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Relationship between economic growth, population and environment: empirical evidence from Ecuador

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Abstract

The main purpose of this research is to identify the relationship between: Economic growth, environmental and demographic variables for a developing country. World Bank data are used for the period 1960-2016. The methodology is based on structural equations and a Vector Autoregressive (VAR) econometric model. Johansen cointegration and Granger causality tests were performed. The results show that the variables are cointegrated. There is a statistically significant long-term relationship between the proposed variables, in addition, one-way direction.

Keywords: Economy and Environment, Climate Change, Industrial Production, Development countries, Sustainability.

Introduction

Current development is conditioned by the environmental degradation that it causes. The relationship between natural resources and the modern development process cannot be avoided (Begum et al. 2015). Energy consumption has spread within industries, increasing the supply of energy in order to improve production or maintain lifestyle, regardless of the countries analyzed (Alam et al. 2016). The increase in carbon dioxide (CO2) emissions into the atmosphere is attributed to different causes. For a group of scientists, energy consumption is responsible for (CO2) emissions, which is one of the main causes of the creation of greenhouse gases in the atmosphere (Alam et al. 2016)This increase in energy consumption is attributed to the increase in production given by economic growth and human well-being (Alshehry y Belloumi 2015). In this sense, there is an important concern about whether the objectives of economic growth and the improvement of environmental quality are mutually exclusive actions (Begum et al. 2015).

According to Alshehry and Belloumi (2015) the endowment of fossil resources causes an overuse of energy and high levels of CO_2 emissions . Ecuador, having an important share of fossil resource extraction within the region, requires studies that analyze economic growth, CO_2 emissions, energy consumption and population growth. The review of the previous literature shows that in Ecuador there is no collection of in-depth studies on this subject, thus detecting a problem that can be attacked through this study and a series of future investigations related to the subject.

According to the Hydrocarbon Regulation and Control Agency (ARCH 2018), Ecuador currently extracts oil from 3,453 wells, at an equivalent of 517,841.75 barrels of oil per day, natural gas production is 34,458,840 cubic feet of natural gas. The Ecuadorian economy is highly dependent on the extraction of fossil fuels. The current GDP of Ecuador in 2017 was 103,059 million dollars, where oil extraction and refining activities contribute 5.13% (Banco Central del Ecuador 2018).

According to data from the World (Banco Mundial 2018) the CO2 emissions into the atmosphere by Ecuador correspond to 43,920 kt in 2014. The consumption of electricity per capita in Ecuador during the year 2014 was 1380, 61 kWh. While the population of Ecuador is currently 16,769,722, with a growth rate of 1.5% per year (INEC 2018).

Previous studies in Ecuador have dealt with the relationship between polluting emissions, economic growth and energy consumption (Rentería et al. 2016); however, these studies do not consider population growth. Other related works analyze the case of Brazil, China, India and Indonesia (Alam et al. 2016); Saudi Arabia (Alshehry y Belloumi 2015); Malaysia (Begum et al. 2015); South Africa (Shakouri y Yazdi 2017); United States of America (Arora y Shi 2016); Countries in transition (Romero, Sánchez-Braza, y Galyan 2018); Countries of the Organization for Economic Cooperation and Development (OECD) (Cho, Heo, y Kim 2015) among others.

This work has as its main objective to identify the relationship between economic growth, CO2 emissions, energy consumption and population growth. Due to the lack of related studies within the Ecuadorian context, this work contributes to the previous literature in two ways: on the one hand, by expanding the series of data analyzed (1960-2016); and mainly by including the Demographic Growth variable within the study of CO_2 emissions, Energy Consumption and Economic Growth. This variable has not been taken into account in previous works related to the subject, thus, it is the first time that the four variables mentioned have been analyzed using data from the Ecuadorian economy. As a strategy to verify the existing relationship, the work uses data from the World Bank, which, after being refined the series, proposes a series of structural equations which are estimated by the Vector Autoregressive (VAR) method, to later be tested the test of Johansen cointegration, thus allowing to identify the long-term relationship between economic growth and the regressive variables proposed in the model.

The work is organized as follows. Following the introductory section; Section 2 carries out a theoretical review of the main related previous works. Section 3 describes the methodology and sources of information used. In section 4, the main results obtained from the methodological application are analyzed. Finally, in section 5, the conclusions of the study are presented.

Theoretical framework

Economic growth and environment.

Economic development is basically created by a society which is carried by an ecological system for the life of living beings, in this way we cannot understand or manage an economy without understanding the importance of the interconnection as a whole of these three systems (Costanza 1991). At the same time, growth and development do not always go hand in hand and true development should be defined in terms of the improvement of sustainable well-being, but not only an improvement in the consumption of material or luxury items. (Costanza et al. 1997). According to Daly and Farley (2004) individuals should seek a balance of four basic aspects of capital for the development of human well-being which are: human capital, natural capital, social capital and construction capital (financial capital is only a standard for capital development and should be handled as such). This association between these capitals is essential to find a balance in economic, social and environmental matters, which helps a society achieve prosperity within its physical, social and psychological space.

The environment is the fundamental basis for the development of biological and leisure activities of all living beings. However, human beings have become a critical factor when seeking harmony with their environment and other species. Historically, the recognition of the impact on Earth by humans has lagged behind due to the magnitude of the deterioration that has been generated and has weakened all efforts to control the damage caused by their own species (Costanza et al. 2007). This effect on earth has been generated due to the unlimited needs that human beings have, compared to the limited resources that the planet provides. It is for this reason that it is urgently needed to change the model of economic growth in which a balance is developed including the environment and society when developing activities that are environmentally friendly and promote sustainable and reasonable growth.

On the other hand, John Elkington British researcher entrepreneur creator of the three pillars of sustainability mentions that the growth of an economy does not have to be based solely on the monetary aspect, but should also be integrated into society and more importantly the planet which It provides us with the resources to develop our economy. In this way, it creates a sustainable methodology known as People, Planet & Profit (Elkington 1998), which refers to the fact that one element cannot function without the existence of another, thus creating an interdependence. This new method has been considered within the business sector in developed countries as a vital part of their daily practices, thus contributing to the reduction of the impact on the environment in terms of degradation and global warming.

Many factors that are part of our economic development have also been related to environmental degradation and the Kuznets Curve in reference to the environment. (Panayotou 2003) suggests that the inverted U-shape of the Kuznets curve reflects a mixture of scale, composition, and technical effects. First, when a society is in an early stage of development, from a pre-industrial phase, rudimentary development and inefficient industries result in a scale of effects and pollution. Second, there is a transition to industrial pollution and finally to the service sector, where composition effects reflect economic growth in sectors where pollution is lower. With high income levels, industrial production is discontinued in favor of more advanced technology and service-oriented production (technical effects) (Hussen 2004).

This evolution implies that pollution levels may not increase in scale with economic growth, if the composition of resource output changes (Vukina, Beghin, and Solakoglu, 1999). In other words, in early stages of economic growth, environmental pollution levels increase until a further turning point is reached, whereby economies experience reductions in pollution levels. Therefore, the Kuznets Curve reflects a relative strength between scale and technical effects (Brock and Taylor, 2005), through which the production of highly technological and productive economic systems contributes to the decrease in pollution levels (Dinda 2004). Under this hypothesis, the technical effects allow the possibility that while countries grow, cleaner technologies supplant other more polluting technologies within the production processes (Hussen 2004).

From this perspective, economies will increase their innovation to avoid technical obsolescence in the energy sector. This, in accordance with the yields generated by cleaner technologies, will cause demand to increase, generating greater benefits for society and the environment (Lorente y Alvarez-Herranz 2016). When the total effect between the relationship between economic growth and environmental pollution is divided, technical effects are the main factor in reducing environmental pollution (Andreoni y Levinson 2001). Finally, the technical effects include the impact of the transfer of knowledge or know-how and advanced technological performance in the environment, causing pollution to increase, unless environmental regulations are stricter to control industries. and global economies (Dasgupta, Hettige, y Wheeler 2000).

On the other hand, an N-shaped Kuznets Curve predicts an increase in the relationship between income and environmental pollution over time (Grossman y Krueger 1995; Moomaw y G.C. 1997; Selden y Song 1994; Shafik 1994; Torras y Boyce 1998). This relationship appears when the connection between economic growth and environmental degradation initially demonstrates a positive effect. However, this relationship becomes negative once the limit of a given monetary income is reached, before it becomes positive again. This aspect assumes that environmental degradation increases (income-minimum) in the initial stage of economic development and then decreases after the required income is reached. Finally, degradation starts to grow again in a third stage marked by high income but low-income growth is measured, as a technique of obsolescence and thus increases the effect of scale when it resurfaces and overcomes composition and technical effects before to get to the second important point of money income. In this case, technical obsolescence leads to a reappearance of increased pollution levels once scale effects exceed composition and technical effects (Lorente y Alvarez-Herranz 2016; Álvarez-Herránz, A., Balsalobre, D., Cantos, J.M., Shahbaz 2017) Next, the relationship between economic growth and energy use is analyzed.

Economic growth and electrical energy.

The review of the literature allows us to identify empirical works that relate energy consumption and economic growth. Most of the studies carried out assess both the role of energy in promoting economic growth and whether energy consumption induces economic growth or decline for individual countries or a group of countries and between developing and developed countries. In this context, Rathnayaka, Seneviratna, and Long (2018) identify some dynamic relationships between economic growth and energy consumption, differentiating four categories: i) unidirectional causality; ii) inverse relationships; iii) bidirectional causality; iv) no causal relationship between these two variables.

Romero et al., (2018) analyze the relationship between economic growth and residential energy consumption in 12 economies in transition during the period 1995-2013, evaluating the Environmental Kuznets Curve (EKC) hypothesis. The estimated results were consistent with the EKC hypothesis, showing that for low-income countries, economic growth has been reducing residential energy consumption. However, for countries with higher income values, economic growth has increased residential energy consumption (Romero, Sánchez-Braza, y Galyan 2018).

For their part, Cho et al., (2015) compare, through a multivariate panel model, the long-term causal relationship between the consumption of renewable energy and the economic growth of 31 countries of the Organization for Economic Cooperation and Development Economic (OECD) and 49 non-OECD countries, for the period 1990-2010. The results showed that the conservation hypothesis of a causal relationship between renewable energy consumption and economic growth is valid in the long term for OECD countries. On the one hand, in developed countries, renewable energy has not played an important role in economic growth, but rather has been growing based on economic growth. In contrast, for less developed countries, renewable energy has played an important role as a production input; Similarly, economic growth has led to increased consumption of renewable energy (Cho, Heo, y Kim 2015).

On the other hand, Barreto and Campo (Alberto y Nieto 2012) studied through a non-stationary and cointegrated panel data model, the long-term relationship between energy consumption and GDP in some Latin American countries for the period 1980 - 2009, adding other control factors such as capital and labor. They proved the existence of a unidirectional causal relationship between this set of variables. The results showed that at the regional level, a 1% increase in energy consumption generates a long-term increase in GDP of 0.40%.

Arora and Shi (2016), using a multivariate model, found that Granger causal relationship between total energy and real GDP in the United States in the period 1973–2014 is bidirectional, especially during much of the 1990s. For each fuel, similar patterns of change were observed in the causal relationship between coal consumption and real GDP in the United States. Oil consumption largely showed a two-way relationship between consumption and GDP, especially after 2009, and natural gas consumption also shows this behavior in the first half of the 2000s where US GDP predicts gas consumption.

Similarly, Shakouri and Yazdi (2017) examined the relationship between economic growth, renewable energy consumption, energy consumption, fixed capital formation, and trade openness for the period 1971-2015 for South Africa. The study used the autoregressive distributed delay testing (ARDL) approach. The results showed that the variables were cointegrated, indicating the existence of a long-term bidirectional relationship between them. A strong interdependence between renewable energy consumption and economic growth was evidenced, indicating that renewable energy is important for economic growth, and that economic growth encourages the use of a more renewable energy source.

Mudarissov and Lee (2014) investigated the causal relationship between energy use and economic growth in the Republic of Kazakhstan during 1990-2008, using the Granger causality test, Dickey-Fuller, and Phillips-Perron unit root tests augmented and the cointegration test. The results showed the existence of bidirectional causalities ranging from energy consumption to economic growth and from economic growth to long-term and short-term energy causality, respectively. In the short run, the causality runs from GDP to energy consumption, and in the long run, energy consumption causes economic growth.

Finally, Destek and Okumus (2017) evaluated, using the panel data bootstrap causality approach , the relationship between energy consumption (oil, natural gas and coal) and economic growth in the G-7 countries during the period 1970 to 2013. The results showed that oil consumption causes economic growth in Germany, Italy, Japan and the United States; economic growth causes oil consumption in Germany and the UK; natural gas consumption causes economic growth in Italy, Japan, the United States and the United Kingdom; economic growth causes natural gas consumption in Germany; coal consumption causes economic growth in Canada; and economic growth causes coal consumption in the United States.

Demographics and environment

In the midst of the Industrial Revolution, at the end of the 18th century, when a more efficient production of food was achieved, as well as medical advances in aspects of hygiene, which affected the demographic growth of a population constantly affected by food crises and infectious and contagious diseases. Malthusian fear of a demographic catastrophe is raised (Vargas 2011).

While population projections are complex, the resulting economic impact of the demographic transition is even more so. To Golley and Tyers (2013) the standard Solow-Swan growth model is essentially pessimistic, with the assumption that declining factor returns and constant labor participation rates in an ageless population ensure that slower population growth reduces GDP growth, but increases per capita income growth.

This is how studies about the way in which the population intervenes in the environment have advanced from the environmental dimension of sustainable development, in the project of an environmental demography, through which it is sought to overcome the simple vision that the relationship population-environment is summarized in the pressure that a large population exerts on resources, and not forgetting that environmental changes also impact the population (Vargas 2011).

Thus, the accelerated growth of the world population is a relatively recent phenomenon. According to some estimates, from the beginning of our era until the year 1000, the population had not exceeded 300 million people, but only 500 years later, the number of inhabitants had already grown, according to various estimates, to between 424 and 484 million. In 1750, this number had already increased by just over 200 million reaching about 700 million people. By the beginning of the 20th century, this population had increased a little more than twice, reaching 1.55 billion inhabitants (Caldwell y Schindlmayr 2002)

With which, the most accelerated growth began in 1950, promoted mainly by the increase in the birth rate and the decrease in mortality (due to a greater use of vaccines, antibiotics and insecticides) in developing regions (Semarnat 2012).

Demographic transition and economic growth

Global environmental degradation has inspired more and more researchers to address the causes of environmental degradation. There is a complex relationship between environmental changes and their driving forces, including economic growth and environmental degradation (McPherson y Nieswiadomy 2005).

Many international organizations recognize environmental degradation as one of the main threats facing the planet, as humans have only been given one Earth to work on, and if the environment becomes irremediably compromised, it could mean the end of human existence. (McMahon 2018)

In another perspective, when the environment becomes polluted, it means that toxic substances have made it unhealthy. Pollution can come from a variety of sources, including vehicle emissions, agricultural runoff, accidental release of chemicals from factories, and poor harvesting management of natural resources. In some cases, the contamination may be reversible with costly environmental remediation measures, and in other cases, it may take decades or even centuries for the environment to deal with the contamination (McMahon 2018).

The relationship between growth and the environment has been studied both empirically and theoretically. The most relevant results indicate that world production per person increased at a rate of 1.4% per year between 1870 and 2000, and recorded the highest growth (4%) in the last century (Maddison 2003).

In fact, some studies indicate that certain non-renewable resources are about to be depleted (Clugston 2012).

Thus, Gómez-López, Barrón and Moreno (2011) from the point of view of economic theory, as the economies grow up worry more about the state of the environment and the preservation of natural resources. In this way, there is a relationship between economic growth and preservation of natural resources.

As additional data we can mention that at the beginning of the 90s the relationship shown by the Kuznets curve finds application in new fields of analysis; and it is concluded that the relationship between some pollution indicators and per capita income can be represented as an inverted U. This relationship was then known as the environmental Kuznets curve; This new curve reveals that some pollution indicators have improved, as a consequence of the increase in income and consumption, which is quite similar to an inverted U.

In this framework, it is generally assumed that richer economies damage and destroy natural resources faster than poor economies, given their consumption, that is, environmental degradation tends to increase as the economic structure of a country increases. or region changes from an agricultural economy to an industrial one, and subsequently, this degradation tends to decrease as one moves from an intensive industrial sector to a service-based economy (Grossman y Krueger 1995).

Methodology

This research aims to identify the relationship between economic growth, CO2 emissions, energy consumption and population growth, in this sense the data has been collected and processed in order to propose a model and its different validation tests.

Data

World Bank's World Development Indicators (WDI) database. Once the data was validated, the variables described below were constructed:

Dependent variable

- GDP per capita (GDPPC) measured in dollars at constant 2010 prices, this variable is used as a proxy for economic growth.

Independent variables

- CO $_2$ emissions (CO_2), measured in metric tons per capita;
- Total population of the country (POB);
- Consumption of electrical energy (CENEL) measured in kWh per capita.

As a strategy to normalize the distance between the variables, the natural logarithm was applied to the proposed variables.

Model Specification

An econometric model and a set of tests were considered as analysis methods. The model allowed estimating the type and measuring the relationship between the specified variables, the Vector Autoregressive (VAR) model has been proposed, which has been estimated through the Johansen cointegration method. The specified model, among other virtues, has the following characteristics: i) they allow a better understanding of the relationship that exists between a set of variables; ii) no restrictions are imposed on the coefficients of the model; iii) it allows estimation through the Ordinary Least Squares (OLS) method; iv) it is not necessary for all variables to be 100% exogenous.

In general, this type of model allows specifying a model where all the variables are considered as endogenous, without restrictions and which is equivalent to a multi- equation model in its reduced form.

GDPpc is measured as a linear function according to the following equation:

$$PIBPCt = f(CENELt, CO2t, POBt) \quad \text{(YO)}$$

In order to determine the long-term relationship between economic growth, energy consumption, CO_2 emissions and population, the following logarithmic linear form is proposed:

$$LnPIBpct = \alpha 0 + \alpha 1LnCENELt + \alpha 2LnCO2t + \alpha 3LnPOBt \quad \text{(II)}$$

To continue with the next phase of analysis, the integration and stationarity of the GDPpc, CENEL, CO_2 and POB variables have been measured using the Dickey and Fuller (1979) unit root tests and Perron and Phillips (1988), in levels and in first differences, with intercept and with intercept and trend, based on Halicioglu (2009) and Saboori and Soleymani (2011).

On the other hand, since the variables are stationary in the first difference, the autoregressive distributed cointegration technique (ARDL) or the Johansen method can be used; however, if one or more variables are stationary at the level and others at the first difference, then the Johansen method cannot be used, but the ARDL can be used to examine the long-run relationship between a set of predetermined variables. In this context, due to the fact that, in the present investigation, all the variables have been integrated in the first differences I (1), the cointegration method of Johansen (1988) will be used, through which the results for the analysis of cointegration between GDP per capita and their respective regressors. The general Johansen cointegration model is represented by the following equation:

$$lnPIBPCt = \alpha 0 + \sum_{i=1}^{n} \alpha 1i\, \Delta LnPIBpct - i + \sum_{i=1}^{n} \alpha 2i\, \Delta LnCENELt - i + \sum_{i=1}^{n} \alpha 3i\, \Delta LnCO2t - i + \sum_{i=1}^{n} \alpha 4i\, \Delta LnPOBt - i + \mu t \quad \text{(III)}$$

Given that the predetermined series turn out to be integrated of the same order, the Johansen method proposes estimating a Vector Autoregressive (VAR) model for the vector of parameters, as detailed in equations (IV), (V), (VI) and (VII).

$$ln\, PIBpc_t = \beta_0 + \sum_{i=1}^{a} \beta_1\, lnPIBpc_{t-i} + \sum_{i=1}^{a} \beta_2\, lnCENEL_{t-i} + \sum_{i=1}^{a} \beta_3\, lnCO2_{t-i} + \sum_{i=1}^{a} \beta_4\, lnPOB_{t-i} + \mu_1 \quad \text{(IV)}$$

$$ln\, CENEL_t = \beta_0 + \sum_{i=1}^{a} \beta_1\, lnCENEL_{t-i} + \sum_{i=1}^{a} \beta_2\, lnPIBpc_{t-i} + \sum_{i=1}^{a} \beta_3\, lnCO2_{t-i} + \sum_{i=1}^{a} \beta_4\, lnPOB_{t-i} + \mu_1 \text{(V)}$$

$$ln\, CO2_t = \beta_0 + \sum_{i=1}^{a} \beta_1\, lnCO2_{t-i} + \sum_{i=1}^{a} \beta_2\, lnPIBpc_{t-i} + \sum_{i=1}^{a} \beta_3\, lnCENEL_{t-i} + \sum_{i=1}^{a} \beta_4\, lnPOB_{t-i} + \mu_1 \text{(SAW)}$$

$$ln\,POB_t = \beta_0 + \sum_{i=1}^{a} \beta_1\, lnPOB_{t-i} + \sum_{i=1}^{a} \beta_2\, lnPIBpc_{t-i} + \sum_{i=1}^{a} \beta_3\, lnCENEL_{t-i} + \sum_{i=1}^{a} \beta_4\, lnCO2_{t-1} + \mu_1 \text{(VII)}$$

Results and Discussion

Below are some results resulting from the application of the methodology described in the previous section. Table 1, shows the main descriptive statistics of each of the variables considered to estimate the econometric model. It should be noted that, to carry out the estimation, all the variables were converted to a natural logarithm in such a way that their distances are reduced and the data is manageable. It is observed that the number of observations is different in each of the analyzed variables, this is fundamentally due to the existing difficulty at the moment of finding data, the series come from different sources, as indicated in the previous section.

Table 1.*Descriptive statistics of the variables***.**

Variable	Observations	Half	Standard deviation	min	Max
GDPPC	57	3637,624	869.0212	2215.092	5428,714
CO2 _	55	1.559526	.7356771	.3253365	2.761702
CENEL	44	602.3148	337.1029	144.5069	1380.61
POP	57	9994361	3614323	4545550	1.64e+07

Table 2, shows the results of the ADF and PP tests for the variables, which indicate that all the variables are non-stationary in I (0) and stationary in their first differences I (1). In both tests, the null hypothesis that a series has a unit root is tested against the alternative of stationarity in the series. The table shows that the first differences of the variables are statistically significant at 1% in the case of most variables, except in the case of the population where it is at 5%. These results confirm the results of the work by Rentería et al. (2016) and also confirm the existence of a relationship between the population variable within the study.

Table 2.*Unit root test*

	Augmented Dickey -Fuller Test		**Philips- Perron Test**	
Variable	**intercept**	**intercept & trend**	**intercept**	**intercept & trend**
Ln GDPPC	-1.414138	-1.974463	-0.990592	-1.751857
LnCO2	-2.623190	-1.502088	-1.615708	-1.661514
Ln CENEL	-1.950084	-2.249990	-1.721184	-2.287942
Ln POP	-2.299731	0.423659	-12.31736***	1.810774
△ ln GDPPC	-4.979334***	-4.976181***	-5.058619***	-5.048435***
△ In CENEL	-4.628893***	-4.817918***	-4.628893***	-4.800664***
△ In CO2	-3.974725***	-8.766624***	-9.117578***	-9.651402***
△ ln POP	-2.987556**	-3.523269**	-2.973564**	-3.534991**

Note: △ indicates the first differences and ** denotes significance level at 5% and *** at 1%, respectively.

Table 3, presents the results of the Johansen cointegration test, which determine the existence of one or more cointegration vectors.

Once the non-stationary series were transformed into stationary series through their first differences, the Johansen cointegration method allowed us to estimate a Vector Autoregressive (VAR) model according to the previously specified system of equations.

As part of the process of the Johansen cointegration test, the statistics of the Trace and Max Eigen tests are presented, which allowed identifying the presence of at least two cointegration vectors. In the same way, the null hypotheses of no cointegration are rejected, which allows establishing a statistically significant ($p<0.05$) long-term linear relationship between GDP per capita (GDPPC) and CO_2 emissions, the total population of the country (POB) and electricity consumption (CENEL).

In this sense, according to the analysis of the literature and empirical evidence reviewed, the existence of a long-term relationship between the proposed variables is confirmed, thus reaffirming previous work carried out in other economies (Pao y Tsai 2011; Alshehry y Belloumi 2015; Begum et al. 2015). Among other consequences, these results mean that in the long term the relationship properties between these variables remain stable, that is, their means and variances remain constant over time.

Table 3. *Evaluation of the statistics of the Trace and Max-Eigen test - (Johansen's cointegration method)*

null hypothesis	**Eingen value**	**trace statistics**	**Critical value**	**Prob.* ***
None *	0.719435	126.2051	63.87610	0.0000
At most 1*	0.575779	72.82513	42.91525	0.0000
At most 2*	0.480279	36.81010	25.87211	0.0015
	Eingen value	Max- Eigen Statistics	Critical value	Prob.* *
None *	0.719435	53.37992	32.11832	0.0000
At most 1*	0.575779	36.01504	25.82321	0.0016
At most 2*	0.480279	27.48743	19.38704	0.0027

Note: *denotes rejection of the null hypothesis at 1% and ** MacKinnon-Haug-Michelis (1999) p-values

In the same way, as a determining factor within the cointegration analysis, it was possible to identify the cointegrating vector that best fits the Trace and Max-Eigen test, with equation (VIII) being the optimal vector.

Cointegrating vector that best fits the Trace and Max - Eigen test:

$$LnPIBt = -0.169799 + 1.843109\,LnCENELt - 1.410820\,LnCO2t + 3.666083\,LnPOBt \quad \text{(VII)}$$

Since GDP per capita is cointegrated with its regressors in the model, the long-term parameters are estimated and the results are presented in Table 4.

As evidenced, most of the estimated coefficients have the expected theoretical or hypothetical signs. These results allow capturing the effect of energy consumption, CO_2 emissions and population growth on economic growth.

Table 4. *Estimated Regression Statistics (Johansen Cointegration Method)*

Dependent variable Variable	Coefficient	Ln GDPPC standard error	t-ratio
Ln CENEL	1.843109	0.28813	6.39679**
Ln CO2	-1.410820	0.15422	9.14979**
Ln POP	3.666083	0.72848	5.03251**
C	-0.169799	0.022228	7.621140**

Note: **Significance at 5%

When analyzing the optimal regression coefficients, it should be noted that the energy consumption coefficient (LnCENEL) is positive and statistically significant at 5%; that is, as energy consumption increases, GDP per capita also increases in the long run. This implies that, with a 1% increase in energy consumption, GDP per capita will increase by around 1.84%. These results confirm the previous works of Cho (2015); Romero (2018).

However, the relationship (negative) between CO_2 emissions ($LnCO_2$) and GDP per capita is not as expected, because in the long term as CO_2 emissions increase, GDP per capita decreases, although the coefficient is also statistically significant at 5%. This relationship assumes that with a 1% increase in CO_2 emissions, GDP per capital will decrease by approximately 1.41%. This result for the Ecuadorian case is contrary to previous studies carried out by (Alam et al. 2016; Alshehry y Belloumi 2015; Begum et al. 2015; Rentería et al. 2016). However, they could be explained by the increase in the costs associated with pollution, which in some way affect national income, that is, the Ecuadorian economy ends up internalizing these costs, causing a negative effect on the country's economic growth. This is a very relevant result since in the previous literature this variable presents another behavior, however the natural wealth of Ecuador could be an unbalancing element. Additionally, it should be noted that there are no previous studies that measure this variable in mega-diverse countries such as Ecuador (PNUMA 2016).

On the other hand, the impact of population size (LnPOB) on GDP per capita is also positive and statistically significant at 5%. This means that if the country's population increases, there will be positive long-term economic growth. Specifically, with a 1% increase in population size, GDP per capita will also increase by 3.66%. The results for the case of Ecuador confirm the work of Galvis (2015) and Pinto Aguirre (2015).

Granger causality test results

In order to identify beyond a simple long-term relationship between GDP per capita and energy consumption, CO_2 emissions and population size, the Granger causality test has been carried out, the which allows determining the existence or not of causality between this set of variables during the period 1960 - 2016 in the Ecuadorian case.

In this sense, the results presented in Table 5 show that, in the first instance, there is causality between GDP per capita and CO_2 emissions and between GDP per capita and the size of the population, due to the fact that the null hypotheses of no causality.

However, there is no causality between GDP and energy consumption, since the null hypotheses of no causality are not rejected. On the other hand, the non-existence of causality between CO_2 emissions, energy consumption, population size and GDP per capita is demonstrated, since the respective null hypotheses are not rejected. These results are relevant since they confirm the importance of CO_2 emissions and population growth as factors that directly affect GDP. In addition to confirming the works of (Pao y Tsai 2011; Alshehry y Belloumi 2015; Begum et al. 2015; Rentería et al. 2016; Alam et al. 2016; Ozturk y Uddin 2012).

Table 5. *Granger causality results: GDPpc and its regressors*

variables	H_0: GDPpc does not cause CO_2 H_1: GDPpc → CO_2			
	Observations	**F— Statistics**	**Probability**	**Decision**
GDPpc → CO $_2$	53	3.59373	0.0351***	If there is causality
CO2 → GDPpc	53	0.00913	0.9909	there is no causality
CENEL GDPpc	42	0.83515	0.4418	there is no causality
GDPpc CENEL	42	1.24339	0.3002	there is no causality
POP GDPpc	55	1.14262	0.3272	there is no causality
GDPpc POB	55	2.57965	0.0859**	If there is causality

Note: ** denotes significance level at 5% and *** at 1%, respectively.
Some conclusions obtained from this research are presented below.

Conclusions

Economic growth is related to various variables in the economy. In this sense, this research studies the relationship between economic growth, CO $_2$ emissions, electricity consumption and demographics in Ecuador. This research has been carried out using data from the World Bank in the period 1971-2016.

Based on the theoretical review, structural equations are applied to propose a model based on Vector Autoregressive (VAR). The proposed model is estimated through the Johansen cointegration test, additionally, in order to verify whether or not there is causality between economic growth and its regressors, the Granger causality test is applied.

This work contributes to the previous literature since for the first time in the case of Ecuador a demographic growth variable is included together with the variables, energy consumption and CO_2 emissions to explain economic growth. This result contributes to new knowledge since it is a case study for a mega-diverse country extremely rich in natural resources, the main research analyzed on this subject has been carried out in countries with scarce natural resources or that have already depleted a large part of its resources due to over-exploitation. Thus, once the proposed methodology was applied, some remarkable findings could be extracted.

This work, through the estimation of the corresponding models, allows capturing the effect of electricity consumption, CO_2 emissions and population growth on economic growth in the Ecuadorian economy.

The four proposed variables present cointegration in the first difference, this has been demonstrated by using the Johansen Cointegration Test. This result for the case of Ecuador confirms previous works where three of the four proposed variables are used (Rentería et al. 2016; Alam et al. 2016; Alshehry y Belloumi 2015; Begum et al. 2015). These results have been validated using the Trace and Max Eigen tests, showing that there are at least two cointegration vectors.

It also highlights that, in the case of Ecuador, there is a statistically significant long-term relationship between the growth of GDP per capita, CO $_{2\ \text{emissions}}$, electricity consumption and population growth, which indicates that in an extended time horizon, the relationship between the variables (mean and variance) remain stable, these findings confirm the previous work of Alam et al. (2016); Alshehry and Belloumi (2015); Begum et al. (2015) , among others.

The results of this study show that an increase in energy consumption, as well as in the population, have a significant positive effect on economic growth. On the other hand, an increase in CO_2 emissions has a negative effect on the growth of the economy, this last result opens the door to interesting studies that delve into the causes of this situation, however, an explanation would be given by the increase in environmental costs that can be internalized by the economy, causing a reduction in growth. Given that, as stated above, there are no comparable studies in this regard, this study contributes as an alternative that explains the importance of environmental care in countries rich in natural resources, since the increase in emissions has a counterproductive effect at the economic level, However, before any type of inference, it is important to delve into the study of countries in the region.

As a complementary part of this study, the causal relationships between variables were tested, thus, it was possible to identify that there is causality between GDP per capita and CO_2 emissions ; between GDP per capita and population size (Coondoo y Dinda 2002; Ozturk y Uddin 2012; Pao y Tsai 2011). Additionally, it was shown that there is no causality between GDP per capita and energy consumption. This result is relevant since it shows that in the case of Ecuador the use of energy does not significantly affect GDP, an explanation for this result could be tied to the industrial structure of the economy, mainly small and medium-sized enterprises, as well as to the industrial sectors developed in the country, however, before making deeper inferences, it is necessary to carry out more research.

Changing the direction of causality shows that there is no significant causality between CO_2 emissions, energy consumption, population, and GDP per capita.

Regarding the limitations of the study, it should be noted that not all variables have the same amount of data. On the other hand, since there are no similar works in Ecuador, the comparison of the results obtained in this research is difficult. The lack of data from a national source and for prolonged periods means that the data must be taken from international sources.

As future lines of research, it is possible to delve into the individual analysis of the variables used in the model, in order to identify their determinants and their impact on the environment, society and the economy. It is also possible to carry out comparative studies between different countries in the region to identify different or the same behaviors.

Disclosure statement

No potential conflict of interest was reported by the authors.

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