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Economic Growth And Environmental Deterioration. An Analysis Of Sustainable Development In Ecuador

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Summary
This article is an inductive argument to evaluate the current relationship between Economic Growth and Environmental Degradation in Ecuador through some variables such as Carbon Dioxide (CO2) and CO2 per capita, Gross Domestic Product (GDP), GDP per capita, Index of Economic Freedom and the Petroleum Production in a period of time from 1970 to 2014. It was analyzed some appraisal parameters and statistics tests to validate the multiple regression models in which CO2 and CO2 per capita do not present a high explanatory capacity. However, there is a direct and influent relationship between the Index of Economic Freedom and the emission of CO2 into the Ecuadorian environment.
Key Words: *Economic growth, Economic development, Income distribution, Environmental economics, Environmental impact assessment.*

I. INTRODUCTION

Brundtland (1987) brings together social, economic and sustainability dimensions by defining the concept of sustainable development as development that meets current needs without compromising the ability of future generations to be self-satisfied. It is this term which, despite not presenting a defined identity, is part of the international lexicon and accepted by governments, international organizations, businessmen and society (Bermejo, 2014).

Mainly because the adverse effects generated on the environment are caused by economic activities such as agriculture and industry, and energy consumption. There is therefore a relationship between environmental pollution and economic growth and population density; understanding that when per capita income increases, the higher the level of consumption of raw materials and energy, and with the high population rate, greater amounts of waste are generated (Falconí et al., 2016).

Urteaga (2009) describes that, within the economic theories of sustainable development, the optimistic current from the environmental economics of the neoclassicists in 1970 promotes the idea of necessary and sufficient growth, understanding that continuous growth presents in its long term a correlation with environmental protection, authors such as Barnett (1979) promote this idea and even state the idea as general and that it can be of use to "poor" countries.

Medina et al. (2017) state that this thought lays its foundations in relation to research in the fifties where economic growth and inequality in income distribution were studied (Ahluwalia, 1976; Alesina et al., 1994; Barro, 2000; Galindo, 2002; Álvarez, 2007; Núñez, 2016), mainly with the contribution of Kuznets (1955), who understands according to Araujo et al. (2015) that economic growth is far from being the only and most accurate measure of well-being; in one of his investigations on the relationship between economic growth (measured through GDP per capita[1]) and income distribution; It is postulated that these variables have an inverted U-shaped relationship. This is understood as the increase in income in the long term generates less inequality (Correa et al., 2005).

This hypothesis, together with Malenbaum's (1978) theoretical framework on the intensity of use, relates the income and demand for materials to an inverted U-shape; promoted new research approaches, leading neoliberal economists such as Beckerman (1972) and Barnett (1979) to promote an existing relationship between economic growth and environmental quality by relating these variables in an inverted U-shape.

In view of the above, this study aims to establish whether variables such as per capita income, economic freedom and the national production of barrels of oil generate an impact on the environment. Understanding the use of the existing multiple regression of the predictor variables and the response variables. This empirical analysis seeks to present new contributions to the existing dilemma between economic growth and the environment in the case of Ecuador, for the benefit of its economic and environmental policy, and to establish the degree of influence of independent variables on the degree of pollution registered in our country.

The research design embodied in the document seeks to characterize the relationship between economic growth and environmental deterioration under the theory of sustainable development through the literature review of authors who have developed similar studies, to then establish the methodological framework that encompasses the development of the empirical study. Subsequently, the results of the research will be manifested before the presentation of the multiple regression model that evidences the identification of the explanatory variables of economic growth and their interaction with the emission of carbon dioxide.

The conclusions contain the analysis of the environment in which the results of the research were developed. The reference contains the list of the works cited in this document and that have been used to outline the study and its results.

II. DEVELOPMENT

1. Literature review

The theory of sustainable development based on the Kuznets environmental curve explores the relationship between economic growth and environmental quality, establishing as an idea that the quality of the environment improves with the increase in income (Correa et al., 2005).

Based on this premise, a series of studies have been carried out, understanding this as empirical evidence that does not determine a single type of relationship between economic growth and environmental deterioration in each of the countries studied by the authors.

Grossman et al. (1992) located their research in Mexico, establishing a relationship between the North American Free Trade Agreement (NAFTA) and the level of pollution under the hypothesis that the reduction in trade barriers affects the environment, expanding the scale of economic activity, altering the composition of its activity, and causing a change in production techniques. used comparable measures of SO2 and smoke with GDP per capita in a representative sample of urban areas located in 42 countries.

Stokey (1998) outlines a theoretical model with a relationship between per capita income and environmental quality, showing that tax and quota schemes have an advantage over direct regulation since they provide the right incentives for capital accumulation. Jaeger et al. (1998) described that environmental damage will first increase and then fall with increasing incomes; The author explains that,

in most natural environments, two different types of services, one rival or private and the other non-rival or public, create a fundamental asymmetry in the aggregation of values.
Cavlovic et al. (2000) evaluated 25 studies using meta-analysis, obtaining 121 observations for empirical study; These demonstrate that methodological choices can significantly influence outcomes. Heil et al. (2001) establish the historical relationship between carbon emissions and GDP, adding to the study a GDP and population projection model that establishes the emissions horizon, adding the variable oil price.
Soytas et al. (2007) evaluate the causal relationship between income, energy consumption, carbon emissions, labor, and gross fixed capital formation from the data obtained by the United States; research shows that income does not cause long-term carbon emissions in Granger's (1969) terms, but rather energy use does, stating that income growth cannot become a solution to environmental problems.
Nasir et al. (2011) use Johansen's (1988) cointegration method to investigate the relationship between Pakistan's carbon emissions, income, energy consumption, and international trade; The authors find that there is a long-term quadratic relationship between carbon emissions and income. Goldman (2012) uses meta-analysis to better understand the specific factors that affect the relationship between economic growth and environmental quality, using panel data and global data; the author states that there is no statistically significant evidence indicating an increase or decrease in the probability of finding a Kuznets curve.
Fosten et al. (2012) use the nonlinear threshold cointegration methodology and a VEC model for the case of the United Kingdom; the authors show that there is no inverse relationship between CO2 per capita, SO2 emissions and GDP.
The literature cited states that in order to establish the relationship between the economic growth of a country and its environmental deterioration, empirical studies have been developed and various statistical tests have been applied to panel data and time series. Techniques used with groups of countries, and individual countries.

2. MATERIALS AND METHODS

This research is framed in a type of inductive reasoning with the application of econometric tests to measure the contribution of socioeconomic growth variables in environmental pollution, manifested in$_{CO2}$ and CO2 emissions per capita.
For the analysis, an annual time series database was used with an evaluation period from 1970 to 2014 of the homologated variables CO2, CO2 per capita, GDP per capita, index of economic freedom[2] and the National Production of Oil Barrels whose basis was obtained from the Central Bank of Ecuador – BCE and the World Bank – WB. The methodological proposal of the research proposes a multiple regression model that establishes the partial regression coefficients that demonstrate the contribution of the independent variables.
For the analysis, economic growth has been divided into the stages that Ecuador has experienced.
To measure the contribution of economic growth in the environmental deterioration of Ecuador, two functions were carried out in which the GDP per capita, the index of economic freedom and the National Production of Oil Barrels were taken as independent variables; while, as a dependent variable of the first function, CO2 and of the second function of CO2 per capita, obtaining the following models:

(1) $\mathrm{CO}_2 = f(\text{PIB per cápita} + \text{índice de libertad económica} + \text{Producción Nacional de Barriles de Petróleo})$

(2) $\mathrm{CO}_{2per\ cápita} = f(\text{PIB per cápita} + \text{índice de libertad económica} + \text{Producción Nacional de Barriles de Petróleo})$

Gujarati et al. (2010) stated that the ordinary least squares method of the German mathematician Carl Friedrich Gauss is considered the classical or standard model of linear regression – MCRL, this being the basis of econometric theory, on which the simple regression and multiple regression models are generated, a model in which there is more than one explanatory or regressive variable.
Generalizing the population regression function (PRF):

(1) $Y_t = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \mu_t$

For the purposes of notational symmetry:

(2) $Y_t = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \mu_t$

Y is the dependent variable, X1, X2, and X3 are the explanatory variables, β1, β2, and β3 are called the partial regression coefficient, μ is the stochastic perturbation term, and t is the t-th time-series observation.
Gujarati et al. (2010) described that the term multicollinearity is attributed to Ragnar (1934), who called multicollinearity the "perfect" or exact linear relationship between some or all of the explanatory variables of a regression model.
Stock et al. (2012) stated that perfect multicollinearity is manifested when one of the regressors is a perfect linear combination of the rest of the regressors, whereas imperfect multicollinearity occurs when one of the regressors is very highly correlated, but not perfectly correlated, with the other regressors. Imperfect multicollinearity differs from perfect multicollinearity because it does not prevent the estimation of regression, nor does it imply a logical problem in the selection of regressors.
Partial correlation is an estimation of the relationship between two variables by removing from them the effects of another mediating or intervening variable, this premise is what enables the use of the partial correlation matrix to establish the existence of a perfect multicollinearity.
Farrar et al. (1967) propose that the partial correlation coefficients should be observed in the regression of Y over X2, X3 and X4; if they are found to be very high, but , and are comparatively low, this may suggest that the variables X2, X3 and X4 are highly intercorrelated and that at least one of these variables is superfluous$R^2_{1.234} r^2_{12.34} r^2_{13.24} r^2_{14.23}$3 (Gujarati et al., 2010).
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the variables X$R^2_{1.234}r^2_{12.34}r^2_{13.24}r^2_{14.23}$[2], X3 and X4 are highly intercorrelated and that at least one of these variables is superfluous[4] (Gujarati et al., 2010).

Wooldridge (2010) establishes the assumption of homoscedasticity when the variance of the unobservable error, conditional on the explanatory variables, is constant. White (1980) establishes a test that aims to test the forms of heteroskedasticity that invalidate the usual standard errors of Ordinal Least Squares (OLS) and the usual test statistics.μ

If the model contains k = 3 independent variables, White's test is based on

(3) $$\hat{u}^2 = \delta_0 + \delta_1 X_1 + \delta_2 X_2 + \delta_3 X_3 + \delta_4 X_1^2 + \delta_5 X_2^2 + \delta_6 X_3^2 + \delta_7 X_1 X_2 + \delta_8 X_1 X_3 + \delta_9 X_2 X_3 + error$$

White's test for heteroskedasticity is the ML statistic5 to prove that all in the equation are zero, except for the intercept, proving as such nine constraints. This hypothesis can be used in test F; both tests have asymptotic justification (Wooldridge, 2010). Ordinal Least Squares – MCO and the usual test statistics.δ_j

For the analysis of the data pursued by this document, Eviews 9 was used as econometric software, which presented the results of the contrasts for the development of the results.

3. RESULTS AND DISCUSSION

The variables under study show a positive slope within the period studied, with a notorious irregular trend in the variables index of economic freedom, CO2 per capita and GDP per capita, which present notorious maximum and minimum critical points, which denotes how susceptible these variables are to economic and population increase despite their positive slope. (Figure 1).

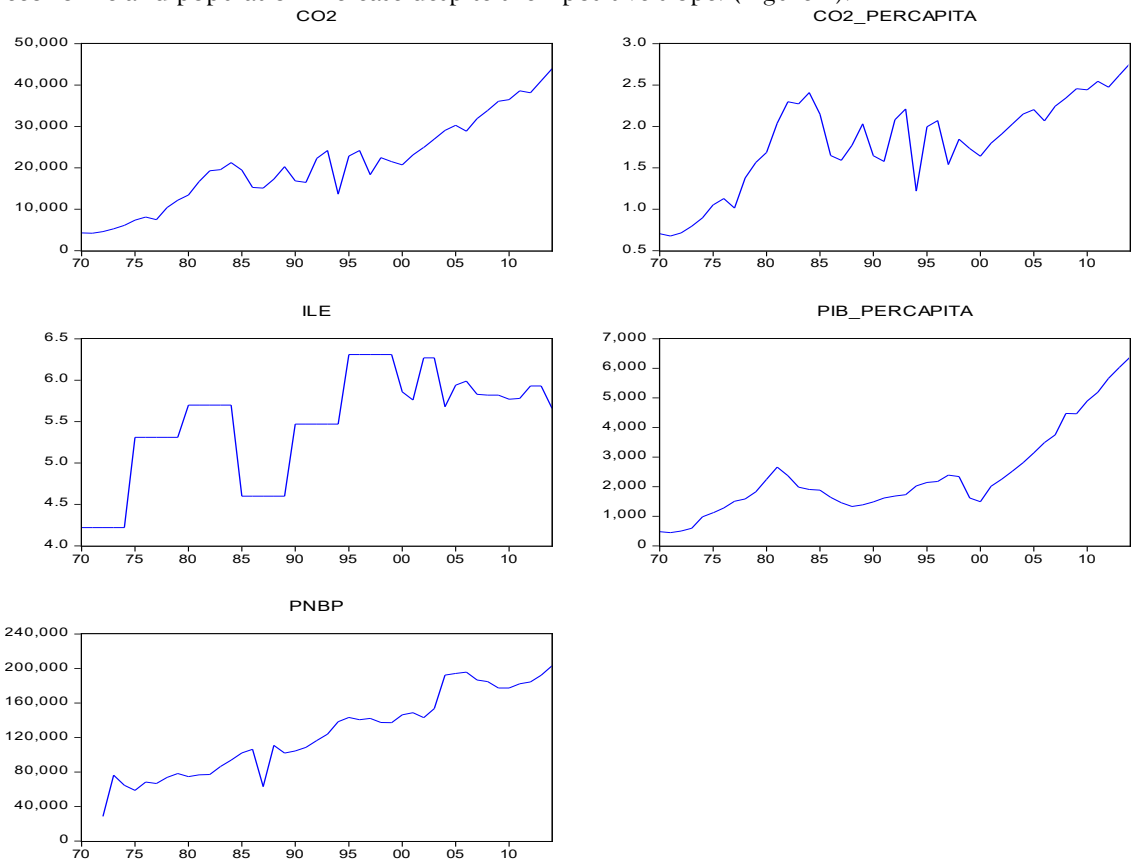

Fig. 1. CO2, CO2 per capita, GDP per capita, index of economic freedom and the National Production of Oil Barrels

The first model favors the result of the values obtained in R2 achieving greater coverage in terms of explanatory capacity, Prob (F-statistic) which seeks a reduction in the probability of committing type I error and the non-existence of serial correlation that evaluates the Durbin-Watson test when determining an independence of the data; placing them above the values obtained in the Akaike info criterion and Schwarz criterion tests, which have a relatively high value (Table 1).

Table 1. Parameter Estimation and Statistical Testing

R2	Prob (F-statistic)	Durbin-Watson	Akaike	Schwarz
0.917163	0.000000	1.418035	18.95153	19.11536

The partial correlation matrix demonstrates the non-existence of multicollinearity since the independent variables studied are not closely related, none of them presenting a value greater than 0.8 (Table 2). Despite this, there is a close relationship between the dependent variable CO2 and the independent variables GDP per capita and National Production of the Oil Barrel.

Table 2. Partial Correlation Matrix

	CO2	ILE	PIB_PERCAPITA	PNBP
CO2	1			
ILE	0.571113	1		
PIB_PERCAPITA	0.905279	0.473972	1	
PNBP	0.904236	0.615561	0.786249	1

The White test corroborates the assertion that the model studied is homoscedastic, that is, that the perturbations have the same variance, and this is constant for the different regressors, (Table 3).

Table 3. White's Test

Heteroskedasticity Test: White			
F-statistic	0.941158	Prob. F(20,23)	0.5038
Obs*R-squared	8.782840	Prob. Chi-Square(20)	0.4576
Scaled explained SS	7.079044	Prob. Chi-Square(20)	0.6289

The final model is CO2 = *f* (GDP per capita + index of economic freedom + National Production of Oil Barrels), which in terms of substitution of coefficients generates the result.

(3) CO2 = 528.698471673*ILE + 3.55754556684*PIB_PERCAPITA + 0.102794080062*PNBP - 2985.45037827

The results show an analysis and interpretation within the ordinal range as there are no alterations in the variables that are part of the aforementioned model. The value expressed by the term stochastic perturbation does not contribute directly to the development of CO2, unlike the variables taken into account for the analysis that contribute to the production of carbon dioxide, mainly the index of economic freedom.

This equation shows a standard deviation of 2909.01; an asymmetry coefficient close to zero and a kurtosis that tends to three, values that corroborate what was shown by the Jarque-Bera test which establishes a proximity to the normal distribution with estimators of Maximum Likelihood (Figure 2).

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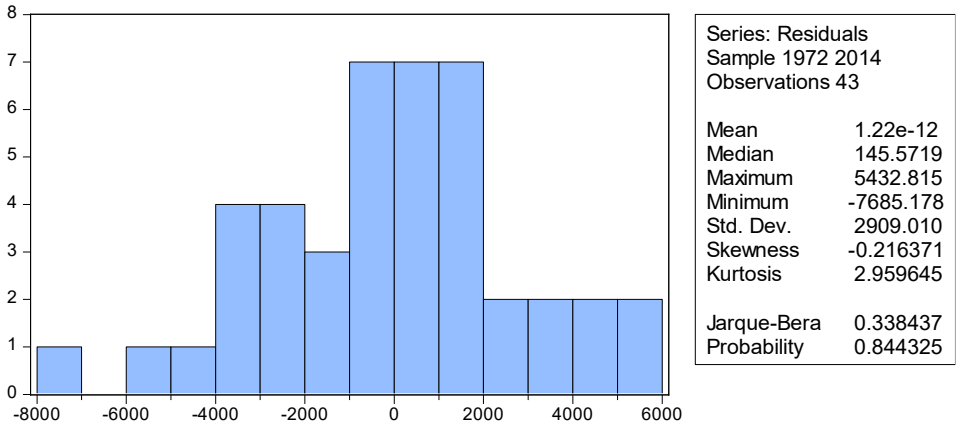

Fig. 2. Histogram – Model 1. Normality Test

The second model presents relatively unfavorable results of the values obtained, R2 presents a low coverage in terms of explanatory capacity, Prob (F-statistic) shows a reduction in the probability of committing type I error, the Durbin-Watson test exposes the possible existence of positive autocorrelation, together with low values obtained in the Akaike info criterion and Schwarz tests (Table 4).

Table 4. Parameter Estimation and Statistical Testing

R2	Prob (F-statistic)	Durbin-Watson	Akaike	Schwarz
0.634310	0.000000	0.828682	0.661682	0.825514

The partial correlation matrix shows the non-existence of multicollinearity since the independent variables studied are not closely related, none of them presenting a value greater than 0.8 (Table 2).

Table 2. Partial Correlation Matrix

	CO2_PERCAPITA	ILE	PIB_PERCAPITA	PNBP
CO2_PERCAPITA	1			
ILE	0.529874	1		
PIB_PERCAPITA	0.768256	0.473972	1	
PNBP	0.707426	0.615561	0.786249	1

The White test corroborates the assertion that the model studied is homoscedastic, that is, that the perturbations have the same variance, and this is constant for the different regressors, (Table 3).

Table 3. White's Test

Heteroskedasticity Test: White			
F-statistic	1.557601	Prob. F(20,23)	0.1693
Obs*R-squared	12.82033	Prob. Chi-Square(20)	0.1709
Scaled explained SS	9.128621	Prob. Chi-Square(20)	0.4255

The final model is CO2 per capita = *f* (GDP per capita + index of economic freedom + National Production of Oil Barrels), which in terms of substitution of coefficients generates the result.

(4) CO2_PERCAPITA = 0.137049071733*ILE + 0.000198425159859*PIB_PERCAPITA + 1.81660180446e-06*PNBP + 0.387319505091

The results show an analysis and interpretation within the ordinal range as there are no alterations in the variables that are part of the aforementioned model. The variables have a common denominator by contributing positively to the production of Carbon Dioxide, mainly the national production of barrels of oil.

The second equation shows a standard deviation of 0.310; and it is related to the first by presenting an asymmetry coefficient close to zero and a kurtosis that tends to three, values that corroborate what was shown by the Jarque-Bera test which establishes a proximity to the normal distribution with estimators of Maximum Likelihood (Figure 2).

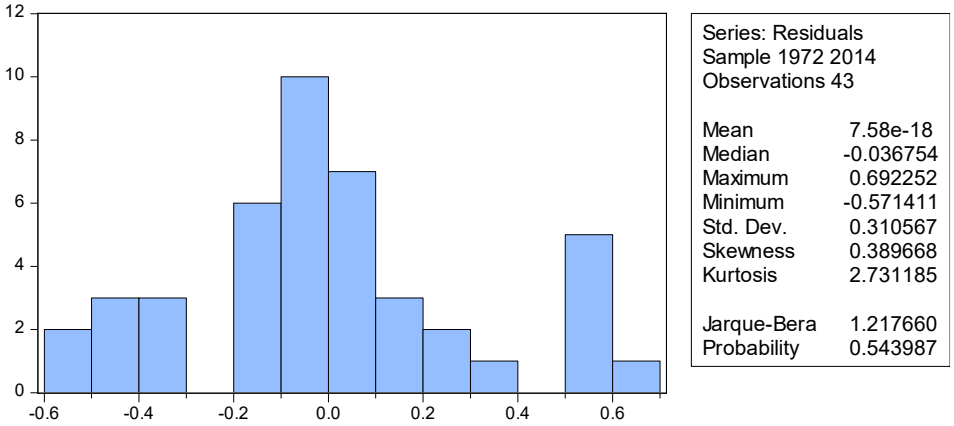

Fig. 2. Histogram – Model 2. Normality Test

III. CONCLUSIONS

There is an empirical relationship between the levels of environmental pollution in countries and their scope in terms of economic development, without establishing the existence of a direct and constant relationship or an inverted relationship either in U, V or N.

Statistical analysis shows that, in the case of Ecuador, CO2 production is in the first stage of the environmental curve.

The models under study differentiated only by the dependent variable are similar, although the one that presents CO2 per capita as the response variable does not have a high explanatory capacity.

There is a direct and influential relationship between the freedom of the rule of law, the size of the government, regulatory efficiency and the openness of markets, expressed in the index of economic freedom and the exploitation of CO2 in the environment of the Ecuadorian territory. While Ecuador has a higher degree of economic freedom, it generates 528.69 kilotons of CO2 in the environment.

In the case of CO2 per capita, the national production of barrels of oil is the most influential variable. By increasing an additional barrel of oil from national production, it generates 1.82 tons of CO2 per inhabitant.

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