Granger Causality EKC Analysis	-Not support EKC -Bi-directional causality GPD, CO2, EN
(Zhang et al., 2022)	Sri langka, Nepal, Pakistan, Bhutan, Bangladesh (South Asia)	1998 to 2018	EKC Analysis	EC,TI -> + CO2 EC,TI -> harms biodiversity
(Muhammad et al., 2022)	23 OECD countries	1990 to 2015.	Causal Relationship	Unidirectional causality GDP-REC Bi-directional causality II-REC
(Hamit-Haggar, 2012)	Canada	1990 to 2007	Causal Relationship	Existance EKC ENC-> +GHG GHG-/ GDP
(Saboori & Sulaiman, 2013a)	5 ASEAN Countries	1971 to 2009.	Cointegration and Granger causality	Bi-directional causality EC-CO2
(SONG et al., 2008)	China	1985–2005	cointegrating relationship, EKC Analysis	cointegrating relationship between the per capita emission of 3 pollutants and the per capita GDP
(Robalino-López et al., 2015)	Venezuela	1980-2025	EKC Analysis	not fulfill EKC hypothesis
(Sugiawan & Managi, 2016)	Indonesia	1971–2010	EKC Analysis	existence of EKC
(Shahbaz et al., 2016)	Banglades, Indonesia, Pakistan, Turki, Mesir, Meksiko, Filipina, Vietnam, Iran, Nigeria, Korea utara	1972–2013	Granger causality, EKC Analysis	existence of EKC hypothesis
(Robalino-López et al., 2014)	Ecuador	1980–2025	System dynamics modeling and EKC analysis	Not support the fulfilment of the EKC
(Shahbaz et al., 2020)	Swedia	1850–2008	cointegration and EKC Analysis	nonlinear cointegration between economic growth and CO2 emissions
(Sephton & Mann, 2013)	Spain	1857 to 2007	cointegration relation and EKC Analysis	long-run non-linear per capita income and CO2 levels
(Khan et al., 2022)	South Asian countries such as Bangladesh, India, Nepal, Pakistan, and Sri Lanka	1972 to 2017	causal relationship	causality between GDP growth and carbon emission and bidirectional causality between economic growth and energy use.
(Feng et al., 2013)	Beijing	2005-2030	system dynamics model	predicted reach in Beijing

In the literature review, this research is divided into three main areas of study: first, studies of causal relationships or cointegration between GDP, energy consumption and gas emissions, second, studies related to various aspects of the EKC hypothesis, and third, system dynamic models that describe how changes in one aspect will affect other aspects in the long run (Robalino-López et al., 2015).

Related to the first field of study, namely causality and cointegration (Xie & Jamaani, 2022), states that renewable energy, green innovation, and environmental taxes significantly reduce carbon emissions, while GDP causes an increase in CO2 emotions in G-7 countries. The relationship between consumption of renewable energy (REC) has a positive relationship with economic growth, real oil prices, income inequality and trade openness. This was studied by Muhammad et al. (2022), but on the other hand, he also found that there was a negative relationship between CO2 emissions in OECD countries. In addition, there is a one-way causality from GDP per capita to renewable energy consumption and a two-way causality between income inequality and renewable energy consumption. The same thing happened in Canada (Hamit-Haggar, 2012), showing that in the long-run equilibrium, energy consumption has a positive and statistically significant impact on greenhouse gas emissions while a non-linear relationship is found between greenhouse gas emissions and economic growth, consistent with the environmental Kuznets curve in the period 1990 to 2007. This significantly increases environmental degradation in the South Asian region. The empirical results show that the use of fossil fuels and energy substantially increases CO2 emissions and causes GHG problems in this region. A study conducted by (Saboori & Sulaiman, 2013a) using the ARDL methodology and the Granger causality test found results that there is a cointegration relationship between variables (economic growth, CO2 emissions and energy consumption) in 5 countries in ASEAN with a statistically significant positive relationship between carbon emissions and energy consumption both in the short and long term. This implies that the level of carbon emissions is found to increase with respect to energy consumption over time in the 5 countries in ASEAN.

Studies on EKC analysis or hypotheses include: (Saboori & Sulaiman, 2013b) shows that it does not support EKC when aggregate energy consumption is used, but when energy consumption is disaggregated based on energy sources such as oil, coal, gas and electricity. This study shows the existence of the EKC hypothesis. Long-term Granger causal tests show that there is a two-way relationship between economic growth and CO2 emissions, with the consumption of new coal, gas, electricity and oil; this means that reducing energy consumption appears to be an effective way to control CO2 emissions but at the same time inhibits economic growth. The South Asian region (Anser et al., 2021)confirmed the EKC hypothesis in this region. Studies in the same area, namely South Asia by Zhang (2022), also show that technological innovation has a significant role in driving economic growth as well as environmental pollution in the form of CO2 emissions and water pollution. Meanwhile, China (Song et al., 2008) showed that the three pollutants, namely gas, water and solid waste, had an inverted U shape or confirmed the EKC hypothesis. Other studies that confirm the existence of the EKC hypothesis are (Sugiawan & Managi, 2016) for Indonesia, (Sephton & Mann, 2013) for Spain and (Shahbaz et al., 2020) for Sweden. In contrast to previous studies (Robalino-López et al., 2015),

which stated that the EKC hypothesis was not fulfilled in Venezuela. The study from (Shahbaz et al., 2016) takes data from 11 countries which are considered by the author to be the most industrialized countries and have the potential for high GDP output and shows that there is an EKC hypothesis.

The third study in this previous study (Robalino-López et al., 2014) of the system dynamics model until 2025 shows that it does not meet the EKC hypothesis, but it is estimated, but it is predicted that Ecuador can achieve environmental stabilization in the near future if economic growth is combined with increased use of renewable energy, increased production of sectoral structures, and the use of more efficient fossil fuel technologies. Meanwhile, the system dynamic model for urban communities in Beijing, China, until 2030 by Feng et al. (2013) predicts that the service sector will gradually replace the industry's dominant status in energy consumption as the largest energy-consuming sector, followed by the industrial and transportation sectors.

EKC research in Indonesia remains important despite the literature gap that has existed, this is because first of all, as one of the countries with the largest population and economies, this research will provide significant insights into the relationship between economic growth and environmental degradation in the context of developing countries. Implicitly, this research will help formulate the necessary steps to sustainable economic growth in Indonesia. Second, although there has been some previous research, this research needs to be continued with the latest data and methods of analysis different from existing research. According to previous research recommendations from Sugiawan & Managi (2016) which stated that research related to CO2 EKC analysis in Indonesia is very few therefore this research is expected to enrich studies in this field. By testing the validity of the EKC hypothesis in Indonesia, this research can make an important contribution in strengthening empirical evidence of the existence of EKC in this country and reveal a more clear pattern of relationship between economic growth, CO2 emissions, and energy consumption in Indonesia. Lastly, this research has high policy relevance. A better understanding of the relationship between economic growth and environmental degradation will enable more effective policymaking in reducing the negative environmental impacts of economic activities in Indonesia. The results of this research can serve as a guideline for governments, companies and communities in designing sustainable development strategies and protecting the environment.

Research Method

Data Sources

In our empirical analysis, we used annual time series data from 1990 to 2019 to determine the EKC by using the variables Gross Domestic Product (GDP), CO2 emissions, and energy consumption. Data were taken from Word Bank. The selection of the timeframe from 1990 to 2019 has several basic reasons. First, the long time span provides a comprehensive picture of the relationship between economic growth, CO2 emissions, and energy consumption in Indonesia. By looking at data over 30 years, we can identify long-

term trends and patterns of relationships between these variables. The next reason, 1990 is an important starting point because, at that time, global awareness of environmental issues and climate change began to increase. Therefore, including the year 1990 in the analysis allows us to see the impact of policy measures and socio-economic changes that have taken place since then ("The History of Climate Change," 2009). Finally, the use of the latest data up to 2019 provides relevant and up-to-date information about economic and environmental conditions in Indonesia.

CO2 emission is the dependent variable, as in previous studies (Al-Mulali et al., 2015; Lau et al., 2014; Osabuohien et al., 2014). besides that, CO2 emission can be used as an indicator to measure the level of energy consumption in a country. Energy consumption is an important factor in the relationship between economic growth and environmental degradation. And GDP and energy consumption are independent variables.

Methodology

This study uses the VECM model because VECM can be used in time series data analysis in EKC (Environmental et al.) research because this model can estimate short-term and long-term effects between variables on time series data. VECM also has the ability to address non-stationary variables or variables that have different levels of integration. One of the advantages of VECM is the existence of error correction (error correction). VECM takes into account short-term errors that will be balanced in the long term (Saboori & Sulaiman, 2013b). In the VECM analysis, several steps were carried out, including determining the optimal lag, cointegration test, causality analysis (Johansen test), Vector Error Correction Model modelling, impulse response function (IRF), and forecasting error variance decomposition (FEVD) (Nugroho et al., 2016). The following are the models in this study:

$$E_t=\beta_0+\beta_1 Y_t+\beta_2 EN_t+\varepsilon_t$$

The equation above, as an integral part of the Environmental Kuznets Curve (EKC), provides a mathematical representation of the dynamics in the relationship between economic growth, energy consumption, and CO2 emissions in Indonesia. In this equation, β0 (Constant) signifies a fixed value representing the baseline of CO2 emissions when the growth rate of Gross Domestic Product (GDP) and energy consumption remains constant. β1 (Estimated Coefficient Yt) measures the change in CO2 emissions due to a one-unit change in the GDP growth rate, expressed in annual percentage terms, providing insights into the contribution of economic growth to changes in CO2 emissions. Meanwhile, β2 (Estimated Coefficient ENt) reflects the percentage impact of total final energy consumption on CO2 emissions, offering an understanding of the extent to which energy consumption influences CO2 emissions. The dependent variable, CO2 emissions (Emisi CO2t), indicates the emission of CO2 at a specific time (t) measured in megatons. The independent variables, Yt representing the GDP growth rate and ENt representing the percentage of energy consumption, together with the error term εt, which accounts for unmeasured factors and random influences, collectively form a comprehensive model.

Result and Discussion

Basic Statistical Test

Table 2 presents descriptive statistics for all the dependent and independent variables in this study. In this table, we can see the mean, median, maximum, minimum, and standard deviation values of each variable. This information is used to get an initial picture of the characteristics and variations of the data before estimating using the Vector Error Correction (VECM) Model.

Table 2 Descriptive Statistical Test

Variable	Obs	Mean	Std. Dev	Min	Max
GDP	30	4.93841	3.684798	-13.1267	8.220007
EMISICO2	30	1.503209	0.3883602	0.8153826	2.299256
ENERGYCONS-N	30	40.48594	11.04382	19.09	58.59753

Correlation Test

Table 3 illustrates the simple correlation values between the independent variable and the dependent variable. In this table it can be seen that all independent variables have a negative correlation with the dependent variable. However, these results cannot be considered valid so further analysis is needed using the Vector Error Correction Model (VECM) to gain a more comprehensive understanding as done by (Sufyanullah et al., 2022; Wang et al., 2022).

Table 3 Correlation Test

	EMISICO2	GDP	ENERGY CONSUMPTION
EMISICO2	1.0000		
GDP	-0.0154	1.0000	
ENERGY CONSUMPTION	-0.9896	-0.0052	1.0000

Unit Root test

Table 4 shows that this research integrates various unit root tests that have been developed previously (Dickey & Fuller, 1981; Pesaran et al., 2001). To fulfill the prerequisites for time series econometric analysis, the unit root test is a crucial first step before estimating the Vector Error Correction Model (VECM) (Ozturk & Acaravci, 2013). In this stage of testing data stationarity, researchers can choose between the Dickey-Fuller (DF) or Augmented Dickey-Fuller (ADF) methods. The results show that of the three variables studied, the GDP variable is stationary at the level level, while CO2 emissions and energy consumption are stationary at the first difference level.

Tabel 1 Uji Dickey Fuller

Variabel	Level		P-Value	First Difference		P-Value
	Test Stat	Critical Value		Test Stat	Critical Value	
GDP	-3.859	-2.989	0.0024	-	-	-
EMISI CO2	0.013	-2.989	0.9596	-5.144	-2.989	0.0000
ENERGY CONS	0.339	-2.989	0.9790	-5.067	-2.989	0.0000

Optimal Lag Test

In this study, the optimal lag was determined using several information criteria, such as the Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hannan Quinnon Criterion (HQ). The test results show that the optimal lag is located at lag 1, which can be seen from the highest number of asterisks (Basuki, 2018).

Table 5 Optimal Lag Test

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-128.259				4.87111	10.0968	10.1386	10.242
1	-74.328	107.86	9	0.000	0.154799*	6.64061*	6.80782*	7.22127*
2	-70.8537	6.9486	9	0.642	.244841	7.06567	7.35828	8.08182
3	-68.2445	5.2184	9	0.815	.435498	7.55727	7.97529	9.00892
4	-56.037	24.415*	9	0.004	.403629	7.31054	7.85396	9.19768

Cointegration Test

The next test is the cointegration test; in cointegration testing, the method used here is the Johansen Test. The purpose of cointegration testing is to identify whether there is a long-term relationship between the variables studied using a predetermined optimal lag (Johansen & Juselius, 1990). Cointegration test results can be identified by comparing the trace statistics and critical value (5%). If the trace statistic value is greater than the critical value, this indicates cointegration in the observed equation. Based on the results of Johansen's cointegration test explains that the value of the trace statistic at this rank is greater than the critical value, so it can be concluded that there is cointegration between variables.

Table 6 Test Johansen Test

Maximum Rank	Eigenvalue	Trace statistic	Critical Value
0	.	41.8349	29.68
1	0.47928	23.5636	15.41
2	0.40481	9.0353	3.76
3	0.27580		

VECM test

Table 7 VECM test

	Coefficient	Std err	z	P>|z|	[95% conf	Interval]
D_demisico2						
_ce1 L1	-2.09957	0.52384	-4.01	0	-3.12628	-1.07287
demisico2 LD	0.772533	0.319103	2.42	0.015	0.147103	1.397963
GDP LD	-0.00628	0.004026	-1.56	0.119	-0.01417	0.001612
Denergyconsumtion LD	296094	0.011438	2.59	0.01	0.007192	0.052027
D_GDP						
_ce1 L1	-0.58293	29.72969	-0.02	0.984	-58.8521	57.6862
demisico2 LD	-11.2218	18.11018	-0.62	0.535	-46.7171	24.27348
GDP LD	-0.30577	0.228497	-1.34	0.181	-0.75362	0.142074
denergyconsumtion LD	-0.58881	0.649136	-0.91	0.364	-1.86109	0.683478
D_denergyconsumtion						
_ce1 L1	23.82848	12.13612	1.96	0.05	0.042113	47.61484
demisico2 LD	-17.7159	7.392856	-2.4	0.017	-32.2057	-3.22619
GDP LD	0.214677	0.093276	2.3	0.021	0.031859	0.397495
denergyconsumtion LD	-0.79748	0.264988	-3.01	0.003	-1.31685	-0.27812

The decision to use a Vector Error Correction Model (VECM) or Vector Auto regressive) VAR depends on the cointegration test results. Through the Johansen cointegration test and information criteria, it is known that there is cointegration between variables (Johansen & Juselius, 1990). This result is then clarified by the value of the cointegration equation through p>chi2, which is less than 5%. Explains that the results of the Johansen cointegration test and the information criteria stating that there is cointegration in the model are appropriate, so use VECM. The variables included in the discussion of the VECM results are variables that have a significant influence on the VECM equation. Checking this

significance is important to ensure whether each variable contributes to the VECM results as done by (Saboori & Sulaiman, 2013a, 2013b; Sufyanullah et al., 2022; Wang et al., 2022). A significant variable is known from a p>chi2 value of less than 5%. Based on the results in the table, in the long run, there are insignificant variables, namely GDP of more than 5%. The VECM estimation results can be seen that the value of p>|z| smaller than the level of the hypothesis used is 5%. but in the GDP variable p>|z| or 0.984 greater than 5%. Meanwhile, energy consumption has a significant relationship in the long run because the p>z value is less than 5%. In the short term, it shows the same results, namely, GDP is not significant or has no effect, while energy consumption looks significant; this indicates that there is a short-term relationship.

TEST IRF Impulse Response Function

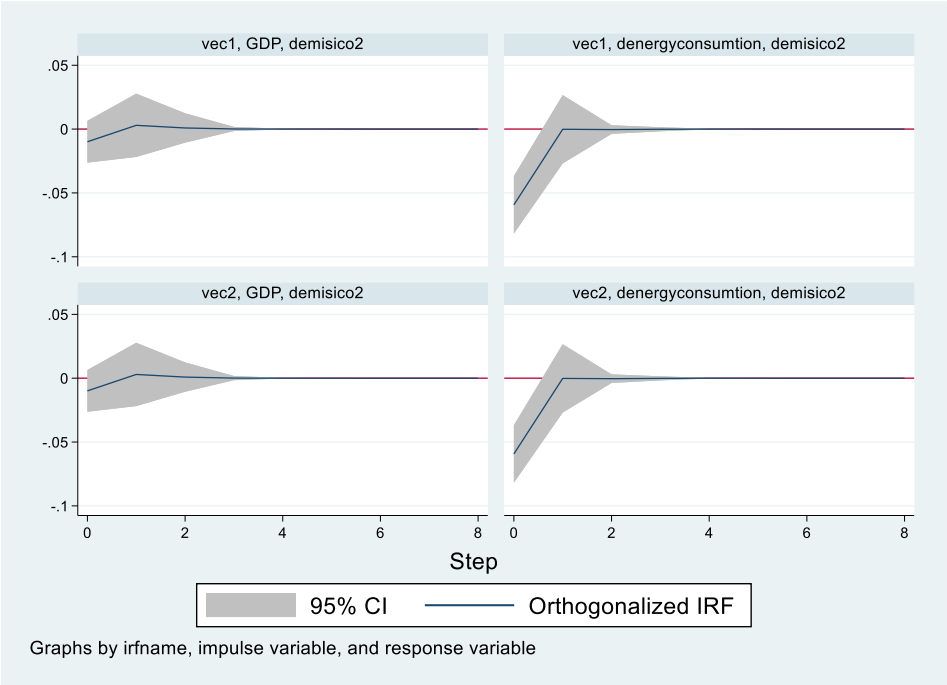

Figure 1 IRF Test

Impulse Response Function provides an overview of how the response of a variable in the future if there is a disturbance in one other variable (Anser et al., 2021). To facilitate interpretation, the results of the analysis are presented in graphical form in the Figure 1. If the impulse response graph shows a movement that is getting closer to the balance point or returning to the previous balance, it means that the response of a variable due to a shock is increasingly disappearing so that the shock does not leave a permanent effect on the variable.

Based on the IRF results in the left figure shows that the change in the GDP variable is in response to a shock/change in the co2 emission variable. At the beginning of the period, the GPD responds negatively in periods 0-1 to changes in shock but in periods 1-3; it

begins to adjust to the next balance point. From periods 3-8, it shows a linear line, meaning it does not respond to changes in CO2 emissions because the trend is flat with the balance line.

The figure on the right shows the change in the energy consumption variable in response to a shock/change in the CO2 emission variable. It can be seen that energy consumption responds negatively to changes/shocks that occur in CO2 emissions in periods 0-1; in periods 1-3, the trend seems to adjust to the balance line and in periods 3-8, it shows that energy consumption does not respond to changes in CO2 emissions because the trends are parallel to the equilibrium line.

Forecasting Error Variance Decomposition (FEVD) Test

Table 8 FEVD test

Step	FEVD (1)	FEVD (2)
0	0	0
1	0.017625	0.630245
2	0.019155	0.629232
3	0.019289	0.629116
4	0.1929	0.629116
5	0.1929	0.629116
6	0.1929	0.629116
7	0.1929	0.629116
8	0.1929	0.629116

This analysis (FEVD) is used to predict how much the variance contribution of each variable affects other variables at this time and in future periods (Basuki, 2018). The Table 8 shows that the estimated forecasting variance decomposition (FEVD) in GDP responds to a contribution of 0.017% CO2 emissions in the first period while in the eighth period, as much as 0.019%; this means that GDP only makes a small contribution. Energy consumption in the first period contributed as much as 0.63%, and in the eighth period, it became as much as 0.62%, indicating that energy consumption contributed quite a lot.

Conclusion

Based on the results of the time series analysis for the period 1990-2019, it can be concluded that the Environmental Kuznets Curve (EKC) phenomenon cannot be found in Indonesia. In this study, the Vector Error Correction Model (VECM) bound test approach was chosen because it is more appropriate to examine long-term and short-term relationships. The results of the analysis show that in the long and short term, CO2 emissions and energy consumption have a significant effect, while economic growth has no significant effect. Therefore, based on these findings, it can be concluded that this study was unable to provide evidence supporting the EKC hypothesis in Indonesia.

In the face of complex environmental challenges, it is important to implement effective policies. Some policy implications that can be carried out are making the switch to clean energy, managing agriculture and forestry in a sustainable manner, controlling waste and pollution, preserving the environment and maintaining the conservation of natural resources, as well as increasing environmental education and awareness. The aim of these policies is to reduce the negative impacts on climate change, biodiversity and environmental quality. By implementing policies in a comprehensive manner, sustainable development will be realized by maintaining a balance between economic growth, environmental protection, and people's welfare.

References

Al-Mulali, U., Saboori, B., & Ozturk, I. (2015). Investigating the environmental Kuznets curve hypothesis in Vietnam. *Energy Policy, 76*, 123–131. https://doi.org/10.1016/j.enpol.2014.11.019

Anser, M. K., Usman, M., Godil, D. I., Shabbir, M. S., Sharif, A., Tabash, M. I., & Lopez, L. B. (2021). Does globalization affect the green economy and environment? The relationship between energy consumption, carbon dioxide emissions, and economic growth. *Environmental Science and Pollution Research, 28*(37), 51105–51118. https://doi.org/10.1007/s11356-021-14243-4

Azomahou, T., Laisney, F., & Nguyen Van, P. (2006). Economic development and CO2 emissions: A nonparametric panel approach. *Journal of Public Economics, 90*(6–7), 1347–1363. https://doi.org/10.1016/j.jpubeco.2005.09.005

Basuki, A. T. (2018). *Aplikasi Model VAR dan VECM dalam Ekonomi*. Fakultas Ekonomi Universitas Muhammadiyah Yogyakarta.

BPS-Statistics Indonesia. (2021). Energy Balances of Indonesia 2017-2021. https://www.bps.go.id/en/publication/2023/02/07/3e4c4125bdafee25433e3da0/neraca-energi-indonesia-2017-2021.html

Dickey, D. A., & Fuller, W. A. (1981). Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. Econometrica, 49(4), 1057. https://doi.org/10.2307/1912517

Feng, Y. Y., Chen, S. Q., & Zhang, L. X. (2013). System dynamics modeling for urban energy consumption and CO2 emissions: A case study of Beijing, China. *Ecological Modelling, 252*, 44–52. https://doi.org/10.1016/j.ecolmodel.2012.09.008

Grossman, G., & Krueger, A. (1991). *Environmental Impacts of a North American Free Trade Agreement*. National Bureau of Economic Research. https://doi.org/10.3386/w3914

Hamit-Haggar, M. (2012). Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. *Energy Economics, 34*(1), 358–364. https://doi.org/10.1016/j.eneco.2011.06.005

Iskandar, A. (2019). Economic Growth and CO2 Emissions in Indonesia: Investigating The Environmental Kuznets Curve Hypothesis Existence. *Jurnal BPPK: Badan Pendidikan Dan Pelatihan Keuangan, 12*(1), 42–52. https://doi.org/10.48108/jurnalbppk.v12i1.369

Johansen, S., & Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration - With Applications to The Demand for Money. *Oxford Bulletin of Economics and Statistics, 52*(2), 169–210. https://doi.org/10.1111/j.1468-0084.1990.mp52002003.x

Khan, M. B., Saleem, H., Shabbir, M. S., & Huobao, X. (2022). The effects of globalization, energy consumption and economic growth on carbon dioxide emissions in South

Asian countries. *Energy and Environment, 33*(1), 107–134. https://doi.org/10.1177/0958305X20986896

Kuznets, S. (1955). Economic Growth and Income Inequality. *American Economic Association, 65*(1), 386–408.

Lau, L. S., Choong, C. K., & Eng, Y. K. (2014). Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: DO foreign direct investment and trade matter? *Energy Policy, 68*, 490–497. https://doi.org/10.1016/j.enpol.2014.01.002

Muhammad, I., Ozcan, R., Jain, V., Sharma, P., & Shabbir, M. S. (2022). Does environmental sustainability affect the renewable energy consumption? Nexus among trade openness, CO2 emissions, income inequality, renewable energy, and economic growth in OECD countries. *Environmental Science and Pollution Research, 29*(60), 90147–90157. https://doi.org/10.1007/s11356-022-22011-1

Nugroho, S. W., Nugroho, S., & Rizal, J. (2016). Analisis Indeks Harga Saham Gabungan dengan Pendekatan Vector Error Correction Model (VECM). Universitas Bengkulu.

Nurlaila, & Yuianto, A. T. (2019). Perkembangan Energi Terbarukan di Beberapa Negara. *Prosiding Seminar Nasional Infrastruktur Energi Nuklir, 11–21*.

Osabuohien, E. S., Efobi, U. R., & Gitau, C. M. W. (2014). Beyond the Environmental Kuznets Curve in Africa: Evidence from Panel Cointegration. *Journal of Environmental Policy and Planning, 16*(4), 517–538. https://doi.org/10.1080/1523908X.2013.867802

Ozturk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics, 36*, 262–267. https://doi.org/10.1016/j.eneco.2012.08.025

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289–326. https://doi.org/10.1002/jae.616

Robalino-López, A., García-Ramos, J. E., Golpe, A. A., & Mena-Nieto, Á. (2014). System dynamics modelling and the environmental Kuznets curve in Ecuador (1980-2025). *Energy Policy, 67*, 923–931. https://doi.org/10.1016/j.enpol.2013.12.003

Robalino-López, A., Mena-Nieto, Á., García-Ramos, J. E., & Golpe, A. A. (2015). Studying the relationship between economic growth, CO2 emissions, and the environmental Kuznets curve in Venezuela (1980-2025). *Renewable and Sustainable Energy Reviews, 41*, 602–614. https://doi.org/10.1016/j.rser.2014.08.081

Saboori, B., & Sulaiman, J. (2013a). CO2 emissions, energy consumption and economic growth in association of Southeast Asian Nations (ASEAN) countries: Acointegration approach. *Energy, 55*, 813–822. https://doi.org/10.1016/j.energy.2013.04.038

Saboori, B., & Sulaiman, J. (2013b). Environmental degradation, economic growth and energy consumption: Evidence of the environmental Kuznets curve in Malaysia. *Energy Policy, 60*, 892–905. https://doi.org/10.1016/j.enpol.2013.05.099

Sephton, P., & Mann, J. (2013). Further evidence of an Environmental Kuznets Curve in Spain. *Energy Economics, 36*, 177–181. https://doi.org/10.1016/j.eneco.2013.01.001

Shahbaz, M., Khraief, N., & Mahalik, M. K. (2020). Investigating the environmental Kuznets's curve for Sweden: evidence from multivariate adaptive regression splines (MARS). *Empirical Economics, 59*(4), 1883–1902. https://doi.org/10.1007/s00181-019-01698-1

Shahbaz, M., Mahalik, M. K., Shah, S. H., & Sato, J. R. (2016). Time-varying analysis of CO2 emissions, energy consumption, and economic growth nexus: Statistical experience in next 11 countries. *Energy Policy, 98*, 33–48. https://doi.org/10.1016/j.enpol.2016.08.011

Song, T., Zheng, T., & Tong, L. (2008). An empirical test of the environmental Kuznets curve in China: A panel cointegration approach. *China Economic Review, 19*(3), 381–392. https://doi.org/10.1016/j.chieco.2007.10.001

Sufyanullah, K., Ahmad, K. A., & Sufyan Ali, M. A. (2022). Does emission of carbon dioxide is impacted by urbanization? An empirical study of urbanization, energy consumption, economic growth and carbon emissions - Using ARDL bound testing approach. *Energy Policy, 164*, 112908. https://doi.org/10.1016/j.enpol.2022.112908

Sugiawan, Y., & Managi, S. (2016). The environmental Kuznets curve in Indonesia: Exploring the potential of renewable energy. *Energy Policy, 98*, 187–198. https://doi.org/10.1016/j.enpol.2016.08.029

Wang, X., Zhang, T., Nathwani, J., Yang, F., & Shao, Q. (2022). Environmental regulation, technology innovation, and low carbon development: Revisiting the EKC Hypothesis, Porter Hypothesis, and Jevons' Paradox in China's iron & steel industry. *Technological Forecasting and Social Change, 176*, 121471. https://doi.org/10.1016/j.techfore.2022.121471

Xie, P., & Jamaani, F. (2022). Does green innovation, energy productivity and environmental taxes limit carbon emissions in developed economies: Implications for sustainable development. *Structural Change and Economic Dynamics, 63*, 66–78. https://doi.org/10.1016/j.strueco.2022.09.002

Zhang, Z., Bashir, T., Song, J., Aziz, S., Yahya, G., Bashir, S., & Zamir, A. (2022). The effects of Environmental Kuznets Curve toward environmental pollution, energy consumption on sustainable economic growth through moderate role of technological innovation. *Environmental Science and Pollution Research, 29*(1), 405–416. https://doi.org/10.1007/s11356-021-16956-y