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Anthropogenic Factors and Environmental Degradation in Indonesia (Empirical studies using the STIRPAT Model)

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Abstract. The decrease in the quality of the environment is one of the key problems currently facing human society, especially if the decrease in environmental capacity to serve human needs is considered to be a factor in the emergence of global warming phonemes. In addition, all human actions are deemed responsible for the decline in environmental degradation. The aim of the paper is to see how, as formulated by the classical STIRPAT model, human activity in Indonesia are considered to be driving factors for the deterioration of environmental quality, particularly population, economic, and technology. The authors used the Extended STIRPAT in this research. CO_2 emissions model explained by several driving factors as a dependent variable In contrast, the additional variables (extended) are foreign direct investment and institutional quality. The data used are the annual time series in Indonesia from 1971 to 2018. This research was investigated using the method of ARDL (Autoregressive Distribution Lag). In the short term, several variables, such as CO_2 emission, Affluence, Technology and Institutional Quality, have a positive effect on decreasing environmental quality. In the only variables that have a positive long-term effect is energy structure, are based on the results of the long-term ARDL estimation method in Indonesia.

Keywords. Institutional Quality, carbon dioxide emission, Extended STIRPAT, Autoregressive Distribution Lag

1. Introduction

One of the most popular approaches to the interaction of economic activity with environmental degradation is the use of the Environmental Kuznets Curves (1) as an analytical tool used to interpret the economy and the decline in environmental quality. Environmental Kuznets Curves is an analytical tool used to test the assumptions presented by (2) that Gross Domestic Product (GDP) is very beneficial for improving its quality. At the current time, Gross Domestic Product (GDP) is a fundamental yardstick for evaluating economic performance, while Gross Domestic Product (GDP) per capita uses as a measure of people's welfare. Although this measure is not a definite measure, it would provide information on economic performance and how production/income generates, and how expenditure can be allocated.

One of the most popular approaches to the interaction of economic activity with environmental degradation is the Environmental Kuznets Curve (EKC) an analytical tool used to interpret the economy and the decline in environmental quality. Environmental Kuznets Curves is an analytical tool used to test the assumptions presented by (2) that Gross Domestic

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Product (GDP) is very beneficial for improving its quality. At the current time, Gross Domestic Product (GDP) is a fundamental yardstick for evaluating economic performance, while GDP per capita uses as a measure of people's welfare. Although this measure is not a definite measure, it would provide information on economic performance And how production/income is generated, and how expenditure can be allocated Using Gross Domestic Product (GDP) as a tool for measuring economic performance and monitoring a region or country's performance has made countries try their best to continuously boost the annual rate of Gross Domestic Product (GDP) (economic growth). The advancement of economic growth, making nature bears the burden of continuous exploitation of natural resources, meets the predetermined economic growth targets(3).

Regarding economic activity, several other causes considered to be the causes of environmental degradation are other problems, including population, technology, energy consumption, and almost all activities related to consumption and production and, evidently, human lifestyles. Responsible for the Current environmental crisis. Environmental Kuznets Curve (EKC) is a formulation used to measure the interplay between environmental degradation and economic activity. The use of IPAT and STIRPAT analysis models is another formulation that is popular among ecological economics, particularly concerning anthropogenic factors as the cause of environmental degradation (4,5) an analytical tool, an interplay Among human activities and environmental variables. Human activity anthropogenic factors consider that become the main driver behind the decrease in this approach's environmental quality include population, affluence, and technological change. (6) The main problem that will become the main focus of attention in the STIRPAT model is population size. One of the main concerns of this model is the human factor with all its activities.

The discovery of a formation that can Portray the anthropogenic factors of environmental problems IPAT has not been able to examine the hypothesis because IPAT is an identity equation as a formulation to analyze the effects of anthropogenic activities since it was introduced by (5) in the early 1970s and (7) who then modified the IPAT formulation by introducing a stochastic approach called Stochastic Impact by Regression on Population, Affluence, and Technology (STIRPAT). At the philosophical level, the existence of the STIRPAT model is colored by interesting debates due to the emergence of accusations against religion as a destructive factor for the environment, especially religions that have monotheistic roots, such as Islam, Christianity, and Judaism, which considered as the foundation of the philosophy of anthropocentrism which is considered the basis of legitimacy for the degradation of the environment in the world, according to (8,9), The emergence of verses in the Holy Book of Monotheism confirms man's superiority as the only one to be the most perfect and superior to other creatures in the universe. Anthropocentrism philosophy itself is a philosophy developed in Europe as a philosophy of relieving humans from God's shackles, which in the Middle Ages was still covered by myths of the ancient Greek era's gods.

Various types of experiments have been carried out to investigate the relationships between human activities and environmental quality decline(Grossman & Kruger, 1992). by using a variety of variables they use to verify the existence of inverted U Shape, or with other approaches such as using the STIRPAT model (Ehrlich & Holdren, 1971; York et al., 2003). However, research using the STIRPAT model to verify the Environmental Kuznets Curve's existence was rarely done before, especially in Indonesia. In this study, researchers used the EKC model and the STIRPAT model alone to test and validate the Inverted U Shape's existence to prove the Environmental Kuznets Curve's existence. Meanwhile, to get the classic driving force from the STIRPAT model, population, Affluence, and Technology.

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In this study, the authors included an extension of the classic STIRPAT model using the Extended STIRPAT model with several modifications, including foreign direct investment and institutional quality variables. The selection of FDI variables is based on foreign direct investment's inherent characteristics, where they are known to be very expansive and exploitative and often ignore environmental factors. Meanwhile, institutional quality is based on the premise that a country's economic activity is not determined by market mechanisms and the policy-making process carried out by a handful of powerful political elites in a country (Carlsson & Lundstrom, 2000). Even some research on environmental degradation is also associated with democracy, which focuses on seeing the positive influence of democracy on a country's environmental problems. While (16) does not link the issue of democracy with environmental policies but rather links the democratic process with economic growth, As has been explained that one of the problems with reducing environmental quality is an economic activity; in this case, economic growth. The existence *of institutional quality* is expressed by (17), which emphasizes that institutions can be in the form of formal rules or other informal constraints. Meanwhile, formal rules are the product of the political policy-making process.

Researchers have used anthropogenic factors to answer the following questions: how are anthropogenic factors impact the decline in environmental quality in Indonesia? Based on the above ideas, the researcher did not use the conventional STIRPAT (Population, Affluence, and Technology) approach. However, the researcher used the Extended STIRPAT by including an additional variable: institutional quality and the variable Foreign Direct Investment. Meanwhile, another variable that varies from previous research is technological variables using variables taken from the energy structure, which is the percentage value of fossil energy use.

2. Materials and methods

The data used in this study are secondary time series with the period of study from 1971 to 2018. This study's type of data is annual—a selection of periods between 1971 and 2018.

Table 1 Data table of research for STIRPAT

Data	Unit	Symbol	Source
• CO2 Emissions	kt	CO_2	World Bank
• The income per capita (Gross Domestic Product per capita	US $	GDP	World Bank
• Population Density	Million / km2	Post	World Bank
• Energy Structure	% of Fuel Fossil Consumption from Total Consumption	ICE	World Bank
• Foreign Direct Investment	US $	FDI	World Bank
• Institutional Quality (Democratization Index)	-	IQ	Center for Systemic Peace

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The steps taken are the search and collection of data, which will be analyzed using Eviews Version 9.

ARDL (p,q_1,q_2,q_3,q_4,q_5) general equation:

$$Log(CO2_t) = \alpha_0 + \sum_{j=1}^{p} \alpha_1 \, CO2_{t-j} + \sum_{j=0}^{q1} \alpha_2 \, Popodnst_{2t-j} + \sum_{j=0}^{q2} \alpha_3 \frac{GDP}{Cap}_{3t-j} \sum_{j=0}^{q3} \alpha_4 \, ES_{4t-j} + \sum_{j=0}^{q5} \alpha_5 \, FDI_{5t-j} + \sum_{j=0}^{q6} \alpha_6 \, IQ_{5t-j} + \varepsilon t$$

The Extended STIRPAT model includes other variables outside the traditional STIRPAT model.

Where :

I = Carbon Dioxide (Metric ton per capita)
A = GDP / Capita Dioxida / capita (US $)
P= Population (
T = Energy Structure (%)
FDI = Foreign Direct Investment
IQ = Institutional Quality

A data analysis method is an approach used to analyze each independent variable's effect on the dependent variable. Based on the hypothesis used in this study, the driving force of environmental impact, using the ARDL-ECM method, there are several steps of analysis, including a stationary test, a cointegration bound test, and the ARDL-ECM method introduced by the ARDL-ECM (18), as well as the classic assumption test.

Autoregressive Distributed Lag (ARDL) is a regression model that includes a variable value that explains either the present value or the past value of the independent variable and the model that includes the lag value of the dependent variable the explanatory variables. The ARDL model is beneficial in empirical econometrics because it makes a static econometric model in a dynamic econometric model by taking explicit account of time's role. This model can distinguish between the dependent variable's short-term and long-term reactions to the change in the explanatory variable's value.

In this study, ARDL bound testing tests the short-term relationship between carbon dioxide (CO_2) emissions, GDP per capita, population density, energy structure, foreign direct investment, and institutional quality. The Eq framework of the ARDL. (1) use The equation :

$$\Delta Log(CO_2) = \alpha_0 + \sum_{j=1}^{p} \alpha_j (\Delta CO2)_{t-j} + \sum_{j=0}^{q1} \alpha_{1j} (\Delta Popodnst)_{1t-j} + \sum_{j=0}^{q2} \alpha_{2j} \left(\Delta \frac{GDP}{Cap}\right)_{2t-j} + \sum_{j=0}^{q3} \alpha_{3j} (\Delta ES)_{3t} + \sum_{j=0}^{q4} \alpha_{4j} (\Delta FDI)_{4t-j} + \sum_{j=0}^{q5} \alpha_{5j} (\Delta IQ)_{5t-} + \varepsilon t$$

In the meantime, there is a long-term relationship between CO_2 emissions, per capita GDP, population density, energy structure, foreign direct investment, and institutional quality. The Eq ARDL framework. (3) shall use the equation:

$$\Delta Log(CO_2) = \alpha_0 + \sum_{j=1}^{p} \alpha_j (\Delta CO2)_{t-j} + \sum_{j=0}^{q1} \alpha_{1j} (\Delta Popodnst)_{1t-j} + \sum_{j=0}^{q2} \alpha_{2j} \left(\Delta \frac{GDP}{Cap}\right)_{2t-j} + \sum_{j=0}^{q3} \alpha_{3j} (\Delta ES)_{3t} + \sum_{j=0}^{q4} \alpha_{4j} (\Delta FDI)_{4t-j} + \sum_{j=0}^{q5} \alpha_{5j} (\Delta IQ)_{5t-} + \varepsilon t$$

ECT_{t-1} is the speed of adjustment, which shows how much the speed of returning to the equilibrium point provides a negative value and is statistically significant. Based on (19), To test the stability of the model using the cumulative sum (CUSUM) and the cumulative sum of square (CUSUMSQ).

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3. Result and Discussion

Researchers used several variables, such as reducing environmental quality as a proxy for the concentration of carbon dioxide emissions, population variables, population density, the Affluence variable, the author used Gross Domestic Product (GDP) per capita, and technology variables to address issues related to driving force. Alternatively, often referred to as the Extended STIRPAT, and the latter is the Institutional Democracy Index, a non-economic variable used to measure Indonesia's institutional quality as a democratic country. All data variables used are taken from the World Bank database from 1971 to 2018, except for the Institutional Democracy Index variable, taken from the Center for Systemic Peace database from 1971 to 2018.

3.1 Data stationarity Test

The first step of the Auto Regression Distribution Lag (ARDL) test procedure is to test the data's stationarity. Based on the root test table results, see the data's stationarity using the Augmented Dickey-Fuller Unit Root Test (ADF) method. For the unit-root test with the degree of integration of absolute statistical values, among others: The absolute value of ADF> α = 1%, 5%, and 10%, then the data is stationary.

The absolute value of ADF < α = 1%, 5% and 10%, then the data is not stationary

Based on the results of the tests carried out, the following results were obtained :

Table. 2
Stationarity Test Results (Intercept and Intercept & Trend)

Variable	Intercept		Intercept & Trend	
	Level	1 st difference	Level	1 st difference
Augmented Dickey- Fuler (ADF)				
CO2	0.4196	0.0000	0.1380	0.0000
POPDST	0.0727	0.1369	0.9533	0.0274
GDP	0.9807	0.0004	0.8756	0.0014
ES	0.1165	0.0000	0.2050	0.0000
FDI	0.0138	0.0000	0.0575	0.0000
IQ	0.8828	0.0000	0.5273	0.0000

Data processed, 2020.

The stationarity test results using the Augmented Dickey-Fuller (ADF) test found that the variables CO2, GDP, ES, and POPDST did not pass the stationary test but passed the first difference level. In the meantime, the Population Density (POPDST) variable passes at the level of 10 percent significance level because, although it has a probability of 0.0727, it has a statistical value more significant than the critical value at the 10 percent confidence level with a value of-2.603944. This value is obtained if the unit root test only includes an intercept. However, if the unit root test includes an intercept and a trend, the probability value is obtained at the level of 0.9533 so that the population density data does not pass the level stage. In the meantime, the first difference test has a probability value of 0.0274. Therefore, it can be concluded that the population density data do not contain a root unit and are declared to be stationary. Meanwhile, FDI based on the probability of testing the level stage was 0.0138 <

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0.05. Thus the FDI variable passed stationarity at the level stage. Based on the unit root test analysis above, there is no variable data used stationary in the second difference stage, so that the ARDL analysis continued.

3.2 Optimum Lag Test

The next process is the process of determining the optimal lag length. The optimal lag test explains how long the influence of one variable is on another. In this study, researchers used the Akaike Information Criteria (AIC). The optimal Lag is obtained based on the lowest AIC value, namely ARDL (4,1,1,1,2)

3.3 Auto-Regressive Distribution Lag (ARDL)

Based on the unit root test results above, the next step is analysis to see if the model's variable data does not contain a unit root, so the next step is to analyze the data using Auto-Regressive Distribution Lag (ARDL).

Table 3: Empirical Model of ARDL

Dependent Variable: LOG(CO2)
Method: ARDL
Date: 12/22/20 Time: 20:30
Sample (adjusted): 1975 2018
Included observations: 44 after adjustments
Maximum dependent lags: 4 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (4 lags, automatic): ES FDI GDP IQ
Fixed regressors: POPDNS C
Number of models evalulated: 2500
Selected Model: ARDL(4, 2, 0, 4, 3)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOG(CO2(-1))	0.781349	0.199146	3.923505	0.0006
LOG(CO2(-2))	-0.908564	0.265206	-3.425882	0.0021
LOG(CO2(-3))	0.631743	0.203993	3.096884	0.0048
LOG(CO2(-4))	-0.339299	0.145440	-2.332910	0.0280
ES	0.024548	0.007753	3.166184	0.0040
ES(-1)	0.004158	0.008409	0.494448	0.6253
ES(-2)	-0.010952	0.006912	-1.584476	0.1257
FDI	-0.003517	0.011883	-0.295981	0.7697
GDP	3.49E-05	5.57E-05	0.626145	0.5369
GDP(-1)	0.000439	0.000105	4.169118	0.0003
GDP(-2)	-0.000466	0.000128	-3.638424	0.0012
GDP(-3)	0.000333	0.000159	2.096612	0.0463
GDP(-4)	-0.000354	0.000117	-3.020138	0.0058
IQ	0.063933	0.013861	4.612325	0.0001
IQ(-1)	-0.089372	0.020522	-4.354967	0.0002
IQ(-2)	0.083314	0.024245	3.436354	0.0021
IQ(-3)	-0.061772	0.017071	-3.618542	0.0013
POPDNS	0.008180	0.004891	1.672313	0.1069
C	-1.929027	0.459512	-4.197992	0.0003

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R-squared	0.992576	Mean dependent var	0.110895
Adjusted R-squared	0.987230	S.D. dependent var	0.463320
S.E. of regression	0.052357	Akaike info criterion	-2.763130
Sum squared resid	0.068532	Schwarz criterion	-1.992685
Log likelihood	79.78887	Hannan-Quinn criter.	-2.477412
F-statistic	185.6810	Durbin-Watson stat	2.362928
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

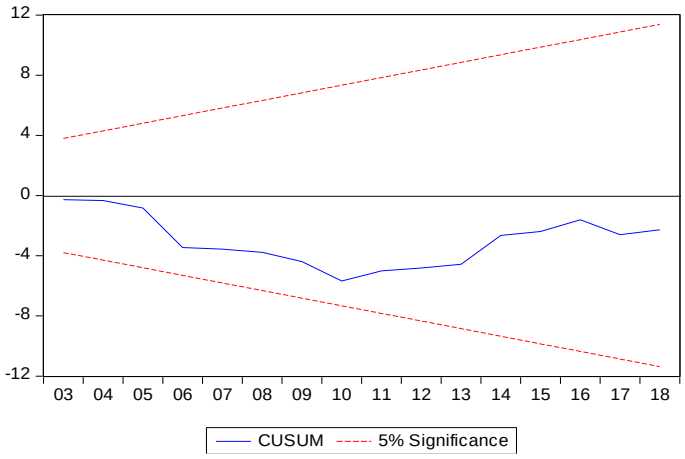
Source: processed data

Based on the results of data processing using the Auto-Regressive Distribution Lag method, an optimal lag combination is selected based on the smallest Akaike Info Criterion (AIC), namely-2.480557, based on the selection of the best AIC model with the optimum lag combination, namely ARDL (4, 2, 0, 2,3) with an R^2 value of 0.992576, which means that 99,25 percent of the variation depends on the AIC. It shows that the model is good enough to be analyzed.

3.4 Model Fit Test (4, 1, 1, 1, 2)

Based on the ARDL test, it was found that the model chosen was ARDL (2,0,3,0,0). Testing the selected ARDL model's suitability was carried out to see whether the research model formed did not contravene the standard rules for econometrics. This test, it performs using the autocorrelation and the stability of the model. the results of the test, or suitability of the model, it can be concluded that the results of the autocorrelation test when viewed from the probability value Δ2 are 0.615 > from 5-007, 1%, 5 %, and 10%, so that the regression model in this study is free from autocorrelation problems.

Based on the CUSUM test, with a confidence level of 95%. Thus, according to the CUSUM and CUSUM Square test images, the model's stability is determined that the blue line is precisely between the red line, which is the 5 % significance line. It proves that the ARDL model (4, 1, 1, 2) is stable.



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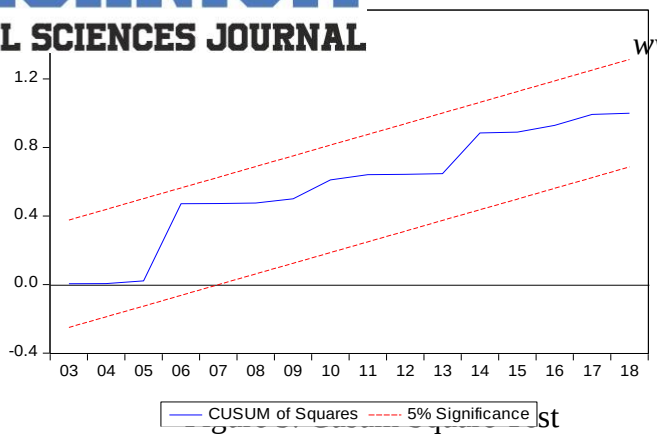

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3.5 Co Integration and Bound Testing

Based on the ARDL diagnostic test results in the table, the selected ARDL model (4, 1, 1, 1, 2) is needed to determine whether the selected ARDL model is suitable and perfect. The Bound test results showed that F's statistical value was 6.996252 > from I0 Bound and I1 Bound in all degrees of significance, and the conclusion is that the ARDL model can be used. At the same time, this figure shows that the variables have long-term relationships.

Table. 4: ARDL Bound Testing

Test Statistic	Value	k
F-statistic	4.515004	4
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Source: processed data

4. Discussion of ARDL analysis results on the STIRPAT model

4.1 The Short-Run estimation result and Analysis of Speed of Adjustment

Based on the Bound testing that has been done, the variables used in this study have long-term cointegration. In the ARDL model (4,2,0,4,3), the Long Run Coefficient results are obtained. The next test uses a value *error correction coefficient* (CointEq (- 1)) or ECT (-1) in the short run ECM model, this value indicates the speed of adjustment is or how far the error will be corrected in each time period. In order to qualify, the coefficient value must be negative, and the probability is significant. Cointegration value is obtained coefficient value-0.834771 with a probability value of 0.0013. This shows that the coefficient is negative and significant, meaning that the model will go to the equilibrium point at a speed of 83.4771%.

Based on the coefficient value obtained, it can also be seen that the value of ecological elasticity (EE) this value is significant to know to see the changes that occur from the variables used to decrease environmental quality (20) in Indonesia, the value of the elasticity coefficient < 1 also shows an inelastic relationship to changes in variable carbon dioxide (CO_2) emissions gives a smaller impact than the changes that occur in the dependent variable because the coefficient value has a value of less than 1. From the results of data processing, the first variable is the increase in carbon dioxide (CO_2) emission levels influenced by the dependent variable

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itself in the past, namely changes in carbon dioxide (CO_2) emissions from previous periods, which have a significant effect on both 1,2, and 3. At lag (-1) produces a coefficient of 0.616120 with a probability value of 0.0054. At Lag (-2), the coefficient value is -0.292444 with a probability value of 0.00405. Finally, the lag (-3) obtained a coefficient value of + 0.339299 with a probability value of 0.0280.

Variable Population Density. Based on the results of the short-term analysis, the coefficient value is obtained 0.0081799, with a probability of 0.1069, which means that change variable *Population density* or changes in population density in the short term have a positive and insignificant effect on changes in-depth changes in the concentration level of carbon dioxide (CO_2) emissions in Indonesia. While the research conducted by (21), who conducted the EKC test in Pakistan, got the same results where the Population Density variable has a negative and significant effect on environmental degradation by using the Ecological Footprint as a proxy for environmental degradation of the research conducted. This situation is related to Indonesia's level of population distribution, which is not evenly distributed, resulting in changes in population density in Indonesia to become an insignificant driving factor.

The next variable is Affluence, which uses a proxy for Gross Domestic Product (GDP) per capita. In the observation year, lag (-1) (- 2) and (-3) obtained a coefficient value of 0.000035 with a probability value> 0.05, while the lag coefficient (-1) 0.000 466, lag (-2) coefficient of -0.000333, and lag (-3) 0.000354 with all probability levels <0.05, among others 0.0012, 0.043 and 0.0058 means that in the short term change Gross Domestic Product (GDP) variable per capita on lag (-1)) (- 2) Furthermore, (-3) are shown to significantly influence change carbon dioxide (CO_2) emissions in Indonesia in the observation year had a positive and insignificant effect on changes in the concentration level of carbon dioxide (CO_2) emissions. However, changes in the level of carbon dioxide (CO_2) emissions were significantly influenced by Gross Domestic Product (GDP) in the previous year, namely lag (-1) and (-3) have a significant positive effect on environmental quality degradation. In contrast, lag (-2) harms environmental quality degradation, and this is related to the results achieved in variable carbon dioxide (CO_2) emissions at lag (- 2) has a negative influence. Based on the two lags' coefficients, it can be concluded that change Gross Domestic Product (GDP) per capita has a positive effect on change carbon dioxide (CO_2) emissions in Indonesia.

The next independent variable is the technology variable, which in this study uses energy structure as a proxy for technological change as measured by the use of fossil fuel consumption divided by the total energy used in Indonesia with a coefficient value of 0.024548 with a probability value of 0.0040, meaning that change The energy structure derived from fossils as a proxy for technological change has a positive and significant effect on change concentration levels of carbon dioxide (CO_2) emissions in Indonesia. Technology, it is expected that technology will impact improving environmental quality. Based on the results obtained, it can be concluded that technological changes using energy structure as a driving factor have a significant positive effect on changes in the concentration of carbon dioxide (CO_2) emissions or a decrease in Indonesia's quality of the environment. This shows that Indonesia's energy utilization technology has not yet expanded and is still heavily dependent on fossil energy sources. Thus, the use of energy, both industrial and transportation fuels in Indonesia, has a significant positive effect on increasing Indonesia's carbon dioxide emissions. This is related to the real conditions that occur. The share of new and renewable energy in the National Energy mix only reaches 13%, with a composition of 0% solar power, 0% wind, 8.8% geothermal, and the remaining 3.7% Biomass. Meanwhile, the percentage of zero-carbon fuels in Indonesia only reaches 5%, while the energy derived from fossils is 67%, the remaining energy comes from

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biomass by 28%. Meanwhile, 67% of fossil energy is divided into Oil 31%, Gas 16%, and Coal 20%.

The variable of Foreign Direct Investment in the short-term estimation has a negative and insignificant effect. Based on this study's results, the coefficient value is -0.003517 with the resulting probability value of 0.07697 > 0.05. A hypothesis is known as the pollutant haven hypothesis (PHH), which states that change Foreign Direct Investment will cause a change in environmental quality in host countries where Foreign Direct Investment is invested is not proven to be significant. Based on the results of statistical tests in Indonesia, the existence of Foreign Direct Investment in the short term has a negative and insignificant effect on environmental quality degradation.

The Institutional Quality (IQ) variable in the year where the observation, lag (-1), lag (-2) resulted in a coefficient value of 0.0693933, - 0.083 314, and 0.061772, respectively, with a probability value of <0.05, which means that it is significant. These results show that changes in Indonesia's democracy index in the observation year have a significant positive effect as a cause change the increase in carbon dioxide (CO_2) emissions in Indonesia. Simultaneously, the lag (-2) resulted in a significant negative effect and was also the cause of the reduction in Indonesia's concentration of carbon dioxide emissions. The results in the year of observation and Lag (-2) are per the hypothesis built in this study. An increase in the institutional quality index in Indonesia should decrease the concentration of carbon dioxide in Indonesia. Because in theory, the effort to question the role of democracy on economic performance in a country includes questions related to environmental issues. The root of this problem cannot be separated from the argument that a country with a good level of democracy has an adequate information disclosure level (freedom of the press) about the environment. (22) This thinking logic is used to build the hypothesis in this study, considering that good environmental quality (institutional quality) will improve environmental quality. In a democratic country, it is believed that openness of information allows citizens to access various kinds of information, especially those related to environmental issues compared to autocratic countries. In autocratic countries, the ruling political elite usually has a higher education level, which tends to hide information from the public, especially concerning environmental issues. (23) This public concern provides space in democratic countries for the check and balance mechanism in a democratic country compared to autocratic countries, which are more closed to information. This further strengthens the findings in the first problem where the policies carried out by the government are mostly directed at increasing economic growth, or more are used to strengthen the scale effect in Indonesia. This policy is related to high economic growth as a measure of the success of a country. The pursuit of economic growth and Gross Domestic Product (GDP) is an effort made by the government as a policy that will impact solving economic problems in Indonesia and a measure of the success of their leadership.

The explanation of the positive results obtained a coefficient value of 0.061772 with a probability value of 0.0013, which means that institutional quality (democracy) is dangerous for the environment because it increases the concentration of carbon dioxide emissions in Indonesia. This result is the same as what was conveyed by (24) that democratic countries tend towards a pro-market government and dangerous to the environment. This situation is what triggers an increase in the concentration of carbon dioxide emissions in a country, as is feared by (25) regarding the existence of the tragedy of Commons, by creating moral hazard, as a result of not clearly defined property of right of natural resources in a country, a certain group of people and individuals exploit natural resources. This potential, in turn, causes danger in the management of natural resources.

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Table 5 Short-run cointegration estimation in Indonesia

Dependent Variable: LOG(CO2)
Method: ARDL
Date: 12/22/20 Time: 20:30
Sample (adjusted): 1975 2018
Included observations: 44 after adjustments
Maximum dependent lags: 4 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (4 lags, automatic): ES FDI GDP IQ
Fixed regressors: POPDNS C
Number of models evalulated: 2500
Selected Model: ARDL(4, 2, 0, 4, 3)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOG(CO2(-1))	0.781349	0.199146	3.923505	0.0006
LOG(CO2(-2))	-0.908564	0.265206	-3.425882	0.0021
LOG(CO2(-3))	0.631743	0.203993	3.096884	0.0048
LOG(CO2(-4))	-0.339299	0.145440	-2.332910	0.0280
ES	0.024548	0.007753	3.166184	0.0040
ES(-1)	0.004158	0.008409	0.494448	0.6253
ES(-2)	-0.010952	0.006912	-1.584476	0.1257
FDI	-0.003517	0.011883	-0.295981	0.7697
GDP	3.49E-05	5.57E-05	0.626145	0.5369
GDP(-1)	0.000439	0.000105	4.169118	0.0003
GDP(-2)	-0.000466	0.000128	-3.638424	0.0012
GDP(-3)	0.000333	0.000159	2.096612	0.0463
GDP(-4)	-0.000354	0.000117	-3.020138	0.0058
IQ	0.063933	0.013861	4.612325	0.0001
IQ(-1)	-0.089372	0.020522	-4.354967	0.0002
IQ(-2)	0.083314	0.024245	3.436354	0.0021
IQ(-3)	-0.061772	0.017071	-3.618542	0.0013
POPDNS	0.008180	0.004891	1.672313	0.1069
C	-1.929027	0.459512	-4.197992	0.0003

R-squared	0.992576	Mean dependent var	0.110895
Adjusted R-squared	0.987230	S.D. dependent var	0.463320
S.E. of regression	0.052357	Akaike info criterion	-2.763130
Sum squared resid	0.068532	Schwarz criterion	-1.992685
Log likelihood	79.78887	Hannan-Quinn criter.	-2.477412
F-statistic	185.6810	Durbin-Watson stat	2.362928
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

Source: processed data

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4.2 The Long-run estimation result (Dynamic Cointegration)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ES	0.021267	0.008581	2.478400	0.0203
FDI	-0.004213	0.014175	-0.297233	0.7687
GDP	-0.000016	0.000028	-0.576612	0.5694
IQ	-0.004668	0.009741	-0.479265	0.6359
POPDNS	0.009799	0.005994	1.634939	0.1146
C	-2.310844	0.161719	-14.289244	0.0000

Source: processed data

Long-term estimation in ARDL is essential because, in this analysis, we can get a long-term relationship from the model created. The Extended STIRPAT model results from the ARDL estimator, which produces a coefficient in the estimation consistent with the resulting model. The only variable that has a significant effect variable is the Energy Structure (Energy Structure), which is statistically proven to affect environmental quality degradation significantly is the Energy Structure (ES). This variable is a variable that represents technological developments, especially the energy technology used in Indonesia. The Energy Structure (ES) variable is measured from the percentage value of fossil fuel consumption of Indonesia's total energy. Industrial and transportation sector. In this study, the results obtained through long-term analysis resulted in the coefficient value of the technology change variable of 0.021267 and a probability value of 0.0203 < 0.05. In Indonesia's energy structure factor, it is a factor that has a positive effect on increasing the concentration of carbon dioxide emissions and is a significant contributor to carbon dioxide (CO_2) emissions in Indonesia. This result is different from the hypothesis used that the variable energy structure harms.

This aspect must also be related to energy consumption efficiency and effectiveness (Begum et al., 2015). Based on (26) In the Environmental Statistics in Indonesia, 2017, the most contributed sector on to Green House Gas Emissions was energy consumption, which amounted to 48 percent, followed by forests, mainly triggered by forest fires, which contributed 26 percent of Green House Gas Emissions, followed by the agricultural sector 11 percent. Other research results, other researchers like (27)) also produce the same result that in Indonesia, energy consumption is a significant contributor to increased carbon dioxide (CO_2) emissions in both the long and short term. The Energy Structure in this study is used to explain technological changes, which is taken from the percentage of energy use from the fossil used compared to the total energy used in Indonesia. The energy factor in Indonesia still depends on energy derived from fossils (28).

Based on this research, it can be concluded of environmental degradation is not solely due to economic problems, but that environmental quality degradation is caused by problems that are structural in human interactions (social system), where there is a relationship between structure and agency in interactions between humans with nature (Structural Human Ecology) (4) part from being related to the anthropogenic factors of humans themselves in treating nature, there is also the influence of political economy policies carried out within a country, the state factor as an agent of community interests has an influence on the management of natural resources used to achieve economic growth targets. In this study to include the institutional

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quality variable in state management, which is represented by the index of democracy in a country, also does not escape the pros and cons of questioning whether democracy will be able to control the decline in environmental quality, or in fact, a democratic system is hazardous for the environment (24).

In the concept of Human Ecology, social system factors play an important role in the process of interaction between humans because of the consequences of human activities with a chain relationship between social systems and ecosystems, because based on these interactions, humans have consequences that result in environmental degradation subtly and involve between generations in a long period of time (29), so that the environmental impact caused is often invisible.

5. Conclusion

This study investigates the determinants of environmental quality degradation in Indonesia for the 1971-2018 time period. It can be concluded that in the short term, the variable which affects environmental quality degradation proxied by carbon dioxide emissions using the STIRPAT approach includes carbon dioxide at a lag. -1, -2 and -3. Meanwhile, the variable population density (population density) and Foreign Direct Investment were not significant determinants of environmental quality and energy structure deterioration. Other variables that are proven to be significant are the variable and Affluence / Gross Domestic Product (GDP) and institutional quality. Apart from that, it is a deep ECM short-term model that shows how much the speed of adjustment (speed of adjustment) or how far the error will be corrected each time. In order to qualify, the coefficient value must be negative, and the probability is significant. Cointegration value is obtained coefficient value- 0.834771 with a probability value of 0.0000. This shows that the coefficient is negative and significant, meaning that the model will go to the equilibrium point at a speed of 83.4%. Meanwhile, in the long term, the only variable that is proven to be a significant determinant of environmental quality degradation is the energy structure as a variable representing Indonesia's technology. At the same time, variables that do not affect include Institutional Quality, Foreign Direct Investment, population density. Based on the data above, it can be concluded that in Indonesia's short term, the CO_2 variable is from the previous lag, and the energy structure is the main driving factor for the increase in carbon dioxide emissions in Indonesia from 1971-2018. Energy Structure shows that Indonesia's technological changes, especially energy technology in Indonesia, still very dependent on energy derived from fossils and are the primary driver of carbon emissions in Indonesia. There is no new technology that can shift energy from a fossil in the economy, especially in production.

Author's contribution

The Authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflict and declare absence of conflicting interest with the funders.

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