

Environmental degradation and economic growth: evidence for a developing country

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Abstract This paper examines the relationship between economic growth and environmental degradation in Ecuador from 1971 to 2010. We estimate this relationship in a country with a heavy reliance on revenue from the exploitation of natural resources, the depletion of vegetation cover in recent decades and a low level of participation of industry in GDP. We show the existence of an inverse relationship between real GDP and vegetation cover, indicating that the output of this country is based on environmental degradation. Through Johansen co-integration tests, we check that there is a relationship of long-term equilibrium between the first differences of real GDP, vegetal cover and the urbanization rate. The ECM shows that there is a short-term relationship between vegetation cover, the GDP and the rate of urbanization. Finally, we did not found Granger causality between the variables. A policy implication based on our findings is that policies to protect the environment should not jeopardize economic growth and not limit the rapid urbanization in the country.

Keywords Economic growth · Vegetation cover · Urbanization · Ecuador

1 Introduction

The effects of climate change and global warming on the quality of life have increased in recent years. It is believed that one of the main causes giving rise to this phenomenon is the growing economic activity and the consequent environmental degradation. In developing countries, the relationship between economic activity and environmental degradation could be more harmful to the environment due to the production structure of these countries. For

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example, Ecuador is a country characterized by a low level of participation of manufacturing in the gross domestic product (GDP); most of national income and state budget come from primary exports aimed at international markets, especially petroleum exports (Central Bank of Ecuador [BCE] 2015). There has been increasing interest in Ecuador in recent years in environmental contamination caused by private sector agricultural activity, especially due to deforestation associated with expansion of the agricultural frontier. Further, this country spends about one-sixth of the national budget to subsidize energy consumption (Ministry of Finance of Ecuador [MFE] 2015). The issue of reducing this spending has generated a broad academic debate with some public policy implications. The main argument for reducing or eliminating this spending is that the subsidy system increases environmental contamination, while not necessarily benefitting low-income persons (Whitley 2013). Nevertheless, institutional weakness and social pressure will likely lead Ecuadorean policy-makers to maintain spending on these subsidies.

There has been increasing research about the relationship between economic activity and environmental contamination owing to the ongoing deterioration of the environment, which is partly the result of overexploitation of natural resources (Gutti et al. 2012; Cronin and Pandya 2009). The theoretical and empirical literature about this relationship is rooted in the environmental Kuznets curve (EKC). The EKC argues that environmental contamination increases in the initial stages of development and then decreases as incomes increase (Stern et al. 1996; Stern 2004). The argument that supports the inverted U-shape of the EKC is based on the idea that in the initial stages of development, increased production translates directly into more contamination. However, as a country develops, the population has more concern about the environment and at the same time, the technology improves and efficiency increases, resulting in the trend of increasing national output over time and contamination increasing at a slower rate. Finally, development allows for channeling resources to reduce the level of contamination (Stern 2004; Azlina and Mustapha 2012). Likewise, it is logical to expect a positive relationship between national output and energy consumption, and that contamination increases as countries urbanize. This occurs because energy is a productive input, because of the increasing demand for manufactured products in the cities and because of the lack of urban environmental planning in developing countries (Medina 2010; Contreras 2005).

There is a wide empirical literature verifying the relationship between economic activity and environmental degradation, in particular the relationship between economic growth, energy consumption and carbon dioxide (CO₂) emissions (Azlina 2012; Saboori and Soleymani 2011; Ang 2008; Chang and Carballo 2011; Hwang and Yoo 2014; Tiwari 2011; Pao and Tsai 2011; Zhang and Cheng 2009; Bhattacharyya and Ghoshal 2009; Shaari et al. 2012; Alam et al. 2012; Arouri et al. 2012; Ghosh 2010; Al-mulali 2011; Shahbaz et al. 2013). Other research has considered trade liberalization (Halicioglu 2009; Shahbaz et al. 2012); trade liberalization and urbanization (Hossain 2012); unemployment (Ozturk and Acaravci 2010); fixed gross capital formation and employment (Menyah and Wolde-Rufael 2010); the economic structure and the price of energy (Azelina 2011); population (Bhattacharyya and Ghoshal 2009), financial development (Shahbaz et al. 2015); among others. Furthermore, other research empirically verifies the hypothesis of the EKC. For example, Narayan and Narayan (2010) in a study of forty-three developing countries, Fodha and Zaghoud (2010) studying Tunisia, and Apergis and Payne (2010) on the Commonwealth of Independent States contribute to the academic discussion about the validity of the EKC. Although the empirical evidence is not conclusive, the results suggest a strong relationship between economic activity and environmental degradation, with greater emphasis during the process of development. This occurs because the increased

manufacturing activity associated with development leads to increased CO₂ emissions (Cherniwchan 2012). However, in countries with low levels of industrialization and high levels of vegetal cover, a serious environmental problem is associated with growing deforestation, also known as the expansion of the agricultural frontier (Djezou 2013) and not with CO₂ emissions. In practice, we cannot expect the relationship between CO₂ emissions and the product has the same intensity in an industrialized economy and a country that depends on the income generated by exports of natural resources.

In Ecuadorean context, the relationship between product, as a proxy for economic activity, and deforestation, as a proxy for environmental degradation, strengthens over time because of the historic dependence of the country on primary exports. The production structure of this country leads the increase in output causes a decrease in vegetal cover (forest area). In this context, the objective of this research is to examine the relationship between the economic activity and environmental degradation in Ecuador using unit root tests of Dickey and Fuller (1979), Johansen co-integration techniques (1988, 1991), error correction model (Engle and Granger 1987), and Granger causality models (1969). Our results indicate the existence of two vectors of co-integration among the first differences of the real GDP, vegetal cover and the urbanization rate. The environmental policy should focus on avoiding the expansion of the agricultural frontier without halting economic growth neither the accelerated process of urbanization that Ecuador is experiencing in recent decades. The need for increasing national output at sustained rates to reach development and for increased efficiency provoking urbanization (Henderson 2003) supports this recommendation. The efforts of environmental policy-makers aimed at limiting the expansion of the agricultural frontier could be more effective by increasing protected areas through legal mechanisms, the creation of more nature reserves and the use of commercial policy instruments.

This work includes four sections additional to the introduction. Section 2 provides a theoretical synthesis of the mechanism that sustains the relationship between economic activity and environmental statistical sources and methodologies employed degradation, as well as a brief review of the related literature. Section 3 describes the materials and methods employed. Section 4 discusses the results found, and finally in Sect. 5, we present our conclusions and discuss the implication of our results on economic policy.

2 Literature review

In order to study the determinants of environmental pollution and design mechanisms to reduce it, in recent years, there has been a growing theoretical and empirical literature that verifies the relationship between economic growth, energy consumption and CO₂ emissions (Pao and Tsai 2011). Three lines of research have been identified in this ample literature, which are oriented to studying the relationship among these variables. The first verifies the validity of EKC, the second examines the nexus between energy consumption and product and the third combines the first two lines (Ozcan 2013; Ozturk and Acaravci 2010; Halicioglu 2009). In practice, we can expect a strong positive relationship between energy consumption and economic growth. When energy consumption increases, increases economic growth, and in turn, increased environmental degradation. A stylized fact that supports this relationship is that all economic activity generates polluting waste. In the economic–environmental literature, this relationship can be studied using the EKC as a

theoretical support (Panayotou 2003; Narayan and Narayan 2010; Fodha and Zaghoud 2010; Apergis and Payne 2010).

The environmental Kuznets curve (EKC) is an extrapolation of the original equity–income relation proposed by Kuznets (1955). Following the underlying logic of the EKC, in the initial stages of development, both production and contamination are low. Thus, as production increases, contamination also increases, and the interest in the quality of the environment is marginal, and therefore, the contamination will increase more rapidly than production. This is strengthened during the transition from an agricultural economy to one based on manufacturing activity (Cherniwchan 2012). However, when countries become more developed and consequently people have higher per capita incomes and the level of education is higher, greater interest arises among the population in the environment quality, which is reinforced by increased efficiency and improvements in the productive technologies used. This results in the contamination increasing at a slower rate than in the early stages of development. The relationship between national output and contamination weakens over time due to pollution caused by manufacturing activity shifted to developing countries (Cherniwchan 2012; Fæhn and Bruvoll 2009). Based on a profit threshold, productive efficiency and greater interest in environmental quality lead to a situation where production is nature-friendly, which reduces total contamination. In this sense, the relationship between the environmental contamination and the economic activity is approximated by an inverted U-shape (Panayotou 2003). In this context, economic growth benefits the current population with higher per capita income and future population with higher incomes and better quality environment.

Well-grounded literature has proposed theoretical formulations to support econometric estimations. For example, neoclassical growth models have been developed to predict the endogenous reductions in the emission of contaminants (Criado et al. 2011). Bertinelli et al. (2012) propose a capital classic model, the optimal age of technology enables the economy to achieve sustainable development options. Silva et al. (2013) develop a model of endogenous growth with subsidies and taxes, where knowledge of the pollution reduction plays a central role that achieves high production rates compatible with low emissions. Galeotti (2007) offered an additional theoretical base to the EKC, without requiring econometric formalization. Finally, utility and production functions have been used to demonstrate the negative effect of environmental policy on long-term economic growth, where the effect is more harmful in open economies than in closed ones (Adu 2013).

The empirical evidence can be classified into two types: Researchers on groups of countries in which the use of panel data econometrics predominates, and researchers on single countries in which the use of time series econometric is mainly applied. With respect to the first group, Chontanawat et al. (2006) verify the causal relationship between the energy consumption and GDP using information for thirty OECD countries and seventy non-OECD countries. These authors found that the two-way causality between energy consumption and GDP is more robust in OECD countries than in developing countries. Similarly, Bhattacharyya and Ghoshal (2009) found that the relationship between increased CO₂ emissions and economic development is more significant in countries with higher populations and higher levels of emissions, suggesting that policies aimed at reducing CO₂ emissions would have more impact on national output in developed countries than in developing countries (Chontanawat et al. 2006; Bhattacharyya and Ghoshal 2009). Likewise, Acaravci and Ozturk (2010) found validity for the EKC in several European countries, but not in the other countries. Using data from Mediterranean countries, Gürlük (2009) verified the EKC, grouping the countries by their level of development and

including socioeconomic variables. With the exception of France, the countries that produce more also contaminate more. In this sense, the empirical literature for a group of countries is not conclusive.

Farhani and BenRejeb (2012) found similar divergence of results in fifteen countries, as did Ozcan (2013) in a research on twelve countries in the Middle East. Their conclusions are contradictory, and Omri (2013) corroborates this discrepancy in a work on fourteen countries in the same region. Giovanis (2013) analyzed the EKC for Great Britain using a dynamic panel with fixed effects and did not find evidence favoring this curve. However, we do find evidence when we use the method of Arellano and Bond (1991) and a fixed-effects logit model. From this perspective, the sensitivity of the results because of the use of this methodology should be noted in the estimations.

Narayan and Narayan (2010) point out that only in the countries of Middle East and Asia considered in their study, the long-term elasticity of income with respect to carbon dioxide is lower than the short-run elasticity. Arouri et al. (2012) found that in the long term, energy consumption has a significant and positive effect on contaminating emissions, and that gross national product (GNP) has a quadratic relationship with CO₂ for the twelve studied MENA countries (Middle Eastern and North African countries). Nevertheless, the coefficients are high in some cases, because of which the evidence supporting the EKC is not solid. In another recent work on the same region, Al-mulali (2011) stressed the importance of petroleum consumption for the growth of the region and noted that CO₂ emissions and petroleum consumption have a long-term relationship with economic growth and the causality is bidirectional among the three variables in the short and long terms. These results are very similar to the conclusions of Apergis and Payne (2010) for the Commonwealth of Independent States, who found bidirectional causality between energy consumption and CO₂ emissions and at least a unidirectional relationship between energy consumption and real product.

Many of the earlier empirical investigations have recognized the risk of public policies aimed at reducing contaminating emissions, in particular in countries where the level of development is low. In developing countries, the need to increase production to provide employment and raise incomes can outweigh the need to conserve the environment and proves to be incompatible with sustainable development. In this sense, recommendations to decrease CO₂ emissions at the cost of increased production should be viewed with caution, given that meeting the basic needs of persons in developing countries represents a realistic justification for the functional form of the EKC. In this respect, there is evidence in Latin America, indicating that conservation policies could be implemented in Argentina, the Dominican Republic, México and Panamá without affecting economic growth, while in Bolivia, El Salvador, Guatemala and Trinidad and Tobago, the conservation the environment cannot be considered without decreasing growth. The other twelve countries (including Ecuador) should focus on economic growth before adopting conservation policies (Chang and Carballo 2011). Obviously, these conclusions are rooted in traditional economics based on economic rationality, which imposes the monetary factor on the environment. These conclusions and the results of several investigations studying the relationship between environmental degradation and economic growth (Saboori and Soleymani 2011; Halicioglu 2009; Azlina and Mustapha 2012; Menyah and Wolde-Rufael 2010; Pao and Tsai 2011) lead to the idea that there is a trade-off between environmental and economic development. However, the potential of Latin America to obtain renewable energy and achieve sustainable industrialization could lead to a situation where increased national output does not necessarily imply greater environmental degradation. After all, environmental sustainability is not incompatible with economic growth, as Adu (2013)

suggests. The possibility of achieving dynamic efficiency with sustainable levels of development and inter-generational equity, improving the welfare of the present generation while conserving resources for future generations, could lead to better understanding between the economic and environmental communities (Chang and Carballo 2011; Munasinghe 1999). In another work on this region, Apergis and Payne (2009) studied six Central American countries in terms of CO₂ emissions, energy consumption and national output, using an error correction panel model. They found that in the long term, energy consumption has a significant and positive impact on CO₂ emissions, while real production presents an inverted U-shape, which supports the hypothesis of the EKC for this group of countries.

There is an extensive empirical literature on the relationship between the economic activity and environmental quality in individual countries, most of the research applying co-integration and causality techniques to verify relations of long-term equilibrium and the direction of causality among variables. For example, evidence for Malaysia suggests there is a long-term relationship between production or income levels, energy consumption, CO₂ emissions and trade liberalization (Ang 2008; Azlina 2012; Shaari et al. 2012; Halicioglu 2009). In the same line, a research on Turkey, Ozturk and Acaravci (2010) included unemployment in the relationship between contamination and product. Their results did not provide evidence supporting the EKC. However, there is a strong two-way causality among variables. Likewise, Pao and Tsai (2011) found a strong two-way causality among the variables, as did Hwang and Yoo (2014), who verified the nexus of EKC variables in Indonesia, with a strong association among the same, with increased national output translating directly into increased environmental degradation. This result is maintained even after controlling for trade liberalization and the urbanization rate (Hossain 2012; Zhang and Cheng 2009). Shahbaz et al. (2012) also achieved verifying the EKC in Pakistan, with the inclusion of trade liberalization. These authors found a causal relationship from economic growth to CO₂ emissions. Energy consumption increased CO₂ emissions in both short and long run, and openness to trade reduces CO₂ emissions in the long run. In another research, Fodha and Zaghoud (2010) found that both CO₂ and SO₂ emissions are associated with GNP. In recent studies, financial development has also been included in the analysis of the relationship between CO₂ emissions, economic growth, and energy consumption (Shahbaz et al. 2015), and the results show that all the variables are co-integrated in the long term. The results of several research suggest that there is short- or long-term equilibrium and bi- or unidirectional causality among the variables of energy consumption, CO₂ and GDP (Alam et al. 2012; Halicioglu 2009; Azlina 2012; Ghosh 2010; Shahbaz et al. 2013).

The conclusions for only one country are consistent with the evidence from research into groups of countries; neither the existence of long-term equilibrium nor the causality between contamination and national output is conclusive. In this sense, the debate continues to be open given that the results differ according to the methodology employed, the country or the geographic regions and their level of development. In particular, differences among results owing to the use of different methodologies can weaken the evidence for or against the EKC hypothesis. For example, Akbostanci et al. (2009) obtained contradictory results using time series and econometric panel data techniques. Nevertheless, the evidence favoring a strong relationship among the variables is greater than the evidence against the EKC. Consideration of where the research takes place can be relevant to understanding particular cases that contribute to new evidence. This work contributes to the recent literature with solid empirical evidence on a country with a strong dependence on natural resource exploitation, with a high level of biodiversity and with high levels of subsidies to

energy consumption. Incorporating the variable vegetal cover as a measure of environmental degradation can better reflect the effect of production on environmental quality in a country with a low level of industrial activity, and consequently, CO₂ emissions are not significant.

3 Materials and methods: statistical sources and an econometric strategy

In order to verify that with increasing national output also increased environmental degradation, this section presents the origin of the data and the econometric strategy used. We use data from secondary sources of information available online. We divide the econometric strategy into the following steps: unit root test of Augmented Dickey and Fuller (1979) and Phillips and Perron (1988), Johansen co-integration test (1988) and Granger causality models (1969) based on error correction models (Engle and Granger 1987). The application of this econometric strategy is similar empirical research developed by Chang and Carballo (2011), Azlina and Mustapha (2012), Halicioglu (2009), Ozturk and Acaravci (2010), among others.

3.1 Data

We used statistical information from the World Development Indicators published by the World Bank (2015) to examine the relationship between the economic activity and environmental degradation in Ecuador during the period 1971–2010. We used the vegetal cover as measurement of environmental degradation. Vegetal cover (VC_{*t*}) is measured in square kilometers of forested area (see Bhattarai and Hammig 2001). GDP is measured in constant 2005 prices, and urbanization measures the rate as a percentage of the total population (UR_{*t*}).

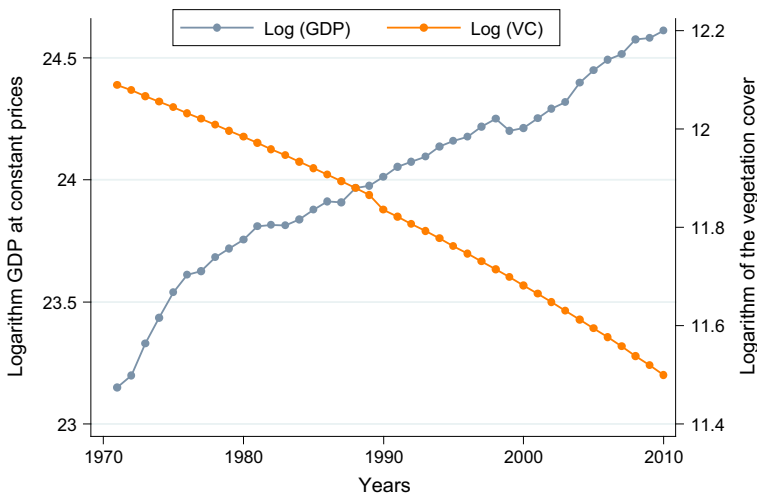


Fig. 1 Relationship between real GDP and the vegetal cover in Ecuador. The authors based on World Bank data (2015)

Figure 1 shows the inverse relationship between economic activity, measured by GDP, and environmental degradation, measured by vegetal cover. The reduction in vegetal cover can be an excellent measure of environmental degradation in countries with low levels of industrial participation in GDP and therefore low levels of CO2 emissions. In practice, the inverse relationship indicates that to the extent that national output increases, vegetal cover decreases, which is consistent with the productive structure of the country. The high dependence on income from primary exports results in increasing exploitation of natural resource and the increasing production of goods associated with agriculture: livestock, bananas, cacao and coffee as well as other natural resource products such as seafood, wood and other, which necessarily results in the destruction of vegetal cover, among other effects. The results shown in the following section confirm this inverse relationship; the country increases its national output by destroying the environment. This relationship indicates that with the current productive structure, the long-term development of the country is not sustainable, leading to the need to reconsider the current productive matrix given that future generations will not have access to the same natural resources as those now being exploited. The negative relationship between vegetation cover and income is similar to the negative relationship found by Bhattarai and Hammig (2001) for Asia.

3.2 Econometric strategy

The strategy applied to verify empirically the relationship between the economic activity and environmental degradation is divided into four steps. In the first step, we verify that the series are non-stationary by Dickey and Fuller (1979) and Phillips and Perron (1988). In the second stage, we use Johansen co-integration techniques (1988) to estimate the long-term equilibrium ratio among the integrated variables I(1). This methodology considers diverse endogenous variables together, and each endogenous variable is explained by its lag values and by the lag values of all the other endogenous variables in the model. In our model, the first differences of the vegetal cover are explained by its lag values in $t - i$ periods and the $t - i$ lags of the first differences of GDP and urbanization rate, respectively. In the same sense, the first differences of the GDP and urbanization rate are explained by their own lag values in $t - i$ periods and by the $t - i$ lags of the other two variables of the model. Equations 1–3 express the estimated VAR. The main objective of this stage is to determine whether vegetal cover, real GDP and the urbanization rate follow a common tendency over time, which contributes to verifying the hypothesis of this research.

$$\Delta VC_t = \delta_0 + \sum_{i=1}^a \delta_1 \Delta VC_{t-i} + \sum_{i=1}^a \delta_2 \Delta GDP_{t-i} + \sum_{i=1}^a \delta_3 \Delta UR_{t-i} + \vartheta_1 \quad (1)$$

$$\Delta GDP_t = \delta_4 + \sum_{i=1}^a \delta_5 \Delta GDP_{t-i} + \sum_{i=1}^a \delta_6 \Delta VC_{t-i} + \sum_{i=1}^a \delta_7 \Delta UR_{t-i} + \vartheta_2 \quad (2)$$

$$\Delta UR_t = \delta_8 + \sum_{i=1}^a \delta_9 \Delta UR_{t-i} + \sum_{i=1}^a \delta_{10} \Delta GDP_{t-i} + \sum_{i=1}^a \delta_{11} \Delta VC_{t-i} + \vartheta_3 \quad (3)$$

The symbol Δ indicates first differences. In the third stage, once the co-integration is verified among the first differences of the vegetal cover, real GDP and the urbanization rate, the equilibrium error E_t is obtained. As suggested Azlina and Mustapha (2012), this vector can be used to estimate an error correction model (ECM) to determine the existence

of short-term equilibrium (Engle and Granger 1987). The statistical significance of the parameter associated with the equilibrium error incorporated into the ECM indicates the correction mechanism that returns to the equilibrium variables in the short run. The ECM model that we estimated is as follows:

$$\Delta VC_t = \alpha_0 + \sum_{i=1}^a \alpha_1 \Delta VC_{t-i} + \sum_{i=1}^a \alpha_2 \Delta GDP_{t-i} + \sum_{i=1}^a \alpha_3 \Delta UR_{t-i} + \alpha_4 ECT_{t-1} + \gamma_1 \quad (4)$$

$$\Delta GDP_t = \alpha_5 + \sum_{i=1}^a \alpha_6 \Delta GDP_{t-i} + \sum_{i=1}^a \alpha_7 \Delta VC_{t-i} + \sum_{i=1}^a \alpha_8 \Delta UR_{t-i} + \alpha_9 ECT_{t-1} + \gamma_2 \quad (5)$$

$$\Delta UR_t = \alpha_{10} + \sum_{i=1}^a \alpha_{11} \Delta UR_{t-i} + \sum_{i=1}^a \alpha_{12} \Delta GDP_{t-i} + \sum_{i=1}^a \alpha_{13} \Delta VC_{t-i} + \alpha_{14} ECT_{t-1} + \gamma_3 \quad (6)$$

where the parameter γ_i is the error terms and the symbol Δ indicates first differences. Although the ARD co-integration offers some advantages over the traditional Johansen co-integration test (1988, 1991) used in this research, in this work, its application was not necessary because all the time series included are I(1). Finally, in the fourth stage, in order to verify the existence of causality and its direction among the three variables, we apply the Granger causality test (1969).

4 Discussion of the results

Before estimating the vector auto-regressive model, error correction model and Granger causality model, we verify the order of integration of the three series used in this research. Table 1 shows the results of the Augmented Dickey and Fuller test (1979) and the Phillips and Perron test (1988), in levels and first differences, with intercept and intercept and trend, respectively. The results reported in Table 1 show that variables contain a unit root

Table 1 Results of unit root test

Variables	Augmented Dickey Fuller test			
	Augmented Dickey Fuller test		Phillips–Perron	
	Intercept	Intercept and trend	Intercept	Intercept and trend
GDP _t	1.17	0.39	0.95	-0.75
GDP _t	-5.14***	-5.23***	-5.23***	-5.29***
VC _t	-0.18	-1.90	-0.18	-2.03
VC _t	-6.14***	-6.08***	-6.16***	-6.08***
UR _t	-0.99	-1.83	-1.29	-1.62
UR _t	-9.88	-10.30	-9.40***	-9.74***

(*) and (**) indicate 10 and 5 % level of significance, respectively

The difference between the Augmented Dickey and Fuller stationarity test (1979) and the Phillips and Perron test (1988) is that the first estimate $\Delta y_t = u - \gamma y_{t-1} + \delta \sum_{i=1}^m \Delta y_{t-i} + \epsilon_t$ and the second estimate $\Delta y_t = \alpha + \beta y_{t-1} + \epsilon_t$

in their levels but stationary in their first differences, indicating that they are integrated at order one $I(1)$.

To verify the relationship of long-term equilibrium among GDP_t , VC_t , and UR_t , after making sure that the three time series including meet co-integration properties, the Johansen co-integration test (1988) is applied to determine the existence of a common long-term trend or co-integration among the variables. Consequently, the co-integration test is applied to the first differences of the three variables. Since the Akaike (1974) information criterion called AIC, which indicates that the optimal number of lags is two, we include this number of lags in the vector autoregressive model. The trace test and maximum value test of the VAR model formalized in Eqs. (1)–(3) show the existence of two co-integration vectors among the first differences of the vegetal cover, real GDP and the urbanization rate. These results confirm the strong long-term association among the three variables of interest of the present research. In the related literature, the dependent variable is the CO2 emissions as a measure of environmental pollution resulting from productive activity (Azlina 2012; Azlina and Mustapha 2012; Hwang and Yoo 2014; Pao and Tsai 2011). However, as discussed previously, our dependent variable is the vegetation cover (VC_t), which seeks to reflect the degree of environmental degradation in a country with little industrial activity and a high dependency on the primary sector. Despite the structural differences between a country that bases its economy on the primary sector and one that bases its economy on the industrial sector, and differences in the extent of environmental pollution, co-integration test results are similar: In the long term, increases in product cause higher levels of contamination. Table 2 summarizes these results.

The results of the third stage of the econometric strategy presented in the previous section, which consists of verifying the existence of short-term equilibrium among the three variables of this research, indicate that there is short-term equilibrium for the estimated equations. Our results are consistent with the findings by Tiwari (2011) in India, a country with a growing industrial activity, and the results shown by Hossain (2012) in a study conducted for Japan, a country characterized by strong industrial activity. Regardless of the differences in how pollution is measured, the results differ from the findings shown by Alam et al. (2012) to Bangladesh. In this sense, the existence of a balance of short term could be conditioned by the productive structure of each country. The Granger causality test indicates that there is no causal relationship between the three variables considered. Table 3 summarizes the results.

The results of Johansen co-integration test indicate that there is long-term equilibrium between the variables included in this study and these results are consistent with the results of Ozturk and Acaravci (2010) and Azlina and Hasim (2012). Using the error correction model, we find the existence of a short-term equilibrium between vegetation cover, GDP and the rate of urbanization. Our results are consistent with those found by Menyah and Wolde-Rufael (2010) and Hossain (2012). Finally, Granger causality tests indicate that

Table 2 Johansen co-integration test

Hypotheses	Trace statistic	Maximum eigenvalue
$R = 0$	25.43 ^a	
$R \leq 1$	10.69	0.33
$R \leq 2$	0.00	0.25

^a Indicates the rejection of the null hypothesis at the 1 % level

Table 3 Results of causality tests based on the error correction model

Variables	ΔCV	$\Delta LGDP$	ΔTU	ECT_{t-1}
ΔCV	–	1.13 (0.51)	2.15 (0.34)	–0.01 (–0.25)
$\Delta LGDP$	0.03 (0.99)	–	2.85 (0.24)	0.95 (5.55)
ΔTU	3.69 (0.15)	–	–	0.11 (0.89)

Figure in the parentheses is the p value for variables and t statistic for ECT

there is no causal relationship between the variables in the short run, and these results are consistent with the results found by Farhani and BenRejeb (2012).

5 Political implications and conclusions

In this research, we verify the relationship between real GDP, vegetal cover and the urbanization rate in a country with the following principle characteristics: high dependence on income from primary exports, drastic reduction in the vegetal cover in recent years with the expansion of the agricultural frontier and low participation of industrial activity in GDP. In relation to stationary series, the statistical analysis indicates an inverse relationship between real GDP and vegetal cover, which is consistent with the productive structure of the country. After obtaining the primary differences to ensure that the series is stationary, co-integration techniques indicated the existence of two long-term equilibrium relationships between the first differences of the vegetal cover, real gross domestic product and the urbanization rate. The ECM indicates that there is short-term equilibrium among these variables. Finally, there is no Granger causality between the variables.

The implications of public policies to address the problem of continuous increases in contamination and, in particular, to reduce the emission of contaminating gases as recommended by cited studies, are oriented to seeking market mechanisms to decrease or limit environmental degradation as the result of increased productive activity (Chang and Carballo 2011; Soyatas et al. 2007; Farhani and BenRejeb 2012). The recommendations highlight the possible adverse effects of policies on production. For example, some research indicates that the application of the recommended policies have limited effect on output (Azlina 2011, 2012; Hwang and Yoo 2014; Hossain 2012; Bhattacharyya and Ghoshal 2009), while the results of other research indicate that such policies can have adverse effects on GDP (Ozturk and Acaravci 2010), while yet other research recommends new policies, alternative energy sources and the identification of priorities (Halicioglu 2009; Menyah and Wolde-Rufael 2010; Ozcan 2013; Mehrara 2007; Friedl and Getzner 2003; Omri 2013; Zhang and Cheng 2009); greater efficiency in the use of inputs and energy resources (Ang 2008; Shahbaz and Lean 2012; Shahbaz et al. 2011); among others. The recommendations in this research are not focused on reducing CO₂ emissions as a measure of environmental contamination, but rather based on the context of the study; we propose a strategy to limit the expansion of the agricultural frontier as a measure of the environmental contamination generated over time by increased production. In an economy with a low level of industrial activity and highly dependent on the primary export sector, environmental degradation as the result of economic activity can be better approximated by the expansion of the agricultural frontier.

An implication for public policy arising from our results is that it would be necessary to limit the expansion of national output in order to reduce the expansion of the agricultural frontier. However, the imperative of increasing national output sustainable over time to reduce poverty and achieve development leads to the conclusion that environmental regulation should put at risk the volatile economic growth of developing countries. Encouraging change in productive activities, more efficient energy use, and, in particular, more efforts in changing energy sources can lead to a situation in which GDP can increase without necessarily harming the environment. Finally, future research may focus on the formalization of the effect of economic activity on other environmental variables of environmental pollution and not focus solely on CO₂ emissions, and the choice of the environmental variable will depend on the economic context and environmental context of each country.

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