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Testing the Environmental Kuznets Curve Hypothesis: An Empirical Study for Peru

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ABSTRACT

This research analyzes the Peruvian engagement against climate change through the impact of the per capita income on the environmental pollution in the national scenario during the annual period of 1980-2019. For this, the logic of the Environmental Kuznets Curve will be used, in which an "inverted U" curve shape affirms that the economic growth is favorable for the environment in the long term because an optimal income point is reached and pollution begins to decline. For this analysis, the national exports are included as a third variable, and also is considered a cubic regression equation to the original Kuznets model. Through the estimation by Dickey-Fuller and Phillips-Perron unit root tests, Granger Causality Test, the Vector Autoregression Model (VAR) method and the Forecast Graphics, it is shown that, similar to other countries of the region, Peru is actually on the initial part of the curve, where income and pollution have a growing direct relation. Finally, the models that fitted the relationship of these variables were the original model and the model with exports included.

Keywords: Economic Growth, Environmental Pollution, Kuznets Environmental Curve, Exports, Peru
JEL Classifications: F18, Q43, Q51

1. INTRODUCTION

Peru's economic growth over the last 40 years has generated greater extraction of national natural resources, affecting more environmental quality. In the years 1990-1999, Peru grew at an average annual rate of 3.9%. The following decade, 2000-2009, the average annual growth rate was 5.6%, and finally, in the years 2010-2019 it was 4% (Ministry of Economics and Finance, 2020). This entire economically favorable scenario for Peru is due to an increase in extractive activities (agriculture, livestock, fishing, manufacturing and extraction of oil, gas, minerals, among others), affecting the preservation of our biodiversity and contributing to environmental deterioration.

Actually, a large number of investigations purpose to evaluate the impact of economic growth within the environment. For this, several researchers decided to use an accessible methodology that would demonstrate the relationship between these variables, both in the short and long term, through the Environmental Kuznets Curve (Grossman and Krueger, 1995). This theory proposes an inverted U relationship between economic growth and environmental deterioration, since as economic growth increases, environmental deterioration has the same behavior; however, there is a turning point where this direct relationship becomes inverse, and environmental degradation begins to diminish while economic growth continues its course. This criterion was applied in both developed and emerging countries, evidencing the existence of the relationship between economic growth and the environment. However, developed countries had already reached the turning point and showed a decrease in pollutants while there was economic growth; this was not the case in most developing countries, as many of them are still in the first part of the curve (Vergara et al., 2018).

The following research is important because its purpose is to study the type of relationship between economic growth and environmental pollution based on the Kuznets Environmental Curve for Peru, during the period 1980-2019, given the increase in carbon dioxide emissions and concern for environmental well-being at the national level (Ministerio del Ambiente del Perú, 2011). In addition, determine the stage of the EKC in the Peruvian economy and compare it with other countries in the region. On the other hand, it is necessary to reinforce the formulation and monitoring of the country's environmental policies for the benefit of sustainable development, all in order to ratify Peru's commitment to environmental issues at the national and international level.

It is worth mentioning that for this research the level of exports will be included in the study, in order to determine their contribution to economic growth and, therefore, their direct or indirect relationship with environmental pollution. Finally, recognize that the quadratic model better expresses the EKC compared to the cubic model for the Peruvian economy.

2. THEORY AND LITERATURE REVIEW

The Environmental Kuznets Curve (EKC) is an application of the Kuznets Curve to the environmental field (Kuznets, 1955), in order to explain the relationship between economic growth and the level of pollution of an economy by means of an "inverted U." The theory states that economic growth is favorable for the environment in the long term, since in a first phase, the income level increases and pollution has the same tendency, but an optimal entry point is reached where pollution begins to go down, since individuals have sufficient income to cover their basic needs and decide to take initiatives to better care for the environment. Grossman and Krueger (1991) were the first to apply the EKC mechanism, seeking to explain the empirical relationship between environmental quality and per capita GDP levels through the following model:

$$E_{i,t} = \beta_{0_{i,t}} + \beta_1 Y_{i,t} + \beta_2 Y^2_{i,t} + \beta_3 Y^3_{i,t} + \mu_{i,t} \quad (1)$$

Where "E" is the level of emissions per capita at time "t," and "Y", "Y^2" e "Y^3" refers to per capita income, income squared and cubed respectively at time "t." Likewise, there are the "β's" which will give the following results:

If $\beta_1 > 0$, $\beta_2 < 0$; $\beta_3 = 0$, gets the original EKC.

If $\beta_1 < 0$, $\beta_2 > 0$; $\beta_3 = 0$, gets the shape of the inverted "U".

If $\beta_1 < 0$, $\beta_2 = 0$; $\beta_3 = 0$, environmental damage shows a linear decrease. On the other hand, $\beta_1 > 0$, $\beta_2 = \beta_3 = 0$, indicates linear growth.

If $\beta 1_1 < 0$, $\beta_2 > 0$ y $\beta_3 < 0$, means that environmental degradation will show an inverted "U", showing that in the long term emissions will decrease but will also increase at certain turning points.

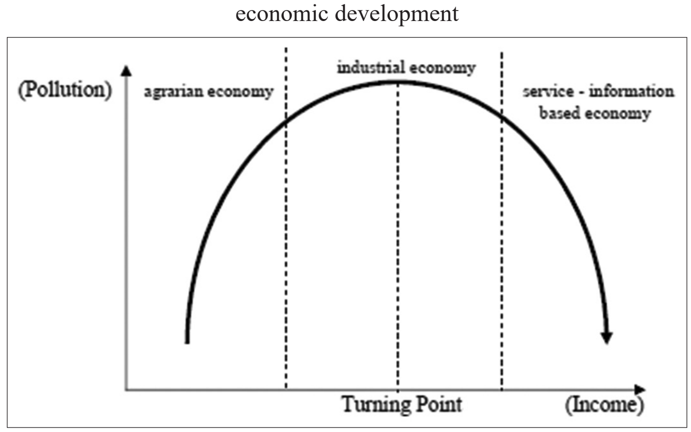
Likewise, Panayotou uses the same mechanics, and based on his research, he shows us a more concise idea of the EKC and its relationship with the main economic industries. According to the author, the highest levels of pollution occur at lower levels of income given the change from an agricultural economy to an industrialized one; and at higher income levels, the change from an industrialized economy to one based on services allows a decrease in the polluted intensity (Panayotou, 2003) (Figure 1).

The pioneers in conducting this study were Grossman and Krueger, where the term Environmental Kuznets Curve (EKC) is introduced to the "inverted U" relationship of the level of income and pollutant emissions (Grossman and Krueger, 1995). Using a data panel for the information collected from the Global Environment System (GEMS), the level of air pollution in urban centers was determined through sulfur dioxide (SO2) and total suspended particles in 42 and 29 countries respectively. Likewise, for hydrographic basins, 287 rivers from 58 different countries were analyzed during the years 1979-1990. Using the mentioned variables through equations in a reduced form in the data panel, it was concluded that the inflection point for the "inverted U" varies according to the type of pollutant; also, the results agreed that the "Turning Point" was generated with an income level less than US$ 8000.

More recently, Sarkodie and Strezov (2019b) employs bibliometric and meta-analysis techniques to analyze historical trends on the EKC hypothesis. The meta-analysis reveals that studies validating the inversed-U shaped relationship observe an average of US$ 8910 as the turning point of annual income level. Most of the studies are based on atmospheric indicators, whereas, oceans, seas, coasts, biodiversity and freshwater indicators are sporadic and limited on EKC hypothesis.

Few studies test the EKC hypothesis on developing countries (Sulemana et al., 2017). Economic growth in developing countries will be more carbon-intensive comparing to developed countries as technological advancement and innovation effects. Early stages of economic development are characterized by a high use of resources which inexorably contribute to increasing ecological footprint and reducing the biocapacity (Sarkodie and Strezov, 2018). Developing countries in Latin America or Africa are also the most vulnerable to climate change and its effects (Sarkodie, 2018).

Figure 1: Evolution of the EKC through the different stages of economic development



Adapted from Paraskevopoulos (2009)

Sarkodie and Strezov (2019a) examined the effect of foreign direct investment inflows, economic development, and energy consumption on greenhouse gas emissions for the top five developing countries emitters of greenhouse gas emissions from fuel combustion (China, India, Iran, Indonesia and South Africa) during the period 1982 to 2016. The results confirm the environmental Kuznets curve hypothesis validity for China and Indonesia and a U-shape relationship is observed for India and South Africa. In the Latin American region, Vergara et al. (2018) analyze the relationship between economic growth and carbon dioxide emissions in seven South American countries during the years 2000-2012. Through time series data, they analyze the variables in the following countries: Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay, Uruguay and Venezuela. Through the smoothing of data by natural logarithms and the application of Ordinary Least Squares, they obtain that the GDP per capita does demonstrate an influence on environmental pollution, maintaining that direct growth relationship within years in study. Mullo Parco (2018) applied the hypothesis of the Environmental Kuznets Curve to the Ecuadorian economy during the years 1970-2015. By transforming the variables into natural logarithms and applying ordinary least squares (multiple regression), he proceeded to calculate whether the Environmental Kuznets Curve was fulfilled. Based on the results obtained, it is observed that Ecuador is in the decreasing phase of the EKC since 2014, due to the implementation of environmental policies that contributed to the generation of less pollution. Therefore, economic growth does generate less environmental pollution in the long term due to the increase in environmental protection areas imposed in the 2008 constitution reform. Litano Boza (2012) relates the Peruvian economic activity and the environment during the years 1970-2010 through the analysis of the Environmental Kuznets Curve. He measures the relationship between various variables: per capita domestic product, national exports, energy intensity and level of per capita emissions of carbon dioxide. Within the econometric analysis, the author develops three analyzes, in their level, logarithm and with growth rates. Therefore, the relationship between the study variables is linear with a positive slope, which indicates that the Environmental Kuznets Curve has not yet been fulfilled in the period under study, since when per capita income increases there is still no decrease in carbon dioxide emissions, therefore, it is in the first stage of the EKC (Litano Boza, 2012).

3. METHOD AND MATERIALS

3.1. Materials

This research considers data under study in annual, stationary and longitudinal time series. All of them were extracted from secondary sources, such as the World Bank and the Central Reserve Bank of Peru. The data under study consists of an annual sample of 40 observations, ranging from 1980 to 2019. All variables were transformed into natural logarithms, obtaining the following: Carbon dioxide (LCO2t) expressed in metric tons per capita, GDP per capita (LGDPt) expressed in thousands of US$ and national exports (LEXPORTSt) expressed in thousands of US$. All tests were carried out through the Eviews program, version 10.

3.2. Empirical Analysis

In the first place, the descriptive statistics of the variables under study were calculated, it should be noted in this section that, due to the high levels of volatility of the variance, the variables were transformed into natural logarithms, in order to obtain a smoothing in the data under study as applied by Vergara et al. (2018) and Mullo Parco (2018) within their investigations.

Then, the Augmented Dickey Fuller (DFA) (1979), Phillips and Perron (1988) and Granger Causality (1969) tests were applied. Consider that for the present tests a significance level of 5% was used.

Then, we proceeded to estimate 3 optimal models for the investigation that derive from the original Kuznets equation, these are the following:

Original model (a):

$$LCO2_t = \beta_0 + \beta_1 LGDP_t + \beta_2 GDP_t^2 + \varepsilon_t \quad (2)$$

Original model and exports (b):

$$LCO2_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LGDP_t^2 + LEXPORTSt + \varepsilon_t \quad (3)$$

Kuznets model in cubic regression (c):

$$LCO2_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LGDP_t^2 + \beta_3 LGDP_t^3 + \varepsilon_t \quad (4)$$

Where:
$LCO2_t$: carbon dioxide emission for Peru in natural logarithm
$LGDP_t$: GDP per capita in natural logarithm
$LGDP_t^2$: Natural logarithm of GDP per capita squared
$LGDP_t^3$: Natural logarithm of GDP per capita cubed
$LEXPORTS_t$: National exports in natural logarithm.
β_0: Kuznets environmental curve econometric model constant
β_1: GDP per capita parameter
β_2: Per capita GDP parameter squared
β_3: Per capita GDP parameter cubed
ε_t: Error emission variable.

Once the proposed models were defined, we proceeded to estimate which of them will be the optimal model for the investigation through the methodology of vector autoregressive models (VAR). Finally, for the environmental Kuznets curve to be fulfilled, there must be a maximum point whose parameters must be 1 positive and 2 negative.

4. RESULTS

At first, the Dickey-Fuller Test and Phillips-Perron Test are used to verify the presence of unit root in the variables. From that, the results are displayed in Table 1:

For both Dickey-Fuller and Phillips-Perron Tests, it is obtain that the three variables in study (*LCO2t, LGDPt, LEXPORTSt*), on its level, has a p-value greater than 5% significance level.

Table 1: Dickey-Fuller and Phillips-Perron tests

Variable	Unit Root Tests	ADF			P-P		
		Intercept	Trend and Intercept	None	Intercept	Trend and Intercept	None
			P-value			P-value	
LCO2	Level	0.6809	0.2815	0.4251	0.6963	0.3253	0.4882
	1st Dif.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LGDP	Level	0.9638	0.1797	0.9913	0.9339	0.3177	0.9929
	1st Dif.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LEXPORTS	Level	0.9840	0.4230	0.9981	0.9721	0.2689	0.9935
	1st Dif.	0.0007	0.0049	0.0002	0.0007	0.0048	0.0002

Source: Own elaboration, with E-views 10 software

Both for the Dickey-Fuller and Phillips-Perron test, in the three variables under study (lnCO2t, lnGDPt and lnEXPORTS) it was obtained that, at their level, they have a P-value greater than the significance level of 0.05 in the tests with intercept, intercept and trend and without any of the above, obtaining non-stationary series. Therefore, we proceeded to look for stationary series, for this we worked with the first differences, for all cases the P-value is lower than the significance level of 0.05, so that the null hypothesis that there is a root is rejected unitary and it is concluded that the series is stationary in first difference; therefore, the variables DlnCO2t, DlnGDPt and DlnEXPORTS are obtained. However, based on the literature previously presented, it was decided to work with the transformed variables with natural logarithms.

Afterwards, the 3 optimal models were estimated through vector autoregressive models (VAR) with the sole purpose of estimating which regression best suits our research and which one would better explain the EKC for the Peruvian economy. As a first step, it was determined to find the selection criterion of the optimal lag, choosing the smallest, it was decided to work with the Akaike Information Criterion (AIC).

4.1. Original Model Based on the Environmental Kuznets Curve (EKC) with Logarithm

$$LCO2_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LGDP_t^2 + \varepsilon_t \quad (5)$$

Once the optimal lag, which is 2, was obtained, the VAR corresponding to the model was estimated. With respect to the R-squared values, the three equations show a high level of goodness of fit (Table 2).

In addition, the Granger causality test was performed in a VAR model where it was obtained that the first block where the regressor is the LCO2 series and the P = 0.0402 is less than the significance level 0.05, for this it is concluded that the null hypothesis that the series should be omitted and these do cause in the Granger sense when returning (Table 3). Likewise, for the second and third block we have the variables LGDP and LGDP^2, where the P = 0.2001 and 0.1832 respectively, being greater than the significance level 0.05; therefore, the null hypothesis that the series should be omitted and do not cause the regressors in the Granger sense is not rejected.

4.2. Original Model Based on the EKC Including Variable Exports and Logarithm

$$LCO2_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LGDP_t^2 + LEXPORTSt + \varepsilon_t \quad (6)$$

Table 2: Estimated autoregressive vector with 2 lags for original model with logarithm

	LCO2	LGDP	LGDP^2
R-squared	0.847835	0.971662	0.975306
Adj. R-squared	0.818383	0.966177	0.970526
Sum sq. resids	0.347973	0.554185	159.0721
S.E. equation	0.105948	0.133705	2.265250
F-statistic	28.78760	177.1563	204.0582
Log Likelihood	35.25146	26.40936	–81.12332
Akaike AIC	–1.486919	–1.021545	4.63807
Schwarz SC	–1.185259	–0.719885	4.93973
Mean dependent	0.215184	9.047296	82.36820
S.D. dependent	0.248607	0.727013	13.19464

Source: Own elaboration, with E-views 10 software

Once the optimal lag, which is 1, was obtained, the VAR corresponding to the model was estimated. With respect to the R-squared values, the four equations show a high level of goodness of fit (Table 4).

On the other hand, in the Granger causality test for a VAR model, it is obtained that the p-value of the variable LCO2 is less than the significance level of 5% with 0.0055, this means that the null hypothesis is rejected that the series should be omitted and they do cause in the Granger sense to return. On the other hand, the variables LGDP, LGDP^2 and LEXPORTS have P-values greater than 5% of significance level with 0.1701, 0.1355 and 0.075 respectively (Table 5). Therefore, the null hypothesis that the series should be omitted is not rejected and they do not cause in the Granger sense to return.

4.3. Original Model Based on the EKC in Third Degree Polynomial Regression

$$LCO2_t = \beta_0 + \beta_1 LGDP_t + \beta_2 LGDP_t^2 + \beta_3 LGDP_t^3 + \varepsilon_t \quad (7)$$

Once the optimal lag, which is 5, was obtained, the VAR corresponding to the model was estimated. Based on the R-squared values, the four equations show a high level of goodness of fit (Table 6).

Following this, the Granger causality test was carried out in a VAR model, for the LCO2 series, the p-value is less than the significance level of 0.05 with 0.0000, which is why the null hypothesis is rejected that the series should be omitted, concluding that the omitted series causes in the Granger sense to return (Table 7). On the other hand, the p-values of the series LGDP, LGDP^2 and

Table 3: Granger causality test for original model with logarithm

Excluded	Chi-sq	df	Prob.
Dependent variable: LCO2			
LGDP	1.540633	2	0.4629
$LGDP^2$	1.783259	2	0.41
All	10.01421	4	0.0402
Dependent variable: LGDP			
LCO2	1.062405	2	0.5879
$LGDP^2$	5.544273	2	0.0625
All	5.987516	4	0.2001
Dependent variable: $LGDP^2$			
LCO2	0.816859	2	0.6647
LGDP	5.831356	2	0.0542
All	6.221052	4	0.1832

Source: Own elaboration, with E-views 10 software

Table 4: Estimated autoregressive vector with 1 lag for original model with exports and logarithm

	LCO2	LGDP	$LGDP^2$	LEXPORTS
R-squared	0.853387	0.970553	0.974718	0.985013
Adj. R-squared	0.836138	0.967089	0.971744	0.983249
Sum sq. resids	0.336136	0.589979	166.8372	0.678314
S.E. equation	0.09943	0.131728	2.215169	0.141246
F-statistic	49.47578	280.1583	327.7124	558.6438
Log likelihood	37.36055	26.39039	–83.68101	23.66968
Akaike AIC	–1.659515	–1.096943	4.547744	–0.957419
Schwarz SC	–1.446238	–0.883666	4.761021	–0.744142
Mean dependent	0.217174	9.029312	82.0422	9.203759
S.D. dependent	0.245629	0.726121	13.17808	1.091342

Source: Own elaboration, with E-views 10 software

Table 5: Granger causality test for original model with exports and logarithm

Excluded	Chi-sq	df	Prob.
Dependent variable: LCO2			
LGDP	0.782866	1	0.3763
$LGDP^2$	0.66409	1	0.4151
LEXPORTS	3.187908	1	0.0742
All	12.61962	3	0.0055
Dependent variable: LGDP			
LCO2	0.774623	1	0.3788
$LGDP^2$	0.00126	1	0.9717
LEXPORTS	4.918281	1	0.0266
All	5.023634	3	0.1701
Dependent variable: $LGDP^2$			
LCO2	0.570772	1	0.45
LGDP	0.00122	1	0.9721
LEXPORTS	5.537413	1	0.0186
All	5.55334	3	0.1355
Dependent variable: LEXPORTS			
LCO2	0.069379	1	0.7922
LGDP	4.906452	1	0.0268
$LGDP^2$	5.13614	1	0.0234
All	6.904693	3	0.0750

Source: Own elaboration, with E-views 10 software

Table 6: Autoregressive vector estimated with 5 lags for the original model in cubic regression with logarithm

	LCO2	LGDP	LGDP^2	LGDP^3
R-squared	0.958816	0.987054	0.988572	0.989841
Adj. R-squared	0.899982	0.968559	0.972246	0.975329
Sum sq. resids	0.092425	0.219213	64.17352	10748.29
S.E. equation	0.081251	0.125132	2.140986	27.70804
F-statistic	16.29694	53.36869	60.55295	68.20729
Log likelihood	54.22955	39.11566	-60.27209	–149.888
Akaike AIC	–1.898831	–1.035181	4.64412	9.765031
Schwarz SC	–0.965623	–0.101972	5.577328	10.69824
Mean dependent	0.222214	9.123583	83.72354	772.6628
S.D. dependent	0.256916	0.705696	12.85147	176.4062

Source: Own elaboration, with E-views 10 software

Table 7: VAR Granger causality test for original model in cubic regression with logarithm

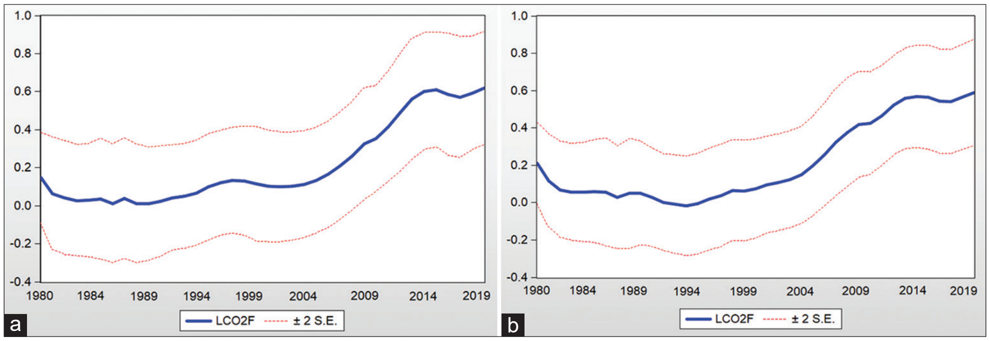
Excluded	Chi-sq	df	Prob.
Dependent variable: LCO2			
LGDP	19.86394	5	0.0013
$LGDP^2$	19.49509	5	0.0016
$LGDP^3$	19.09636	5	0.0018
All	47.44071	15	0.0000
Dependent variable: LGDP			
LCO2	3.965199	5	0.5544
$LGDP^2$	7.527506	5	0.1843
$LGDP^3$	7.345672	5	0.1962
All	16.15047	15	0.3721
Dependent variable: LGDP^2			
LCO2	3.89951	5	0.564
LGDP	7.506036	5	0.1856
$LGDP^3$	7.18254	5	0.2074
All	16.65712	15	0.3398
Dependent variable: LGDP^3			
LCO2	3.923705	5	0.5605
LGDP	7.290689	5	0.1999
$LGDP^2$	7.154504	5	0.2094
All	17.19665	15	0.3072

Source: Own elaboration, with E-views 10 software

$LGDP^3$ are greater than the significance level of 0.05 with 0.3721, 0.3398 and 0.3072 respectively, which is why the null hypothesis that the series should be omitted, concluding that these do not cause Granger to each of their returning.

On the other hand, the impulse response analysis was performed for the VAR for the three models. In model (a), according to the LCO2 series, a slight response (value changes) can be noticed and it is mainly explained by own impulses throughout the 10 periods. With respect to model (b), according to the LCO2 and LEXPORTS series, slight moderate responses can be observed that are explained by own impulses throughout the 10 periods. Finally, the impulse-response of the model (c) the LCO2 series remains intact for the four graphs and there are no movements and sudden or slight changes of the same returning. For the three cases, with respect to the series LGDP and $LGDP^2$, their responses are explained by impulses from the other returning.

Figure 2: National Kuznets curve of the proposed model (a and b): Original model in the Environmental Kuznets Curve (EKC) with logarithm and original model based on the EKC including export variable and logarithm respectively. (a) Original model based on the Environmental Kuznets Curve (EKC) with logarithm. (b) Original model based on the EKC including variable exports and logarithm



Source: Own elaboration, with E-views 10 software

For both models (a) and (b), the curve continues to rise and has not yet reached its optimum point called Turning Point where it begins to descend, this means that the Peruvian economy is located before the point of inflection (Figure 2).

Finally, after having carried out all the corresponding tests, the following is concluded from model (c): This third model presents multi-collinearity problems, according to the literature, one way to correct this problem is by suppressing those variables that are correlated with each other, helping to reduce collinearity (Wooldridge, 2015). Therefore, it is decided to suppress the variable GDP^3 as it is not really significant to the model, since the model originally proposed by Kuznets was the quadratic equation but not the cubic one. Therefore, model (c) is discarded within our research, having as valid models only models (a) and (b).

5. DISCUSSION AND CONCLUSION

The following research analyzed the relationship between economic growth and environmental pollution based on the Kuznets Environmental Curve for Peru during the period from 1980 to 2019, given the increase in carbon dioxide emissions and concern for environmental well-being at national level. According to the results, the economic growth expressed in GDP per capita does influence the levels of environmental pollution during the years 1980 to 2019. However, the "inverted U" of the Kuznets Environmental Curve would not be shown since Peru as a developing country still presents high levels of inequality in income distribution, which delays reaching the "Turning Point" that would lead to a decrease in pollution levels as the level of per capita income increases.

As observed in similar developing countries, the shape of an "inverted U" is not yet presented (Reyno, 2005). However, there is a direct relationship between the emission of pollutants expressed in CO_2 and per capita income, indicating that Peru is still in the first part of the curve. In Colombia, Correa (2005) conclude that for carbon dioxide, sulfur dioxide and biological oxygen demand, the Environmental Curve of Kuznets is in the growing phase. Similarly, Vergara et al. (2018) applied the logic of the Kuznets Environmental Curve to 9 South American countries during the years 2000-2012. In this research, the assumption of the "inverted U" relationship between carbon dioxide and per capita income is not met; concluding that, within the years of study, the relationship between CO_2 and GDP per capita is monotonously increasing, coinciding with the results obtained in our research. Within the national antecedents, Huanchi and Calsin (2018) sought to determine the relationship between economic growth and environmental deterioration, expressed in carbon dioxide and sulfur dioxide, for the Peruvian economy during the years 1910-2010. As a result, they obtained that within the period under study there is a stable long-term relationship between economic growth and environmental degradation, concluding that Peru is still in the growth stage in reference to the EKC. This supports once again the results obtained in this research, since, despite having carried out a more updated study (data until 2019), the direct positive relationship between both variables is still seen, supporting that the Peruvian economy does not reach the long-awaited "Turning Point".

Likewise, after doing the econometric tests on the quadratic and cubic model, it is concluded that the quadratic model better expresses the EKC for the Peruvian economy since its variables are significant, unlike the cubic model that had multicollinearity problems due to the presence of the variable GDP^3. These results confirm that, although an attempt was made to implement a study with a cubic variable to know the long-term behavior of the model, for our variables it works correctly in the quadratic model within the period under study (1980-2019).

Given the current situation of Peru in terms of development, if it is desired to reach the optimal income level to improve environmental quality levels in the medium term, the Peruvian State must not only focus its efforts on regulations in favor of the environment, it must also prioritize reducing the levels of inequality within the country. With a better distribution of wealth, there would be greater equality of opportunities for the population. One way to contribute to the reduction of inequality within Peru is by providing better education in the most remote areas of the country, with the purpose that they are better trained and, in the future, can access quality and better paid jobs. In the same way, the creation of financial inclusion programs will allow more people to have access to credits, savings, transactions, among others. The measures previously described would contribute to the growth of the gross domestic product from a higher level of consumption, investment, tax collection, among others, which in the long term would also be reflected in an environmental improvement.

Finally, policies are recommended to promote other productive sectors and not only focus on primary and extractive activities as the main source of income. Through training, tools and innovation, the same residents could dedicate themselves to the transformation of goods and the services sector, seeking in the medium term to specialize in it and not only dedicate themselves to extraction, which would provide greater added value to their products, obtaining higher levels of incomer per capita from exported products/services and; therefore, seeking to improve environmental quality in the short, medium and long term.

REFERENCES

Correa, R.F.J., Vasco Ramírez, A.F., Pérez Montoya, C. (2005), La curva medioambiental de Kuznets: Evidencia empírica para Colombia. Semestre Económico, 8(15), 13-30.

Dickey, D., Fuller, W.A. (1979), Distribution of the estimators for time series regressions with a unit root. Journal of the American Statistical Association, 74(366), 427-431.

Granger, C.W. (1969), Investigating causal relations by econometric models and cross-spectral methods. Econometrica: Journal of the Econometric Society, 37(3), 424-438.

Grossman, G.M., Krueger, A.B. (1991), Environmental Impacts of a North American Free Trade Agreement. Mass., USA: National Bureau of Economic Research Cambridge.

Grossman, G.M., Krueger, A.B. (1995), Economic growth and the environment. The Quarterly Journal of Economics, 110(2), 353-377.

Huanchi, W., Calsin, G. (2018), Curva Ambiental de Kuznets: Evidencia empírica para la economía Peruana, periodo 1972-2010. Semestre Económico, 4(2), 107-133.

Kuznets, S. (1955), Economic growth and income inequality. The American Economic Review, 45(1), 1-28.

Litano Boza, W.E. (2012), Estimación de la Curva Ambiental de Kuznets en la Economía Peruana: Producción y Medio Ambiente. Periodo: 1970-2010. Piura: Castilla-Piura Apartado Postal

Ministerio del Ambiente del Perú. (2011), Plan Nacional de Acción Ambiental Perú 2011-2021. Ministerio del Ambiente del Perú. Available from: http://www.minedu.gob.pe/comision-sectorial/pdf/planes/planaa-2021.pdf

Ministry of Economics and Finance. (2020), Marco Macroeconómico Multianual 2021-2024 Multi-year Macroeconomic Framework 2019-2022. Cambodia: Ministry of Economics and Finance, p235. Available from: https://www.mef.gob.pe/pol_econ/marco_macro/MMM_2021_2024.pdf

Mullo Parco, À.O. (2018), Crecimiento Económico y Medio Ambiente: Aplicación de la Curva Ambiental de Kuznets Para el Ecuador, Periodo 1970-2015, B.S. Thesis. Ecuador: Universidad Nacional de Chimborazo.

Panayotou, T. (2003), Economic Growth and the Environment (No. 2). Available from: https://www.unece.org/fileadmin/DAM/ead/pub/032/032_c2.pdf

Paraskevopoulos, D. (2009), An Empirical Analysis of the Environmental Kuznets Curve Hypothesis Over Two Centuries: Evidence from the UK and US, PhD Thesis, Master Thesis. Greece: University of Macedonia. Available from: https://www.dspace.lib.uom.gr/handle/2159/13512?locale=en

Phillips, P.C.B., Perron, P. (1988), Testing for a unit root in time series regression. Biometrica, 75(2), 335-346.

Reyno, J.E. (2005), La economía Mundial y América Latina: Tendencias, Problemas y Desafíos. Clacso. Available from: https://www.clacso.org.ar/libreria-latinoamericana/contador/sumar_pdf.php?id_libro=264

Sarkodie, S.A. (2018), The invisible hand and EKC hypothesis: What are the drivers of environmental degradation and pollution in Africa? Environmental Science and Pollution Research, 25(22), 21993-22022.

Sarkodie, S.A., Strezov, V. (2018), Assessment of contribution of Australia's energy production to CO2 emissions and environmental degradation using statistical dynamic approach. Science of the Total Environment, 639, 888-899.

Sarkodie, S.A., Strezov, V. (2019a), Effect of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Science of the Total Environment, 646, 862-871.

Sarkodie, S.A., Strezov, V. (2019b), A review on environmental Kuznets Curve hypothesis using bibliometric and meta-analysis. Science of the Total Environment, 649, 128-145.

Sulemana, I., James, H.S., Rikoon, J.S. (2017), Environmental Kuznets Curves for air pollution in African and developed countries: Exploring turning point incomes and the role of democracy. Journal of Environmental Economics and Policy, 6(2), 134-152.

Vergara, J.C., Maza, F.J., Quesada, V.M. (2018), Crecimiento económico y emisiones de CO_2: El caso de los países suramericanos. Revista ESPACIOS, 39(13), 17.

Wooldridge, J.M. (2015), Introductory Econometrics: A Modern Approach. Scarborough, ON, Canada: Nelson Education.