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Analysis of the evolution of greenhouse gases and their connection with the economic growth

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Abstract

This article aims to develop quantitative research, using the method of ordinary least squares to estimate the causal relationship of economic and energy variables with environmental deterioration. The GDP of the primary, secondary and tertiary sectors, the population and its relationship with the increase in CO2, and the place they have in the Kuznets curve is analyzed. Land uses and their relationship with atmospheric pollution were also examined. Data from a decade was taken for Mexico since it is among the 15 countries that generate the most Greenhouse Gases (GHG) worldwide. We know in advance that the reduction of emissions entails an economic cost, which to date is still uncertain and varies in different situations, but despite the economic cost of reducing GHG, it was found that it is perfectly possible for the economy to continue growing, even when it reaches a zero-emissions model, which has a positive implication for the implementation of economic policies with environmental measures.

Keywords: Greenhouse gases, economic growth, Kuznets curve, energy consumption.
JEL classification: P28, Q43, Q54.

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Análisis de la evolución de los gases de efecto invernadero y su vínculo con el crecimiento económico

Resumen

Este artículo tiene como objetivo desarrollar una investigación cuantitativa, empleando el método de mínimos cuadrados ordinarios para estimar la relación de causalidad de variables económicas y energéticas con el deterioro ambiental. Se analiza el PIB de los sectores primario, secundario y terciario, la población y su relación con el aumento del CO2 y el lugar que tienen en la curva de Kuznets. Se examinaron también los usos de la tierra y su relación con la contaminación atmosférica. Se tomaron datos de una década para México ya que es uno de los 15 países que genera más Gases de Efecto Invernadero (GEI) a nivel mundial. Sabemos de antemano que la reducción de las emisiones conlleva un coste económico, que hasta la fecha es aún incierto y varía en diferentes situaciones, pero a pesar del coste económico que supone la reducción de GEI, se encontró que es perfectamente posible que la economía siga creciendo, aun cuando llegue a un modelo de cero emisiones, lo que tiene una implicación positiva para la implementación de políticas económicas con medidas medioambientales.

Palabras clave: Gases efecto invernadero, crecimiento económico, curva de Kuznets, consumo energético.
Clasificación JEL: P28, Q43, Q54.

1. Introduction

Global warming is one of the main concerns worldwide, because it is an ecological, economic and social problem. One of the main causes of global warming is greenhouse gases as a result of human activities (Ring, Lindner, Cross and Schlesinger, 2012). In recent decades the planet has experienced an increase in temperature, which constitutes a threat to the planet due to the continuous increase in greenhouse gas emissions (Casper, 2010). The objective of this research is to study the evolution of CO2 emissions mainly due to the transcendental role they play on the environment and their side effects; as well as answering various questions, including showing the relationship between economic growth and population growth with the emission of greenhouse gases and global warming, in addition, in parallel, it contributes to answering the question about the possibility of obtaining economic growth with a rate of zero emissions.

Greenhouse gas (GHG) emissions include: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), fluorinated gases, among others. Of all of them, the most common is carbon dioxide, which is the gas with the greatest warming potential (National Institute of Ecology and Climate Change, 2020), which is also considered responsible for approximately half of the retained atmospheric heat and 50% of the greenhouse effect (Goel and Bhatt, 2012; Bacon and Bhattacharya, 2007). Due to this fact, many scientists affirm that there is a direct link between warming and greenhouse gas emissions, with carbon dioxide being the most directly related to the increase in global temperature. Carbon dioxide is mainly caused by human activities (Goel and Bhatt, 2012; Lotfalipour, Falahi, and Ashena, 2010; Houghton, 1996), of all kinds, whether in industry, in the field (agriculture, deforestation) or related to transportation and other human activities.

It is also important to understand the role that fossil fuels play in increasing carbon dioxide emissions, since the burning of fossil fuels releases large amounts of CO2 into the environment in a matter of minutes, however, it has taken millions of years for fossil fuels to form (Goel and Bhatt, 2012), Due to this fact, the exploitation of hydrocarbons must be optimized and energy diversification sought, with new alternatives through the use of renewable energies. It is an inescapable fact that every economy requires energy to produce goods and services, and despite the fact that there are other alternatives, fossil fuels continue to be the main source for production and transportation, even knowing that they are non-renewable resources and that they contribute strongly to the environmental deterioration of the planet (Barreto, 2018).

Since there is an evident relationship between production that promotes economic growth and the use of fuels that deteriorate the environment. In this regard, three points of view have been put forward: *i*) The scale effect states that an increase in per capita income occurs from a greater consumption of raw materials and energy, and therefore, large amounts of waste are generated and necessarily it implies greater emissions of pollutants, so that economic growth has a direct inference on the deterioration of the environment; *ii*) As the economy grows, its structure also changes, so there could be a trade-off between what is polluted in the environment and the actions taken to counteract said pollution, having an ambiguous effect on the environment;

iii) Changes in the level of income can induce changes in the preferences of people, an increase in the level of income can change preferences towards the search for a better quality of life and take actions that lead to it, using technologies less polluting (Grossman and Krueger, 1995; Panayotou, 1997; Labandeira, León and Vásquez, 2007).

Environmental economics exposes the relationship between economic growth and environmental pollution, based on the development process of a country, as income increases, environmental quality initially deteriorates until reaching a maximum point, later environmental quality improves and the income also increases. The three versions of the relationship between economic growth and the environment is known as the environmental Kuznets curve, having an inverted U behavior (Labandeira, León and Vásquez, 2007).

This research joins the general concern about the current situation of the planet, mainly due to damage to the environment. Environmental deterioration is a consequence of the economic activities that man carries out, this fact puts the environment and the activity itself at risk, which is why the dilemma persists if human activities already reach a scale in which the environment is severely affected. To establish the analysis, statistics collected from greenhouse gas emissions were used, and with them is studied the existing relationship of economic growth with carbon dioxide emissions. It is important to highlight that the importance of understanding this link lies in the fact that it is necessary to provide an economic-environmental analysis that serves as a tool for private companies that seek to encourage environmental care and/or government institutions, that through the data they can observe the incidence of production associated with economic growth in the environment through greenhouse gas emissions, and generate knowledge that contributes to the generation of knowledge that supports energy policies that seek to optimize and make efficient the use of resources with a view to sustainability.

2. Literature review

This article considers three lines of research that include economic growth, energy consumption and environmental pollutants. The first line focuses mainly on environmental pollutants and the link with production, that is, an analysis of the Kuznets curve, which implies that from low levels of per capita income, environmental degradation increases, but after certain level of income, decreases. There are several authors who come to this conclusion. Grossman and Krueger (1991) find that for two pollutants at low income levels concentrations increase, but decrease at higher incomes. Selden and Song (1994) studied the emissions of four air pollutants with similar results: the pollutants will decrease in the long term.

Holtz-Eakin and Selden (1995) in their study used panel data to estimate the relationship between CO2 emissions and GDP, they consider that CO2 is a fundamental greenhouse gas for global warming predictions. They conclude that emissions growth continues because output and population will grow faster in low-income countries relative to a declining marginal rate.

Jardón, Kuik and Tol (2017) in their research set out to analyze the empirical relationship between carbon dioxide emissions per capita and economic growth in a panel of 20 countries in Latin America and the Caribbean, using a logarithmic regression model. The authors found results that confirm the existence of an environmental Kuznets curve considering the assumption of cross-independence.

Catalán (2014), makes an estimate of the Kuznets environmental curve for 144 countries, by specifying a panel data model, concludes that countries with low per capita income tend to increase per capita emissions and thereby increase the environmental deterioration, on the other hand, countries with high per capita income show a reduction in emission levels.

Conversely, other authors have found direct evidence supporting a strictly monotonic relationship between GDP per capita and carbon dioxide. Among them, Cole, Rayner and Bates (1997) found that environmental indicators of global impact increase monotonically as income increases. De Bruyn, Van Den Berg and Opschoorac (1998), estimated a dynamic model, the results show that economic growth has a direct positive effect on emission levels. Roca, Padilla, Farré, Galletto (2001) study data on six air pollutants and conclude that pollutant emissions grow when income increases.

For their part, the authors Pinilla, Díaz and Sánchez (2018) analyzed the relationship between economic growth and CO2 emissions for several Latin American countries using the cointegration panel technique. The authors conclude that 70% of the countries studied show a positive and growing relationship between income and emissions. The aforementioned researchers agree that the studies carried out are in the first part of the Kuznets curve.

The second line of research is related to energy consumption and economic growth. This link suggests that economic growth and energy consumption can be determined jointly and that the direction of causality cannot be determined a priori. As an example of this line of research is the author Asafu Adjaye

(2000) who estimates the causal relationships between energy consumption and income for the countries of India, Indonesia, the Philippines and Thailand using cointegration analysis, the results of his study indicate that in the short run, one-way Granger causation is from energy to income in India and Indonesia, however, two-way Granger causation is from energy to income in Thailand and the Philippines.

Paul and Bhattacharya (2004) examine the causal relationship between energy consumption and economic growth in India. They apply an Engle-Granger cointegration approach combined with the Granger causality test, and found that there is a two-way causality between energy consumption and economic growth.

Yoo and Kim (2006) have the objective of investigating the causal relationship between energy generation and economic growth in Indonesia, using time series techniques, the results obtained indicate that there is a unidirectional causality that goes from economic growth to the generation of income. energy, without any feedback effect.

Finally, the third approach is a combination of the two previous lines, it analyzes the relationship between economic growth, energy consumption and environmental pollutants. Within this approach, are the studies of Ang (2007), who uses cointegration techniques to determine the causal relationships between pollutant emissions, energy consumption and production, in France, the results provide evidence of the existence of a fairly strong long-term relationship because the variables and causality analysis support that economic growth exerts a causal influence on energy growth and pollutant growth. For Ang (2008) the main objective was to examine the long-term relationship between production, pollutant emissions and energy in Malaysia, through a cointegration analysis, the findings were that pollution and energy use are positively related to production in the long term and the causal relationship goes from economic growth to growth in energy consumption both in the short and long term.

Gómez (2011), set out as objectives to analyze the relationship between economic growth, energy consumption and polluting emissions of the Mexican economy, using time series with vector autoregressives (VARs), Granger causality tests and impulse response functions. It concluded that there is a positive relationship between economic growth, energy consumption and CO2 emissions and that CO2, natural gas and coal emissions are highly volatile, therefore a change in economic growth, pollutant emissions and energy consumption grow more than the product itself.

Lotfalipour, Falahi, and Ashena (2010) set out to investigate the causal relationships between economic growth, carbon emission, and fossil fuel consumption, using an integration analysis with the Toda-Yamamoto methodology. The results they obtained showed that there is a unidirectional Granger causality from GDP and two surrogate variables of energy consumption (petroleum products and natural gas consumption) to carbon emissions, they also show that carbon emissions, petroleum products and total consumption of fossil fuels do not lead to economic growth, although gas consumption does.

3. Materials and methods

The methodology used in this article was divided into two stages: On the one hand, the quantitative analysis of carbon dioxide, methane and nitrous oxide emissions is carried out, these three greenhouse gases were chosen considering their high potential for global warming. The methodology for this chapter was divided into two stages: *a*) The quantitative analysis of carbon dioxide, methane and nitrous oxide emissions; these three greenhouse gases were chosen considering their global warming potential. The period of analysis covers from 1990 to 2019; *b*) The method of ordinary least squares is used to estimate the relationship between economic growth and CO2 emissions, it is limited to only CO2 because it is the most abundant and has the first place in terms of warming potential. Carbon dioxide is defined as independent variable, and GDP by sectors (primary, secondary and tertiary) and population as dependent variables. The statistics analyzed are official data from the Bank of Mexico, the World Bank, and the National Institute of Ecology and Climate Change.

4. Model and/or theoretical foundation

The relationship between economic growth and environmental deterioration was verified econometrically, carbon dioxide emissions were chosen as the dependent variable, and economic growth by sectors (primary, secondary and tertiary) and population were chosen as independent or explanatory variables, using a log-linear distributed lag model (Guajarati and Porter, 2010). In economics, the dependence of one Y variable (the dependent variable) on one or more other X variables (the explanatory variables) is seldom instantaneous.

Y often responds to *X* within a period of time, which is called a lag (Ec. 1).

The general model is specified as follows:

$$lnY_i = \alpha + \beta_1 X_i + \beta_2 Z + ui \qquad Ec.1$$

where:

Y: is the dependent variable, it is an indicator of environmental deterioration, it represents the natural logarithm of per capita emissions of carbon dioxide in metric tons.

X: is the economic indicator, represented by the gross domestic product by economic sector (primary, secondary, tertiary), in millions of constant 2013 pesos.

Z: it is a social indicator, in this case the population is considered in millions of people.

U_i: is the error term, it is a measure of error that is committed when estimating the model, it is the part of the dependent variable that is not explained in the model that was estimated.

The particular model would be represented as follows:

$$lnCo_2 = \alpha + \beta_1 primary\ GDP_{t-1} + \beta_2 secundary\ GDP_{t-1} + \beta_3 tertiaryGDP_{t-1} + \beta_4 Population + ui \qquad Ec.2$$

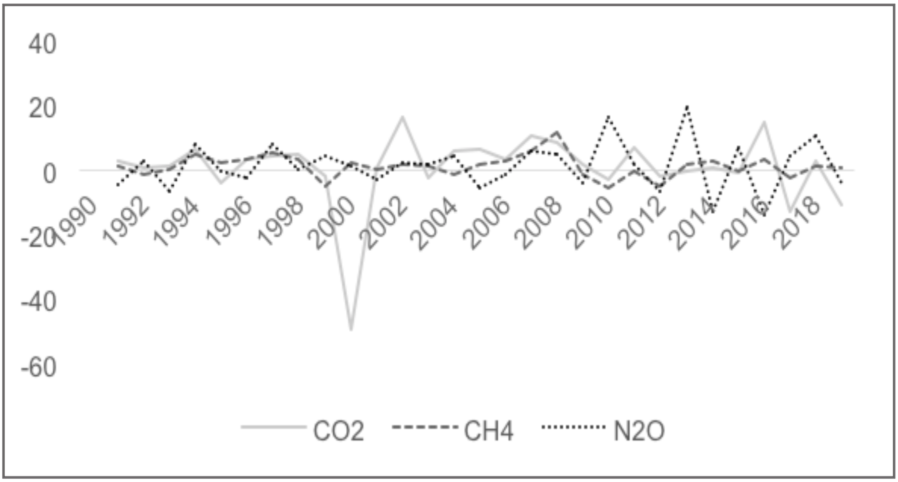
The studies that seek the relationship between growth and environmental deterioration are based on environmental economics, which supports that economic growth tends to generate more pollution at the beginning, then it stabilizes and reaches a turning point, after which environmental deterioration decreases.

4. Results and discussion

Carbon dioxide emissions in Mexico during 2019 were 444 504 901 Gg of CO2e, for which it was placed in the ranking of the 15 countries that pollute the most. Carbon dioxide is one of the most abundant greenhouse gases and of greatest importance due to its global warming potential. During the period 1990-2019, CO2 emissions show a constant trend, in the year 2000 emissions of carbon decreased by 40% compared to the previous year 1999, however, despite the notable decrease, in 2002 a growth of 16% is observed (Fig. 1), although a constant trend is observed in the period.

Methane (CH_4) is located in 28th place considering its global warming potential, the growth rates in magnitude are more conservative, observing an annual growth rate close to 12% in 2008 (Fig. 1), being the highest of the analyzed period, on the other hand, the emissions statistics show a growing trend, going from 117,840.42 Gg of CO2e in 1990 to 175,558.46 Gg of CO2e in 2019.

Nitrous oxide ranks 265th for its global warming potential, just like methane, a growing trend is observed from 28 337.97 Gg of CO2e in 1990 to 41 190.82 Gg of CO2e in 2019. In 2013 the annual growth rate was approximately of 20%, being the highest of the period (figure, 1).

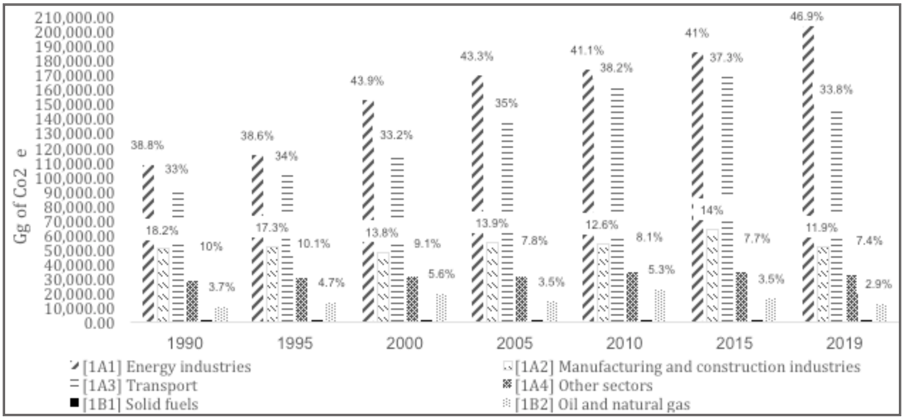


Source: own elaboration with data from the National Institute of Ecology and Climate Change, 2020.
Note: net emissions.

Figura 1
Growth rates of greenhouse gases

Fuel burning activities represent around 95% of total CO_2 emissions, within this category the energy industries have been growing, the percentage of participation in 1990 was 38.8% and by 2019 it became 46.9%.

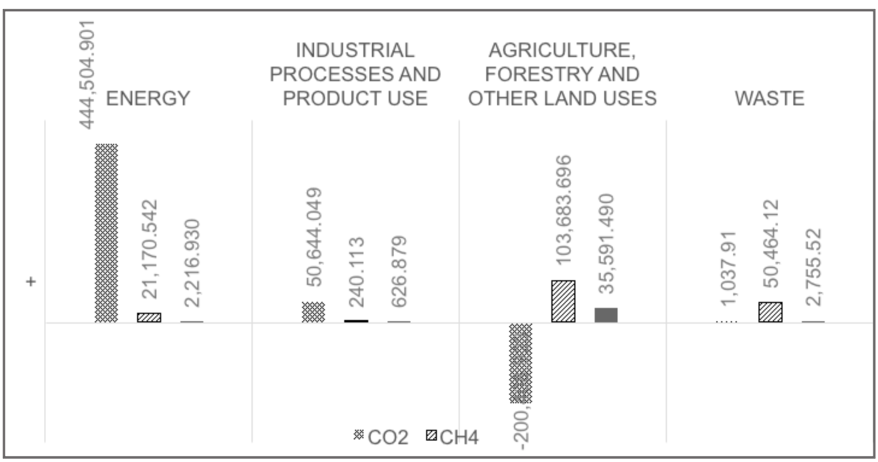
The energy industries include: the main activity to produce electricity and heat, oil refining and solid fuel manufacturing and other energy industries. Another component that is important due to its percentage of participation is transport, which represents just over 30%. The manufacturing and construction industries participated with 12% in 2019. Other sectors such as commercial, institutional, residential, agriculture, forestry, fishing and fish farms, contributed around 7% in 2019 (figure, 2).



Source: own elaboration with data from the National Institute of Ecology and Climate Change, 2020.

Figure 2
CO2 Emisions from energy by category

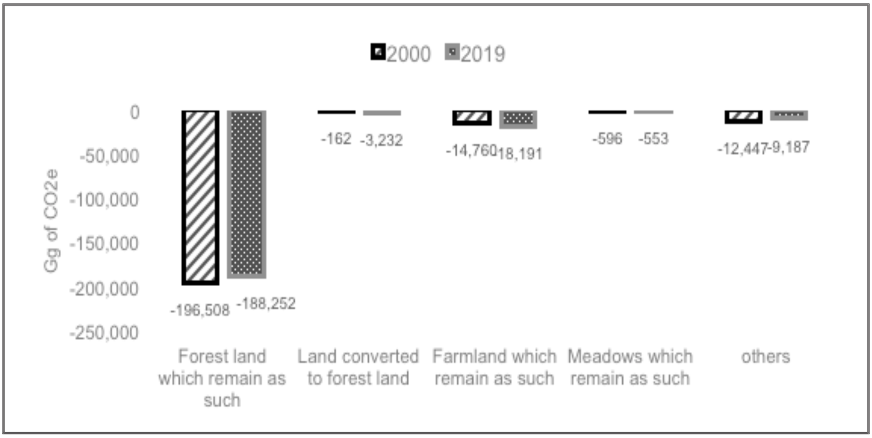
During 2019, the energy generated emissions of 444 504.90 Gg of CO2e; the industrial processes and use of products 50 644 Gg of CO2e; on the other hand, agriculture, forestry and other land uses helped offset carbon dioxide emissions with 200 408.92 Gg of CO2e. However, agriculture, forestry and other land uses as a whole are the sector that generate the most methane emissions with 103,683 Gg of CO2e and also more nitrite oxide with 35 591.50 Gg of CO2e (figure, 3).



Source: own elaboration with data from the National Institute of Ecology and Climate Change, 2020.
Note: Gg of CO2e.

Figure 3
Net greenhouse gas emissions 2019

It should be noted that, within land uses that help reduce CO2 emission levels, they come mainly from forest land that remains as such, since these are given the function of carbon sinks; in 2019 it contributed 188 252 Gg of CO2e to the cause; however, it decreased compared to 2000, having a contribution of 196 508 Gg of CO2e. The contribution in the reduction of CO2 from land converted to forest land was 3 232 Gg of CO2e during 2019, comparing the data with 2000 that the share of land converted to crops was -162 Gg of CO2e, probably indicating that there has been more work to reconvert land to forest land (figure, 4).

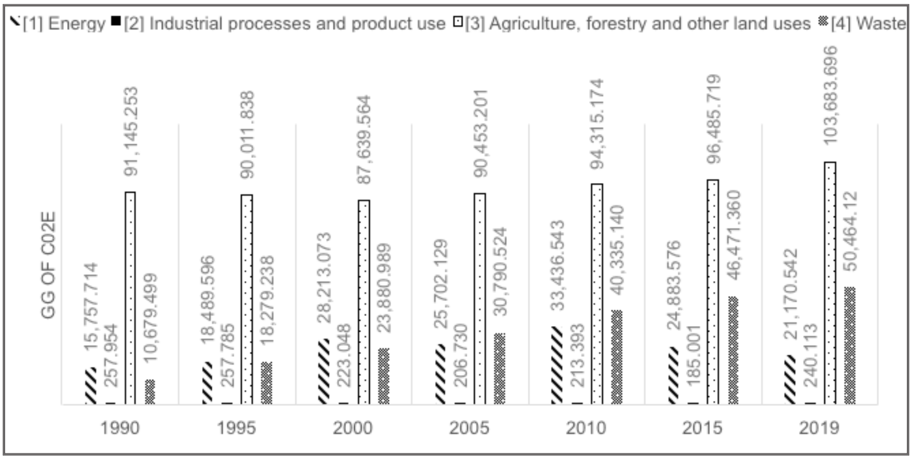


Source: own elaboration with data from the National Institute of Ecology and Climate Change, 2020.

Figure 4
CO2 Emission 2000, 2019

Thus, as forest land and land converted to forest land are a palliative in CO2 emissions, land converted to cropland has the opposite effect, land converted to cropland went from generating 867 Gg of CO2e in the 2000 to 5829 Gg of CO2e in 2019, in almost 20 years it had an average annual increase of 10.5%. These data suggest that there has been an increase in farmland and that they emphasize how alarming the situation is, because it is well known that due to the increase in population, land use changes from forest land to other uses. of an agricultural, livestock and/or housing type, which means that the planet has fewer possibilities to reduce its CO2 emission levels.

Agriculture is the sector that generates the largest amount of methane emissions, contributing around 60% of total CH4 emissions (figure, 5), and in particular the livestock sector is the one that contributes 98% of CH4 emissions accounted for within the agricultural sector, through enteric fermentation with a participation of around 80% and the rest is through manure management. Breaking down by type of animal, cattle are the main source of methane emissions, generating 95% of enteric fermentation and 60% of manure management (table 1).



Source: own elaboration with data from the National Institute of Ecology and Climate Change, 2020.

Figure 5
Mehtane emissions (CH4) 1990-2019

Table 1
Methane emissions from agruculture, forestry and other land uses

Years	1990	1995	2000	2005	2010	2015	2019
Net emissions (Gg de CO2e)							
Agriculture, forestry and other land uses	91 145.25	90 011.84	87 639.56	90 453.20	94 315.17	96 485.72	103 683.70
Livestock	90 400.42	88 525.22	86 368.25	89 103.92	93 330.17	95 562.88	102 105.89
% with respect to agriculture, forestry and others	99.18	98.35	98.55	98.51	98.96	99.04	98.48
a) Enteric fermentation	74 855.49	72 449.08	70 780.71	72 384.99	76 355.31	78 080.46	82 287.31
% with respect to agriculture, forestry and others	82.13	80.49	80.76	80.02	80.96	80.92	79.36
Bovines	70 012.32	67 945.44	67 024.68	68 605.29	72 675.89	74 450.82	78 458.33
% compared to enteric fermentation	93.530	93.784	94.693	94.778	95.181	95.351	95.347
Sheep	924.62	977.57	871.53	1 227.81	1 417.67	1 614.16	1 691.81
Goat	1 363.24	1 318.35	1 132.45	1 167.59	1 251.27	1 135.15	1 180.79
Horses	1 513.52	1 265.29	1 017.06	768.83	520.60	439.92	437.98
Mules and donkeys	662.95	534.61	406.26	277.91	149.67	110.38	109.49
Pigs	378.84	407.83	328.73	337.55	340.22	330.03	408.91
b) Manure management	15 544.93	16 076.14	15 587.55	16 718.93	16 974.85	17 482.42	19 818.59
Bovines	8 692.02	8 391.33	9 329.02	10 008.10	10 658.52	11 208.22	11 898.00
% compared to manure management	55.9154967	52.1974164	59.8491705	59.8609057	62.7900298	64.1113674	60.03455
Sheep	10.85	11.45	10.64	14.51	16.54	18.76	19.52
Goat	15.63	15.13	12.95	13.50	14.03	13.25	13.68
Horses	144.03	121.26	97.83	73.85	47.16	40.90	42.39
Mules and donkeys	63.44	51.52	39.30	26.51	13.25	10.58	10.81
Pigs	5 967.50	6 455.06	4 920.08	5 058.07	4 557.43	4 431.18	5 896.23
Poultry	651.45	1 030.39	1 177.73	1 524.39	1 667.94	1 759.54	1 937.97

Source: own elaboration with data from the National Institute of Ecology and Climate Change, 2020.

Nitrous oxide had an average annual growth of 1.3% for the period, going from 28 337.97 in 1990 to 41 190.82 in 2019. The sector that generates the most N20 emissions is agriculture, forestry and other land uses with 86% of the total nitrous oxide emissions, where cattle participated in 2019 with 23% of this sector generating 35591.49 Gg of CO2e; aggregate sources and non-C02 emission sources from the land account for 77% (table 2).

Table 2
Ni trous oxide emisions

Years	1990	1995	2000	2005	2010	2015	2019
Net Emission (Gg de CO2e)	28 337.97	28 258.99	31 982.24	32 198.64	40 108.02	42 953.35	41 190.82
[1] Energy	2 888.18	3 098.78	3 419.74	3 671.52	3 487.48	2 965.15	2 216.93
Fuel burning activities	2 879.061	3 082.56	3 387.541	3 656.11	3 445.98	2 923.94	2 182.89
[2] Industrial processes and product use	872.91	1 300.96	550.69	336.18	691.53	671.12	626.88
[3] Agriculture, forestry and other land uses	20 911.77	19 942.42	23 766.69	24 774.44	32 806.06	36 377.17	35 591.49
Livestock	5 539.70	5 183.14	5 226.42	5 476.47	7 339.49	7 646.08	8 166.32
Aggregate sources and non-CO2 emission sources from land	15 372.07	14 759.28	18 540.27	19 297.97	25 466.56	28 731.09	27 425.18
Direct N2O emissions from managed soils	9 502.61	8 238.14	11 160.08	11 058.04	16 698.71	19 076.85	18 752.68
Indirect N2O emissions from managed soils	4 240.73	4 333.13	5 053.03	5 365.89	5 736.14	6 523.46	6 748.26
Indirect N2O emissions from manure management	1 481.01	1 729.42	1 947.96	2 450.59	2 742.35	2 872.18	1 316.28
[4] Waste	3 665.11	3 916.84	4 245.12	3 416.49	3 122.95	2 939.911	2 755.52

Source: own elaboration with data from the National Institute of Ecology and Climate Change, 2020.

Econometric analysis

The model is expressed as:

$$lnCO2 = -0.1089 + 1.8156primary\ GDP_{t-1} + 4.6702secundary\ GDP_{t-1} \\ - 4.1222tertiaryGDP_{t-1} + 1.4868Population + ui$$

The economic interpretation of the model is as follows:

The GDP (primary, secondary and tertiary) with a lag of one period implies that the effect that these variables have on CO2 emissions is not reflected immediately, but over the course of a period.

Primary GDP and CO2 show, in principle, a direct relationship, when GDP increases, CO2 also increases. In this case, an increase of one million pesos in primary GDP increases CO2 emissions by 181.56 metric tons. However, this value is not statistically significant in the model, therefore, it is not possible to make any statement in this regard. Primary sector activities include: agriculture, livestock, forestry, fishing, hunting and trapping, and related services.

For its part, there is a direct relationship between secondary GDP and CO2, so an increase of 1 million pesos in secondary GDP will increase CO2 emissions by 467.2 metric tons, a value that is statistically significant. Secondary GDP includes: mining, electricity, water, gas supply, construction, manufacturing industries, food industry, beverage and tobacco industry, fashion industry, clothing manufacturing, paper industry, etc.

Regarding the relationship between tertiary GDP and CO2 emissions, it is inverse, so an increase of one million pesos in tertiary GDP decreases CO2 by 412.22 metric tons, the value being statistically significant. The tertiary sector includes all kinds of services: financial, professional, scientific and technical.

As for the population increase of one million people, it implies that emissions increase by 148.68 metric tons, a value that is statistically significant.

4.1 Econometric interpretation:

The model is considered to have an acceptable fit with a coefficient of determination of 76.8% (table 3). The Durbin-Watson test was performed to detect serial correlation.

The hypotheses to be tested are: H_0 there is no correlation between the residuals and H_A the residuals are correlated. Critical values d_L =0.805 y d_U=1.528 at the significance level of 0.01%. Decision rules, reject H_0: *if* $d<d_U$ or if $(4 - d) < d_U$, as well as d =1.581>d_U =1.528 H_0 is not reject, that is, there is no correlation between the residuals.

Table 3
Model: MCO, using observations 1996-2019 (T = 24)
Dependent variable: l_CO2 (Metric tons per capita)

	Coefficient	Typical dev.	t-statistic	p-value
const	−0.108014	0.243404	−0.4438	0.6622
Primary GDP_1	1.81560e-07	1.34193e-07	1.353	0.1919
Secondary GDP_1	4.67020e-08	6.99650e-09	6.675	<0.0001***
Tertiary GDP_1	−4.12228e-08	8.01037e-09	−5.146	<0.0001***
Population	1.48682e-08	3.51784e-09	4.227	0.0005***
Media dependent v.	1.367643	D.T. dependent variable		0.049972
Sum residual square	0.013326	D.T. regression		0.026483
R-square	0.767983	R-square corrected		0.719138
F (4, 19)	15.72267	p-value (F)		7.79e-06
Log-verisimilitude	55.89879	Akaike criterion		−101.7976
Schwarz criterion	−95.90731	Hannan-Quinn criterion		−100.2349
rho	0.176952	Durbin-Watson		1.581520

Source: own elaboration with data from Gretl output.

4. Conclusions

Of the greenhouse gases, CO2 emissions are the most abundant, being this gas the one that occupies position one due to its global warming potential. Hence, this research adds to the obvious concern of scientists and institutions to promote actions that counteract the level of emissions. One of the measures is to conserve forest land and convert land from other uses to forest land, so that these can function as carbon sinks.

Agriculture contributes 60% of methane emissions, with the livestock sector being the main producer of methane, in particular cattle are a source of CH4 emissions. It is here, where the dilemma arises between what measures to take to avoid environmental deterioration, since livestock activity in Mexico is predominantly economic, which also functions as a livelihood for a large part of the population.

For its part, GDP growth in the secondary sector implies higher CO2 emissions, which increases environmental deterioration. The results suggest that both the primary and secondary sectors have not been sufficiently developed, since they can be considered to be in the first part of the Kuznets curve, where economic growth is accompanied by an increase in negative externalities in the environment.

Tertiary GDP growth has a negative relationship with CO2 emissions, it is considered that the tertiary sector has developed enough, since an increase in tertiary GDP indicates a decrease in CO2.

The increase in population is a factor that puts environmental quality at risk, because as the number of people increases, there is a greater amount of CO2 in the environment. Since the human activities that damage the environment are many. The economic activities that people carry out every day involve the use of resources that lead to changes in land use and felling of forest areas. In addition to this, fossil fuel burning activities are carried out, which are an important source of CO2 emissions.

On the other hand, it is perfectly possible that world economies continue to grow, even with a zero-emissions model (UCT, 2021). Other mathematical models, such as that of the Journal of Cleaner Production, show that sustained GDP growth is possible even after assuming the cost of eliminating the pollution that is generated.

It is very important to consider two stages, an innovation phase and a non-innovation phase. We know in advance that the reduction of emissions entails an economic cost, which to date is still uncertain and varies in different situations, circumstances and of course the country, for example, the cost for China would not be the same as the cost for a developing country like México. The real cost of climate neutrality implies both the reduction of pollution and the adoption of innovation and development measures to achieve alternatives, one of these alternatives could be renewable energies.

It is important to highlight that the applied model yields very interesting data, since we can affirm that despite the economic cost of reducing greenhouse gases, the economy will continue to grow.

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