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Research Article

Economic Growth and Expansion of the Agricultural Frontier, Case Study: Ecuador (1985 - 2015)

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Abstract

In this research, the relationship between the agricultural frontier and production for Ecuador in the period 1985 - 2015 is analyzed. It begins with a review of the existing literature, then, econometric models of autoregressive vectors and error correction are used. The results show that as production rises, an increase in the agricultural frontier is generated; results that are consistent when additional covariates are added. Among the main results, it is observed that the autoregressive vector model demonstrates that the variables (production and agricultural frontier) have a long-term equilibrium relationship. Also, the error correction model indicates that as the gross domestic product increases, the agricultural frontier expands. In conclusion, the results are coherent with each other and reinforce the idea that the Ecuadorian economy in the period of the analysis is still tied to dependence on livestock products.

Keywords: Agricultural Frontier; Co-integration; Production; Ecuador

Introduction

In developing countries with high natural biodiversity, one of the most critical problems is the expansion of the agricultural frontier [19]. The advances in science have made it possible to understand that forests play a fundamental role in the process of soil, water, and air regeneration through the absorption of carbon [12]. However, the quality of life is affected directly and sometimes in a radical way by the massive elimination of forested areas, as Repetto [38] points out. Deforestation is the permanent destruction of forests to make the land available for other uses. According to the Food and Agriculture Organization of the United Nations (FAO), it is estimated that about 7.3 million hectares of forest (more or less the size of Panama) are lost each year.

Worldwide, the decline in native forests has generated concern. The pervasive and rapid decline of native forests recorded worldwide is one of the most serious environmental problems at the beginning of this century [22,29,39]. This problem is constant in developing countries, which may prefer deforestation rather than delay the growth of production that is the basis for development.

The expansion of agricultural borders and cities are related to deforestation and fragmentation [28]. Agricultural expansion has been the most critical factor since the beginning of the 20th century in environmental economics. While urban expansion increased radically towards the end of the 20th century, in countries like Ecuador, the growth of cities decreases arable land and agricultural and livestock activities require expanding the agricultural frontier to increase production. Projections of population growth suggest that this trend will worsen in the next 30 years [3,31].

Antrop [3] points out that the dissociation between environmental damage and the increase of production becomes a complex element that hinders the achievement of sustainability. On the one hand, there is the limited carrying capacity of the planet and, on the other hand, the limited stock of available natural resources. Furthermore, in the prevailing economic system, increases in production are more important than environmental degradation [45]. If economic growth continues at the same pace, environmental damage will also grow, generating irreversible effects on the planet's biodiversity and human health.

Bearing in mind that during most of the 20th century, resources were relatively cheap and easy to obtain and that human beings are dependent on: the availability of natural resources, ecosystem services for food, shelter, clothing, climatic stability, and many other elements; as we surpass the limits of the biological capacity of the planet, human activity exerts ever greater pressure on the planet. The overexploitation of fisheries, the expansion of the agricultural frontier, deforestation, and burning of fossil fuels are some of the main causes of environmental damage, which is why terrestrial ecosystems, can no longer keep up with the demands of humanity. Changing this is possible, but it requires tools to monitor and manage our resources [2].

In this context Ecuador has not been the exception, the Political Constitution of the Republic (2008), states that all citizens have the right to live in a healthy environment, pollution-free and in harmony with nature (Article 66).

With this background, the present investigation analyses the agricultural frontier and the growth during the last 30 years in Ecuadorian; for its fulfillment, it is estimated using an econometric model. The present investigation answers the following questions:

- What is the relationship between economic growth and the agricultural frontier in Ecuador during the period 1985 - 2015?
- Is Ecuador's economic growth sustainable, given the amount of limited natural resources?
- Do the country's production, exploitation and conservation structure have an effect on the depletion of renewable resources in the short and long term?
- This research aims to examine the relationship between economic growth and the expansion of the agricultural frontier in Ecuador using time series for the period 1985 - 2015 and using as well statistical information published by the World Bank.
- The historical analysis of the agricultural frontier's evolution measured by the jungle area in Ecuador in the period 1985 - 2015 shows that the agricultural frontier has been reduced throughout the period in a sustained manner and the previous analysis determines that the variable will continue with a negative trend in the coming years given the economic structure of the country.
- The application of a basic econometric model allowed us to formally analyze the relationship between the two variables in the last three decades. The initial result that emerges from the co-relationship analysis is that there is a negative relationship between the two variables: as the gross domestic product increases, the jungle area decreases. The result is confirmed by the econometric model. When the GDP increases by one percent, the jungle area decreases by 0.43% in the simple regression, and by 0.56% in the multiple regression. The two coefficients are statistically significant at 5%. This implies that national production is associated in part to the exploitation of the country's natural resources, such as the expansion of the agricultural frontier for agricultural or livestock production.
- The approach and estimation of a VAR auto-regressive vector model showed that there is at least one co-integration vector; this allows demonstrating that the agricultural frontier and the gross domestic product have a long-term relationship in the period analyzed.
- Finally, the error correction model allows demonstrating that the agricultural frontier and the gross domestic product have a short-term equilibrium relationship; that is, changes in the gross domestic product are immediately converted into changes in the agricultural frontier. The result is that due to the country's high dependence on raw materials, especially in livestock and agricultural activities, whenever the economy produces more goods of this type, the agricultural frontier is affected.

Some theoretical conceptions

Decreasing returns and natural capital

The total productivity of the factors is considered as a measure, which is part of the elements that influence economic growth, [2] comments that this variable represents 80% of the growth of developed countries and 40% of developing countries.

The theory of diminishing returns establishes that, in the initial stages of development, increases in capital generate large increases in production [2,43]. Subsequently, increases in capital generate increases in production to the same extent that capital increased; and finally, large capital increases generate small increases in production [43].

The theory of diminishing returns is relevant for the analysis between the agricultural frontier and the GDP because if it is nec-

essary to increase production (Y), it is necessary to increase more and more the productive factors (natural capital) as well, due to the decreasing functional form of the production [7]. In the case of Ecuador, this implies that, to increase GDP, it is necessary to greatly expand the agricultural frontier to achieve only small increases in production. Hence the importance of technology so that factors of production reach increasing returns to scale [39].

The existing evidence shows that, in the seventies, the total productivity of production factors worldwide increased, which led to a sustained decline over the next twenty years in the industrialized countries, and a little less strong decline in the underdeveloped countries, with certain exceptions for countries such as China and Brazil that have maintained a dynamism without alterations in the last thirty years [24].

Concerning the growth rate of inputs for agriculture, the trend is clearly to decrease steadily in industrialized countries, while in the underdeveloped ones, since the late seventies to date, the dependence is greater [24].

The increase in technology means that certain limits have been set aside in the production process, but the current intensity of production processes, based on the same technology designed to permanently increase productivity, has once again called into question the availability of natural spaces for production, especially due to the excessive use of fertilizers [36]. The intensive use of natural capital or natural resources to maximize production and consumption has led to the destruction of habitat, regardless of the growth sustainability.

On the other hand, the relationship between growth (increase in GDP) and the expansion of the agricultural frontier, in everything that refers to primary production, is currently analyzed based on prices that do not include the ecological costs in its production costs [33]. Environmental permissiveness allows several countries to trade with low environmental costs for companies, while countries with greater regulation have higher costs and their prices in trade are higher. When a country excludes environmental costs in trade it is known as ecological dumping. This results in generating an ecological debt, since development is generated from a "natural capital", without taking into account the use of the interests that nature produces.

Ecological dumping

The protection of the environment has a multidisciplinary nature, which means that the legal systems for protecting it are diverse, both in the area of public and private law [10]. The theory of ecological dumping supported by Cabanillas Sánchez [10], Daly and Von Droste [14], argues that this concept refers to the situation in which a government uses lax environmental standards to support domestic companies in the international market.

When economic development is generated from a natural capital or natural resources, without counting the environmental degradation caused by the exploitation of natural resources, an ecological debt is generated [14]. In the Brundtland Report published in 1984, an outline was made of the problems of sustainability that would imply the lack of internalization of the environmental costs generated by production processes aimed at maximizing profits. In this sense, the eco-dumping or ecological dumping analyze the differences between the prices of the suppliers that internalize and those that do not the social costs of environmental degradation (pollution, depletion of resources, loss of biodiversity, etc.), generated by a certain productive activity, where it was determined that those who seek means of remediation towards nature will find themselves at a disadvantage [18].

Some theoretical conceptions about environmental sustainability

The need for production processes to be sustainable over time has gained more interest in recent years, this is reflected in the growing scientific publications on issues of environmental economics. The emergence of these development ideas that give importance to the environment is known as the theory of environmental sustainability. In this regard, Carmona [11], Rabago [37] point out that, although at first innovation represented that moment in history where theoretical knowledge and expert knowledge were fed back from society to transform both society and knowledge, it also had as a defining element the decontextualization, that is, the removal of local life from its context.

The definition of sustainable development that "refers to the capacity that the human system has developed to meet the needs of current generations without compromising the resources and opportunities for the growth and development of future generations," was first expressed by Daly, and Von Droste [14], remaining as the most accepted definition in the entire community when talking about sustainable development.

That is why the concept of sustainable development and the theory of environmental sustainability seek to modify the approach to economic growth based on the economy's traditional measures

and elements since the use of the Gross Domestic Product (GDP) is criticized as a basic measure to calculate economic growth because it tends to deviate from one of its fundamental purposes: to reflect the population's living standard.

Another theory that analyzes the problem of the environment is what is known as utilitarian theory, this bases its analysis on ethics that maintains as a norm the search for the greatest possible welfare for as many individuals as possible [37]. That is why when considering the expansion of the agricultural frontier as the result of a utilitarian vision of nature, and the propagation of a linear production model whose sole objective is to supply consumption at the expense of whatever it is without giving importance to the problems such as the indiscriminate felling of forests, the emission of gases, the dumping of liquids and materials into the environment without any regulation or criteria, a fair and satisfactory model based on intensive and destructive practices cannot be conceived.

In this sense, Rabago [37] leads to understanding that the term: common natural assets counteract the utilitarian vision of the goods of nature as merchandise, that is, as resources for economic activities, because the other attributes are not taken into account (which cannot be represented by a market price although some have it). Rather than assigning an appropriate price, what should be considered is whether it is correct to assign prices to all environmental services, and this is where the main error of the promoters of nature's marketing practices lies.

In the 1950s, Simon Kuznets proposed a relationship between economic growth and degradation of the environment, resulting in an inverted U-shaped curve, in which, in the first phases, degradation increases as income increases, but then it gets better [26]. This theory, according to empirical studies, is not fulfilled, because it does not include all the indicators.

Since the beginning of the nineties, the analysis of the relationship between economic growth and environmental pressures has been greatly influenced by what is known as the "Kuznets Environmental Curve" hypothesis. According to this hypothesis, from a certain level of income, greater economic growth would be accompanied by improvements in environmental quality [40].

Despite the scarce empirical evidence that some environmental problems have diminished in rich countries, none of the contaminants that have been considered in the literature have shown that they unquestionably follow the presumption of CKA [9,20] and it has also been put into question whether the econometric techniques used allow us to derive the causal relationship that supposes this hypothesis [44].

There are several authors [4,17,25], who assume feasible that the CKA hypothesis is only fulfilled in the case of pollutants with local and short-term effects, where the environmental and health impacts are clearer and the intervention costs lower (case of SO_2), while, in the case of pollutants with more global effects, in the longer term and whose reduction is more complicated (case of CO_2), the environmental pressure would increase with the level of income. The interesting conclusion of the study by Repeto [38], was that the comparison of different indicators of pressure or environmental degradation with per capita income led, depending on the cases, to decreasing curves, in the form of an inverted U, or growing.

Since the empirical results are partial, diverse, and often contradictory, some economists celebrated the supposed finding as proof that "there is clear evidence that, although economic growth usually leads to environmental degradation at an early stage of the process, finally the best and probably the only way to achieve a decent environment in most countries is for them to get rich [42].

Factors that modify the agricultural frontier

The investigations that relate the agricultural frontier with the gross domestic product are diverse, one of them is the one made by Hauwermeiren [28]. where the authors explore the validity of the Kuznets environmental curve hypothesis (EKC) for the deforestation in France, Germany, Greece, Portugal, and Turkey, one of the conclusions reached by the authors is "Deforestation is an indicator of environmental degradation due to its relevance as a global environmental concern, with the expansion of agriculture being one of its main causes.

The research proposed by Zambrano-Monserrate., *et al*. [47] determined that in Mexico tropical forests decreased by 4,000 hectares; and total forests, by 7 100 hectares in recent years. Another conclusion reached by the authors is that agricultural uses increased by 55% and 175%, respectively. The research carried out by Nené-Preciado, González, Mendoza and Silva [35] confirms these results.

Farfán, Rodríguez-Tapia y Mas [23] conclude in their research that the choice of government measure is the main factor to explain the variations in deforestation; especially environmental policy,

property rights, the presence of environmental NGOs, and the rule of law [46] investigate deforestation in the Brazilian Amazon and find that one of the main factors that affect deforestation or expansion of the agricultural frontier is commercial opening, specifically the trade in agricultural and timber products. Also, they find that property rights have a significant impact on the control of deforestation because the landowners can limit the invasion of timber exploiters.

Barretto, Berndes, Sparovek, and Wirsenius [5] carry out global research to validate the results of previous research and show that agricultural trade is one of the main factors causing deforestation. These authors show that countries with different levels of relative forest cover react differently to a shock in the value of agricultural exports. The impact of trade is high in countries that still have a large proportion of forest cover, while it is lower in countries with a smaller remaining forest cover. These results are very applicable to the Ecuadorian context because the country is dependent in part on agricultural and livestock production, for which the forests have to be cut down to produce these goods.

Methodology

The dependent variable is the expansion of the agricultural frontier measured by the number of jungle area hectares. The independent variable is the Gross Domestic Product as a measure of economic growth. Therefore, the initial model is presented in the following equation:

$$\log AF_t = \beta_0 + \beta_1 \log AGDP_t + \varepsilon_t \ (1).$$

Where represents the logarithm of the agricultural frontier and is the logarithm of the gross domestic product. While the terms and are the parameters that are going to be estimated in the regressions. Finally, represents the stochastic error term. Equation (1) relates arable land as a measure of the agricultural frontier and GDP. However, there are other factors that also affect Ecuador's agricultural frontier based on its social and economic characteristics, such as, for example, exports (X), gross capital formation (FBK), foreign direct investment (IED), natural resources (RN), among others. As exports increase, the economy has more resources for saving, for consumption, and therefore, people will demand more goods and services, which puts pressure on the agricultural frontier. As an economy builds new physical infrastructure, there is a greater need for resources that come from nature. Finally, when more natural resources are used, the agricultural frontier expands. Therefore, the following extended econometric model is presented, which captures the effect of GDP on the agricultural frontier and other factors that affect the dependent variable.

$$\log FA_t = \beta_0 + \beta_1 \log PIBA_t + \beta_2 \log X_t + \beta_3 \log FBK_t + \beta_4 \log IED_t + \beta_5 \log RN_t + \varepsilon_t \ (2).$$

Table 4 and 5 show the results obtained when estimating the regressions proposed in equations one and two. Before presenting the parameters obtained, an analysis is performed. This analysis focuses on the co-relationship matrix of all variables, both dependent and independent, that are included in the econometric model of equations 1 and 2.

A Self-Regressive Vectors model (known as VAR) evaluates the existence of a long-term equilibrium relationship between the variables included in one of the models. The options that can be found are the following: the first one is there is a balanced relationship between the variables and the second one is there is no equilibrium relationship between the variables of the model. If there is a long-term relationship between the variables, there may be one or several co-integration vectors. For this purpose, a model that captures this intention is proposed. For which, the following aspects are taken into account: [32] co-integration model to verify the long-term relationship between the variables and an error correction model, known as VEC, to evaluate the short-term relationship between the variables.

For the long-term equilibrium, an econometric model of autoregressive vectors is proposed. In the logic of the VAR models, the variables are endogenous and each series is determined by their lags and the lag values of the independent variables. The autoregressive vector model is proposed for the variables included in equation number 1. Equations number 3 and 4 raise the VAR model as follows:

$$\Delta FA_t = \alpha_0 + \alpha_1 \sum_{i=1}^{n} GDPA_{t-i} + \alpha_2 \sum_{i=1}^{n} \Delta AF_{t-i} + \mu_{1t} \ (3).$$

$$\Delta GDPA_t = \alpha_3 + \alpha_4 \sum_{i=1}^{n} \Delta AF_{t-i} + \alpha_5 \sum_{i=1}^{n} GDPA_{t-i} + \mu_{2t} \ (4).$$

Where Δ is the operator of first differences; is the agricultural frontier; while is the agricultural gross domestic product. Finally, the parameter is the stochastic error. The period analyzed in the VAR model is from 1980 - 2016. According to the authors [30], shows the variables of time series in levels are non-stationary, which means that the variables increase or decrease over time. However, it is necessary to verify if the two series have this behavior [38]. Following this process, it was found that two variables

analyzed in this investigation have a lag length of order 1, which was determined by Dickey and Fuller [18]. With the series in first differences, the VAR model-whose results are reported later- was estimated. By using the VAR model, it is determined if the agricultural frontier and the gross domestic product have a long-term equilibrium relationship. This long-term equilibrium model must incorporate a categorical variable that reflects the change of the Ecuadorian economy experienced in 1999 as a result of dollarization, after the economic and financial crisis.

The second model proposed is an error correction model to verify if there is a short-term equilibrium. In this model, according to Johansen [30], the short-term equilibrium implies that the dependent variable responds immediately to the shocks of the independent variable. The error correction model is known as VEC proposed by Akaike [1] states that the error term obtained in the VAR model is delayed by one period and is included as an independent variable in the VEC model, which also includes a dichotomous variable for the structural change of the economy after 1999. With these elements, the VEC model is proposed in equations 5 and 6:

$$\Delta AF_t = \alpha_0 + \alpha_1 \sum_{i=1}^{n} GDPA_{t-i} + \alpha_2 \sum_{i=1}^{n} \Delta AF_{t-i} + \alpha_3 E_{t-1} + \mu_{1t} \quad (5).$$

$$\Delta GDPA_t = \alpha_4 + \alpha_5 \sum_{i=1}^{n} \Delta AF_{t-i} + \alpha_6 \sum_{i=1}^{n} GDPA_{t-i} + \alpha_7 E_{t-1} + \mu_{2t} \quad (6).$$

In addition to the variables previously defined, is the equilibrium error of the VAR model, generated to verify the existence of short-term equilibrium. According to Johansen [30], if the parameter or coefficient associated with this term is statistically significant, it is concluded that there is equilibrium in the VEC model. In the logic of this research, if there is short term balance in the VEC model means that the agricultural frontier has immediate changes in the face of changes in production.

Results and Discussion

Statistics results

The first statistical result analyzed is the degree of association between the variables considered in the econometric model. The co-relationship coefficient goes from -1 to 1. If the co-relationship between two variables is -1 means that there is a perfect negative co-relationship; whereas if it is 1 there is a perfect positive co-relationship. The value of 0 indicates that there is no co-relationship. Table 1 shows the association between the variables.

Table 2 shows the descriptive statistics of all the variables included in the investigation. In all the variables there are 37 observations, except for the income variable of natural resources, which contains 36 observations. Also, all the variables are expressed in logarithmic scale so that the scale is adjusted and the estimated parameters are interpretable as elasticities.

Another of the interest indicators within the descriptive statistics is the standard deviation, which shows the dispersion of these statistics with regards to time. The results determine that the variable which has greater dispersion is direct foreign investment, meaning that this variable increases or decreases over the years. The jungle area has the least variation and the rest of the variables have an intermediate variation.

	Lvaba	Ltc	Las	Lfbk	Lx	Lied	Lrn
Lvaba	1.0000						
Ltc	-0.9538	1.0000					
Las	-0.9973	0.9531	1.0000				
Lfbk	0.9375	-0.9450	-0.9408	1.0000			
Lx	0.9789	-0.9140	-0.9735	0.8910	1.0000		
Lied	0.3861	-0.2733	-0.3946	0.2489	0.4074	1.0000	
Lrn	0.4675	-0.4950	-0.4499	0.4752	0.4987	-0.1922	1.0000

Table 1: Co-relationship between the variables included in the econometric model.

Variable	Obs	Media	Desv. Estándar	Min.	Máx.
Lvaba	37	22.20404	0.4437	21.3727	22.8706
Ltc	37	14.16055	0.1589	13.8301	14.31264
Las	37	11.81321	0.0482	11.73698	11.89347
Lfbk	37	23.18401	0.3996	22.69189	23.98147
Lx	37	23.18381	0.5308	22.31692	23.86339
Lied	36	19.4849	1.031597	17.50439	21.00204
Lrn	36	2.110255	0.4522	1.065507	2.859351

Table 2: Descriptive statistics of the variables from the model.

Economic results

Table 3 shows the regression results obtained when estimating equation number 1. Initially, it can be seen that 81% of the variations in arable land are explained by variations in the gross domestic product. The variations of the dependent variable (arable land) that come from the model are greater (0.74) than the variations of the residues (0.16), so it is affirmed that the model has adequate explanatory capacity.

The coefficient that measures the GDP relationship in the agricultural frontier is 0.43, which means that when the GDP varies by

one percent, the arable land decreases by 0.43%. This coefficient is statistically significant since the probability is 0.00 and the statistical parameter t is greater than 2 in absolute values (12.38).

Table 3 results from equation 1.

ltc	Coef.	Desv. Estándar	t	P > | t |
lvaba	-0.294722	0.0344	-8.57	0.000
const	20.70457	0.7641	27.10	0.000
R-squared	0.6770			

Table 3: Equation 1 estimation.

As exposed in the discussion of equation 2, other factors that explain the arable land variations. Therefore, table 4 shows the estimation of the extended model. On the one hand, it can be observed that the determination coefficient increases to 0.94, which indicates that 94% of the variations in arable land are explained by variations in GDP, exports, the gross formation of fixed capital, direct foreign investment, the gross added value of agriculture, and natural resources. Since it is now a multiple regression the F statistic is statistically significant, which means that, jointly and simultaneously, the independent variables have a statistically significant effect on the variation of the arable land.

Ltc	Coef.	Desv. Estándar	t	P > | t |
Lvaba	0.0887	0.1344	0.66	0.515
Lfbk	-0.2560	0.0438	-5.85	0.000
Lx	-0.0959	0.1055	0.91	0.371
Lied	0.0133	0.0160	0.83	0.412
Lrn	0.0144	0.0239	0.60	0.551
Dum	-0.1071	0.0344	-3.11	0.004
Const	20.1095	0.9607	20.93	0.000
R-squared	0.9372			

Table 4: Equation 2 estimation.

The inclusion of exports in the model is justified by the fact that the country's exports are mostly primary products, such as bananas, flowers, shrimp, coffee, cocoa, among other products that require extensions of Arable land for its production. Within the same model, the fixed capital gross formation is related to the previous explanation, since the accumulation of the country's productive capital is oriented towards the primary sector, which affects the amount of arable land. Foreign direct investment is similar, since it focuses on the extraction of natural resources, and thus is related to the income generated by natural resources.

The previous model contains some aspects of interest, one of which is that the model adjustment is high, the source of variation of the dependent variable that comes from the model (0.73) is much higher than the source of variation that comes from the error (0.04). Also, the effect of GDP on land maintains its statistical importance, and the variables: direct foreign investment and gross value added of agriculture are statistically significant as well. Finally, the inclusion of the dichotomous variable to reflect the dollarization is highly significant, evidencing a change in the arable land since the economic and financial crisis in Ecuador.

Results of short and long-term models

The previous regressions are the basic regressions that allow us to determine three things: first, the direction of the relationship between the dependent variable (agricultural frontier) and the independent variable (GDP), the relationship between the dependent variable (agricultural frontier) and the control variables (exports of goods and services, gross fixed capital formation, direct foreign investment, the gross value added of agriculture, and the income of natural resources); second, it was possible to determine the statistical significance of the parameters obtained; and thirdly, the strength of the relationship between the variables was obtained by the value taken by each parameter obtained.

Co-integration analysis

The advance of knowledge in the economy and econometrics makes it necessary to verify the long-term relationship between the variables. Table 5 presents the results obtained on co-integration: The first one points out that there is an equilibrium vector between the agricultural frontier and the gross domestic product. This result means that, in the long term, there is an equilibrium relationship between the agricultural frontier and the gross domestic product. That is, if the GDP varies, the agricultural frontier also varies.

Table 5 results of the Johansen co-integration test.

This result is based on the productive reality of the country, which is dependent on the agricultural, mining, and forestry sector, and other activities that expand the agricultural frontier causing havoc in nature [21] affirm that agricultural trade is a key factor in deforestation in poor countries. The result presented by these authors is consistent with the productive reality of Ecuador, which has several agricultural products aimed at international trade [30] find that the weakness of democracy is a causal factor of deforestation.

Maximun rank	parms	LL	Eigen value	Trace statistic	Critical value
0	3	102.50545	.	70.7217	29.68
1	8	120.78867	0.64822	34.1553	15.41
2	11	137.45337	0.61414	0.8259*	3.76
3	12	137.86631	0.02332		

Table 5: Johansen Co-integration.

In table 5, the asterisk of significance shows that there are at least two co-integration vectors. The Johansen co-integration test has been used extensively in the determination of equilibrium relationships between the variables of interest, and, in this research, allowed to demonstrate that the agricultural frontier and the agricultural gross domestic product of the country have a long-term relationship between them, with the implications derived from this result.

Results of the VEC model

The results obtained in the second model (VEC) are shown in table 6, where it is demonstrated that there is a short-term equilibrium between the two variables: agricultural frontier and gross domestic product.

Beta	Coef.	Desv. Estandar	z	P > |z|
_ce1				
dltc	1	.	.	.
dlvba	0.2333	0.3162	0.74	0.461
dum	0.0306	0.0328	0.93	0.351
E_1	-1	0.4095	-2.44	0.015

Table 6: Results of the VEC model.

The probability of the coefficient associated with the equilibrium error is 0.015, which implies that the coefficient is statistically significant at 5%. Consequently, it can be concluded that there is a short-term equilibrium relationship between the agricultural frontier and the product. Therefore, it can be said that the changes in the agricultural GDP effectively turn into immediate changes in the agricultural frontier of the country. Damette and Delacote [15] indicate that the economic determinants that because deforestation is the institutional weakness of developing countries that do not have the political will to stop deforestation through laws, and the same level of gross domestic product. The results of these authors are very applicable to the Ecuadorian context. especially in the Amazon, where the jungle has been largely destroyed and those responsible for environmental policy have not done enough to limit this form of environmental degradation. Damette and Delacote [16] find that the deforestation of the Amazon basin grows at high rates without there being a serious concern about this problem. The knowledge of the problem can also help to become aware. In this aspect, Brown, D., Brown, J., and Brown, C. [8] shows with international data that knowledge is key to reduce deforestation and prevent the expansion of the agricultural frontier.

In a preamble, a historical analysis of the jungle' areas evolution in Ecuador in the period 1980 - 2016 was carried out. The graphical analysis shows that the vegetation cover (jungle area) has been reduced throughout the analyzed period in a sustained manner. Besides, the analysis of the deforestation problem in the country offers us a pessimistic view of how natural resources are being used because they are unsustainable resources. This problem is part of a more generalized pattern; other countries in the region also experience reductions in their vegetation cover [6,41].

Those responsible for environmental policy (Ministry of the Environment, Ministry of Agriculture, Associations, etc.) should establish clear policies to prevent the jungle area from decreasing over the years. The empirical evidence shows that it is possible to limit the decrease of vegetation cover through public policies aimed at changing patterns of wood products consumption, trade rules, and incentives [34]. The fact that vegetation cover is decreasing and the agricultural frontier expanding requires greater attention from society, especially from those responsible for environmental policies.

The previous analysis leads us to believe that the agricultural frontier variable will follow a negative trend in the coming years given the country's economic structure. Also, it was linked to the evolution of GDP as a measure of economic growth, showing thereof has increased during the analysis period. Although it has periods of reduction, such as in the 1999 economic and financial crisis, normally the trend of the GDP is growing. Increases in agricultural GDP

occur due to the expansion of the agricultural frontier. The case of the Amazon is more alarming because of the biodiversity that exists in this rainforest. Studies carried out in countries with Amazon basins suggest that it is possible to control the expansion of the agricultural frontier through greater regulation of the natives' productive activity [13].

The application of a basic econometric model allowed a formal analysis of the relationships between the two variables in the last three decades. The initial result that emerges from the co-relationship analysis is that there is a negative relationship between the two variables: as the agricultural gross domestic product increases, the jungle area decreases. The result is confirmed by the econometric model. When the agricultural GDP increases by one percent, the jungle area decreases by 0.29% in the simple regression and by 0.08% in the multiple regression. The two coefficients are statistically significant at 5%.

This implies that national production is associated in part to the exploitation of the country's natural resources, and the expansion of the agricultural frontier for agricultural or livestock production. Similar results have been found in recent research, especially in the determinants of the expansion of the agricultural frontier [8]. Therefore, the recommendation is that those responsible for public policy promote greater specialization in industry and services since they not only generate more development but also contribute to maintaining the jungle area because the population will be dedicated to other activities that require more specialization and this model would achieve more sustainable development.

The approach and estimation of the VAR model showed that there is at least one co-integration vector, which allowed to demonstrate that the agricultural frontier and agricultural GDP have a long-term relationship in the period analyzed. The result proposed from this model is that the two variables move together in time because they have a strong equilibrium relationship. The estimation of the VEC model allowed to demonstrate that the agricultural frontier and agricultural GDP have a short-term equilibrium relationship; that is, changes in agricultural GDP are immediately converted into changes in the agricultural frontier. The result is that due to the country's high dependence on raw materials, especially for livestock and agricultural activities, every time the economy produces more goods of this type, the agricultural frontier is affected.

Conclusion

The last recommendation is based on the influence of time: due to the existence of a short and long term relationship between the agricultural frontier and agricultural GDP, the country should change its productive structure in the long term so development can be sustainable. The current conditions and reality of the country mean that the increases in production are partly the result of agricultural and livestock activities (bananas, flowers, cocoa, metals, among others). Therefore, to reduce deforestation, a change in productive activities oriented towards value-added activities is necessary. This can be achieved through stable and conscious policies over time so that the development of our country is more sustainable.

Bibliography

1. Akaike H. "A New Look at the Statistical Model Identification". *IEEE Transactions of Automatic Control* 19.6 (1974): 716-723.

2. Andrade y Defaz. "Huella Ecológica del Ecuador". Principales avances y resultados (2017).

3. Antrop M. "Changing patterns in the urbanized countryside of Western Europe". *Landscape Ecology* 15 (2000): 257-270.

4. Apergis N and Ozturk I. "Testing environmental Kuznets curve hypothesis in Asian countries". *Ecological Indicators* 52 (2015): 16-22.

5. Barretto AG., *et al*. "Agricultural intensification in Brazil and its effects on land-use patterns: an analysis of the 1975–2006 period". *Global Change Biology* 19.6 (2013): 1804-1815.

6. Beckerman W. "Economic growth and the environment: whose growth? Whose environment?". *World Development* 20.4 (1992): 481-496.

7. Blanchard OJ. "Macroeconomía: aplicaciones para Latinoaméricana". Prentice-Hall (2011).

8. Brown D., *et al*. "Land occupations and deforestation in the Brazilian Amazon". *Land Use Policy* 54 (2016): 331-338.

9. Bruyn y Heintz. "The Environmental Kuznets Curve Hypothesis". In: J.C.J.M. van den Bergh (ed), UK, (1999): 656-677.

10. Cabanillas Sánchez A. La reparación de los daños al medio ambiente, Pamplona, Aranzadi (1996).

11. Carmona AR. "El dumping ecológico: el papel de las medidas comerciales". *Development* 21.11 (1994): 1729-1748.

12. Chidiak M., *et al*. "Captura de carbono y desarrollo forestal sustentable en la Patagonia Argentina: Sinergias y Desafíos" (2003).

13. Culas R. "REDD and forest transition: Tunneling through the environmental Kuznets curve". *Ecological Economics* 79 (2012): 44-51.

14. Daly HE and Von Droste B. Medio ambiente y desarrollo sostenible: más allá del informe Brundtland (No. 333.7 MEDamb) (1997).

15. Damette O and Delacote P. "The Environmental Resource Curse Hypothesis: TheForest Case. Working Paper". INRA-LEF (2009).

16. Damette and Delacote. "On the economic factors of deforestation: what can we learn from quantile analysis?". *Economic Modelling* 29.6 (2012): 2427-2434.

17. Díaz M and Cancelo M. "Emisiones de CO2 y azufre y crecimiento económico: ¿Una curva de Kuznets ambiental?" *Regional Sectorial Economic Studies* 9 (2009).

18. Dickey and Fuller. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root". *Journal of the American Statistical Association* 74 (1979): 427-431.

19. Djezou W. "Optimal conversion of forest land to agriculture: Evidence from C Côte d'Ivoire". *Journal of Agricultural Studies* 1.2 (2013): 13-36.

20. Ekins P. "The Kuznets Curve for the Environment and Economic Growth: Examining the Evidence". *Environment and Planning A: Economy and Space* 29.5 (1997): 805-830.

21. Engle and Granger. "Co-Integration and Error Correction: Representation, Estimation and Testing". *Econometrica* 55.2 (1987): 251-276.

22. FAO. "Situación de los bosques del mundo 2001". Roma (2001).

23. Farfán Rodríguez-Tapia and Mas. "Análisis jerárquico de la intensidad de cambio de cobertura/uso de suelo y deforestación (2000-2008) en la Reserva de la Biosfera Sierra de Manantlán, México". Investigaciones Geográficas 90 (2016): 89-104.

24. Fuglie. Productivity Growth and Technology Capital in the Global Agricultural Economy (2010).

25. Grossman GM and Krueger AB. "Environmental Impacts of a North American Free Trade Agreement". National Bureau of Economic Research, Working Paper Nro (1991): 3914.

26. Grossman and Krueger. IAEE 17th Annual International Energy Conference, Stavanger (1991).

27. Gujarati and Porter. Econometría. México D.F., México: McGraw-Hill/Irwin, Inc (2010).

28. Hauwermeiren. Manual de Economía Ecológica. Santiago, Chile: Abya-Yala (1999).

29. Hunter I and Schuck A. "Increasing forest growth in Europe—possible causes and implications for sustainable forest management". *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology* 136.2 (2002): 133-141.

30. Johansen. "Determination of cointegration rank in the presence of linear trend". *Oxford Bulletin of Economics and Statistics* 54.3 (1992)

31. Kuchelmeister G. "Árboles y silvicultura en el milenio urbano". Unasylva 200 (2000): 49-55.

32. Leblois Damette and Wolfersberger. "What has Driven Deforestation in Developing Countries Since the 2000s? Evidence from New Remote-Sensing Data". *World Development* 92 (2017): 82-102.

33. Navarrete D. "Análisis sistémico de la agriculturización en la pampa húmeda argentina y sus consecuencias en regiones extrapampeanas: sostenibilidad, brechas de conocimiento e integración de políticas". United Nations Publications 118 (2006).

34. Nené-Preciado., *et al*. "Land cover and land use change in coastal basins from the Central Pacific coast of Mexico". *Investigationes Geográficas* (2017): 94.

35. Nené-Preciado AJ., *et al*. "Cambio de cobertura y uso de suelo en cuencas tropicales costeras del Pacifico Central Mexicano". *Investigaciones Geográficas, Boletín del Instituto de Geografía* 74 (2017): 64-81.

36. Nieto-Garibay A., *et al*. "El uso de compostas como alternativa ecológica para la producción sostenible del chile en zonas áridas". *Interciencia* 27.8 (2002): 417-421.

37. Rabago. "Austerity and healthcare privatization in times of crisis: are there any differences among autonomous communities?" (2015).

38. Repetto R. "The Extent and Rate of Deforestation". En: Repetto R. and Gillis M. (Eds.). Public Policies and the Misuse of Forest Resources, 2-15. World Resources Institute. Cambridge University Press, USA (1988).

39. Rivas ÁMM. "Las leyes del desarrollo económico endógeno de Kaldor: el caso colombiano". *Revista de Economía Institucional* 10.18 (2008).

40. Roca and Padilla. Emisiones Atmosféricas y crecimiento económico en España: La curva de Kuznets ambiental y el protocolo de Kyoto (2003).

41. Salahodjaev. "Does Intelligence Improve Environmental Sustainability? An Empirical Test". *Sustainable Development* 24 (2016): 32-40.

42. Shafik and Bandyopadhyay. "Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence". World Development Report. Working Papers (1992).

43. Solow y Swan. El Modelo de Crecimiento Económico Aplicado a la Contaminación y su Reciclaje (1956).

44. Stern and Common. "Is the on Environmental Quality: Time Series and Cross-Contry Evidence" (2001).

45. Uclés D. "El valor económico del medio ambiente". *Ecosistemas* 15 (2006).

46. Wehkamp Koch Lübbers and Fuss. "Governance and deforestation – a meta- analysis in economics". *Ecological Economics* 144 (2018): 214-227.

47. Zambrano-Monserrate., *et al*. "Testing environmental Kuznets curve hypothesis in Peru: The role of renewable electricity, petroleum and dry natural gas". *Renewable and Sustainable Energy Reviews* 82 (2018): 4170-4178.