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Impacts of Economic Growth on Environmental Sustainability in Mexico

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Abstract: The persistent tension between economic growth and environmental sustainability has significantly influenced Mexico's development trajectory. This ongoing challenge complicates efforts to reconcile economic progress with ecological responsibility. The present research examines the relationship between economic expansion and CO_2 emissions in Mexico from 1965 to 2018, utilizing GDP per capita and Industrial Value Added as explanatory variables. Data from Nationally Determined Contributions were supplemented with information from the World Bank, INEGI, and INECC. A multiple regression model, estimated using Alternating Least Squares, was employed to address multicollinearity among predictors. The analysis demonstrates a statistically significant positive relationship: increases in GDP per capita and industrial activity are associated with higher CO_2 emissions. These findings indicate that Mexico's economic growth has remained carbon-intensive, with industrialization and rising income levels closely linked to increased emissions. The results underscore the need for future policy to focus on decoupling economic growth from carbon emissions to promote sustainability.

Keywords: climate change, economic growth, econometric model, CO_2 emissions, Mexico, sustainability.

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1. Introduction

The prevailing model of sustained global economic growth has often resulted in natural resource depletion, driven by a linear "produce–use–dispose" pattern that negatively impacts ecosystems and human well-being. This persistent conflict between economic growth and environmental sustainability warrants further investigation, especially in emerging economies such as Mexico, where economic expansion has coincided with increasing environmental pressures.

Sustained economic growth strategies, emphasizing development and improvements in quality of life, have historically been advocated by many Keynesian, Neo-Keynesian, and Post-Kaleckian scholars (Onaran and Galanis, 2014; Onaran, Stockhammer and Grafl, 2011; Stockhammer, Onaran and Ederer, 2009; Naastepad and Storm, 2006–2007; Stockhammer and Onaran, 2004; Bowles and Boyer, 1996, cited in Sánchez, 2022:92), as well as by Classical (Smith, 1776; Ricardo, 1817) and Neoclassical economists (Marshall, 1890; Walras, 1874; Hicks, 1939), and numerous international institutions. In contrast, Marxist theory (Marx, 2015) and its proponents were among the first to question the ethical foundations of economic growth, emphasizing its reliance on profit maximization, overexploitation of human capital and natural resources, and an ever-expanding consumption model. However, their primary concern centered on deteriorating living and health conditions among the proletariat and lower working classes, rather than environmental degradation.

Nordhaus (2018) and Stern (2006), underscore the urgent need for a paradigm shift to improve climate conditions essential for the survival of the planet, its ecosystems, and humanity (United Nations, 1987). The Anthropocene era illustrates how human activities have surpassed planetary boundaries, prompting global governance initiatives to mitigate global warming by reducing greenhouse gas (GHG) emissions, measured in carbon dioxide equivalent (CO_2e). This approach originated with the Kyoto Protocol, which identified six GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) (Frohmann and Olmos, 2013).

Ruiz (2020) and Correa (2004) have established a direct relationship between economic growth—particularly as measured by GDP—and environmental degradation. In the context of Mexico, this relationship is especially significant due to the country's status as a major GHG emitter in Latin America. Mexico has committed to international climate agreements and is implementing strategies to achieve these objectives, such as vehicle emissions testing in major cities and carbon taxes currently applied in eight states (Hernández and Urzúa, 2024). These initiatives align with the Paris Agreement, signed at COP21, which aims to limit the global temperature increase to below 2°C (United Nations Climate Change, 2018).

Gavito et al. (2017) document how Mexico's socio-ecological heterogeneity has intensified pressures on ecosystems, especially in regions where agricultural expansion and industrial activity drive resource depletion. Likewise, García-Lara, Peralta, and Salazar (2017) show that increases in agricultural productivity remain closely tied to unsustainable land-use practices and elevated emissions, particularly in export-oriented farming systems. These findings suggest that key productive sectors driving Mexico's economic growth still depend on resource-heavy methods, which worsen environmental issues stress.

Ramírez and Delgado (2017) demonstrate that Mexico's industrial structure remains dependent on fossil-fuel-based processes, which significantly contribute to national CO_2 emissions despite efficiency gains at the firm level. In parallel, Ríos-Orozco and Cárdenas (2017) find that technological innovation in key productive sectors has not translated into meaningful reductions in environmental impact because institutional and market barriers limit the adoption of cleaner technologies. Together, these studies underscore that Mexico's economic expansion continues to generate environmentally harmful externalities, reinforcing the need for policy strategies that decouple growth from emissions.

In this context, the present study analyzes the effects of Mexico's economic growth model by examining the relationship between GDP per capita, Industrial Value Added, and CO_2 emissions from 1965 to 2018. The objective is to provide evidence to inform policy decisions, support the fulfillment of international commitments, and increase awareness of the environmental trade-offs associated with economic growth.

2. Materials and Methods

2.1. Mexico's NDC Macro Analysis

According to Ibarrarán et al. (2022), Mexico is the second-largest emitter of GHGs in Latin America. In response, Mexico set reduction targets known as Nationally Determined Contributions (NDCs), which must be updated every five years, and progress must be reported to the United Nations Framework Convention on Climate Change (UNFCCC).

Emissions for the NDC are measured in tons of carbon dioxide equivalent (CO_2e), aiming to express the emissions of different GHGs in a single unit, using CO_2's warming potential as the reference metric. This is calculated by multiplying each GHG's emissions by its respective global warming potential, which varies by gas, as shown in Table 1 (Frohmann and Olmos, 2013).

Table 1. GHGs and Their Global Warming Potential

Greenhouse Gas	Global Warming Potential
CO_2	1
CH_4	28
N_2O	265
HFCs	1300
PFCs	8600
SF_6	22,200

Source: Frohmann and Olmos, 2013.

The initial results for Mexico date back to 2015, when the country submitted its first NDC, pledging to cut emissions by 22% by 2030 compared to its baseline. This baseline was based on the most recent emissions inventory available, which for Mexico is from 2013, when a total of 665 million tons of carbon dioxide equivalent (CO_2e) were emitted (ICM, 2021: 2).

The table below illustrates this reduction commitment, indicating that Mexico's total emissions are around 762 million tons of CO2e, compared to 973 million tons of CO2e under a scenario with no reduction's scenario.

Table 2. CO_2 Emissions in Mexico's NDC Report

	2013	2020	2025	2030	2030* (with reduction)
Transport	174	214	237	266	218
Electricity generation	127	143	181	202	139
Residential & commercial	26	27	27	28	23
Oil & gas	80	123	132	137	118
Industry	115	125	144	165	157
Agriculture & livestock	80	88	90	93	86
Waste	31	40	45	49	35
Subtotal	633	760	856	941	776
LULUCF**	32	32	32	32	-14
Total emission	665	792	888	973	762

Source: Own elaboration based on SEMARNAT en ICM, 2021:2.

Note:

* The table includes two 2030 scenarios: with no reductions vs. with the NDC reduction target.

** LULUCF = Land Use, Land-Use Change, and Forestry.

Figure 1 presents the sectoral distribution of greenhouse gas emissions in Mexico under the 2015 NDC, comparing observed levels for 2013 and projected values for 2020, 2025, and 2030, as well as the 2030 mitigation scenario.

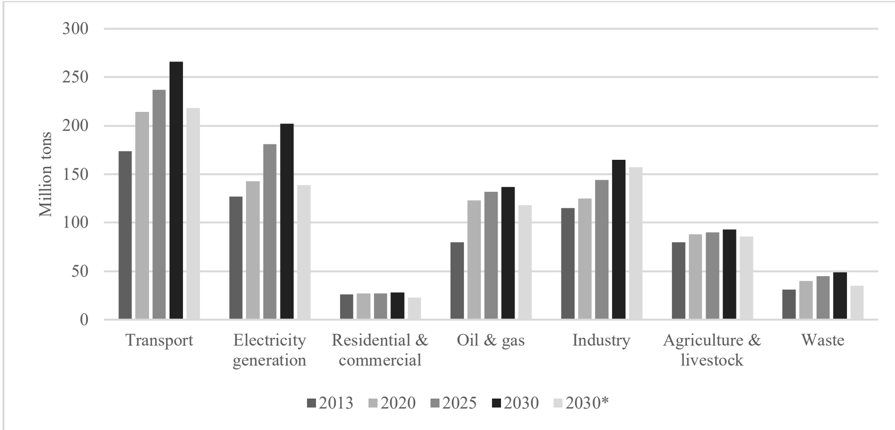

Figure 1. Mexico's 2015 NDC Report
Source: Own elaboration based on SEMARNAT in ICM, 2021:2.

However, in 2020 (see Table 2), Mexico updated its baseline (2013) compared to the figure reported in 2015, creating a new version with different and more lenient targets for reducing CO_{2e} emissions. The revised baseline estimated 991 million tons of CO2e for a zero-reduction scenario and 773 million tons under a 22% reduction scenario by 2030.

This adjustment indicates that Mexico's progress in mitigation has been questioned following its submission of a revised NDC by the end of 2020. The ICM (2021) report highlights a lack of ambition compared to other countries, as the revision introduced a new baseline that ultimately led to less stringent emission reduction commitments.

Table 3. Mexico's CO_2 Baseline ($MtCO_2$) by Industry

	Baseline (MtCO2e)			
	2013	2020	2025	2030
Transport	174	201	225	250
Electricity generation	149	166	174	186
Industry	124	149	173	199
Agriculture & livestock	98	106	114	122
Oil & gas	73	70	93	101
Waste	44	50	52	56
Residential & commercial	26	26	27	28
LULUCF* (emissions)	21	36	42	49
Total gross emission	709	804	902	991
LULUCF* (removals)	-169	-163	-161	-158

Source: Own elaboration based on SEMARNAT in ICM, 2021:3
Note: * LULUCF = Land Use, Land-Use Change, and Forestry.

Figure 2 displays the projected sectoral evolution of greenhouse gas emissions in Mexico's 2015 NDC, illustrating changes across seven major sectors for the benchmark years 2013, 2020, 2025, and 2030.

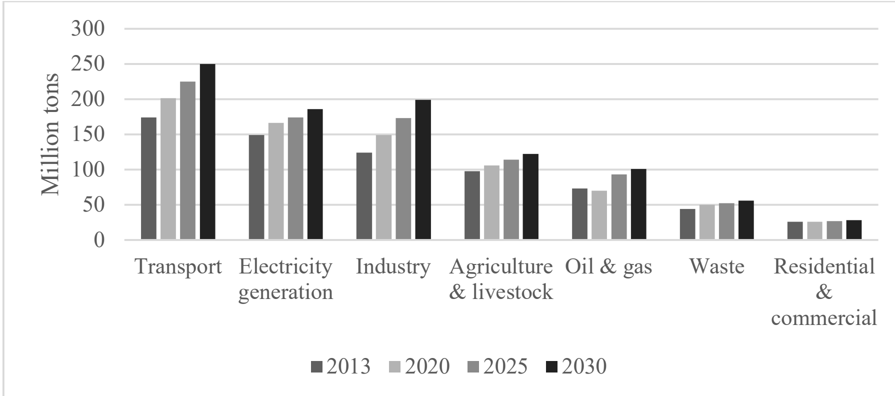

Figure 2. Mexico's 2020 NDC Report
Source: Own elaboration based on SEMARNAT in ICM, 2021:3

However, it is important to recognize that a key, cost-effective strategy at the government level has been to enhance regulations targeting better energy efficiency and fuel performance in new vehicles sold in Mexico.

This measure alone has the potential to reduce approximately 20 million tons of CO_2e emissions annually before the 2030 target, which is especially important for mitigating some of the effects of global warming.

2.2. Variables and Exploratory Data Analysis

For this study, a multiple regression analysis was performed to explore the relationship between CO_2 emissions and two independent variables over the observation period from 1965 to 2018. The variables used in the analysis are as follows:

Table 4. Model Variables

Type of Variable	Name	Units
Dependent	CO_2 Emissions	Kilotonnes
Independent	GDP per capita	Constant prices*
Independent	Industrial Value Added	Constant prices*

Source: Own elaboration.

Note: * Units are expressed in constant U.S. dollars based on the year 2010.

The data were obtained from the National Institute of Statistics, Geography, and Informatics (INEGI). An exploratory data analysis was performed to understand the key features of the variables. Additionally, correlation tests were conducted to assess the relationships among the variables.

To analyze the variables and gain an initial understanding of their behavior, we conducted a visual exploration of the data. Regarding the dependent variable, Figure 3 illustrates a consistent increase in CO_2 emissions, characterized by a clear upward trend and minimal fluctuations. As observed, CO_2 emissions in Mexico have risen significantly due to the country's economic growth and industrial development over the past few decades.

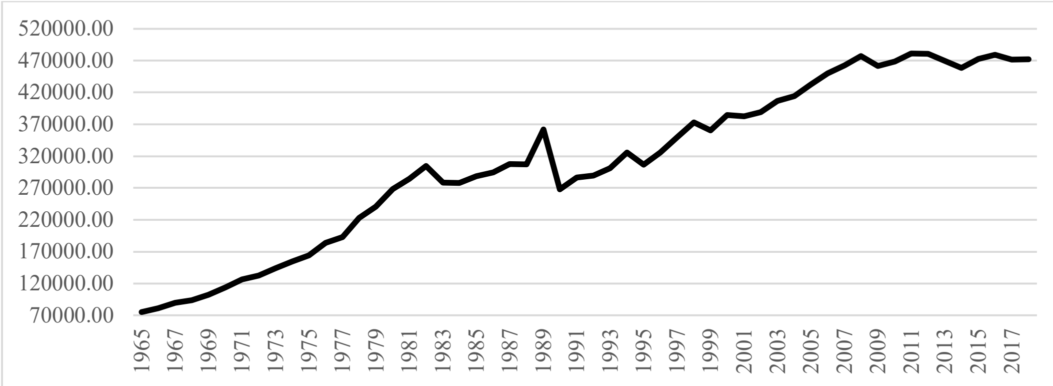

Figure 3. CO2 Emissions
Source: Own elaboration using data from INEGI.

The behavior of GDP per capita in Mexico, shown in Figure 4, indicates a general upward trend. Starting at approximately $4,561.14 in 1965, GDP per capita experienced fluctuations over the years but overall showed steady growth, reaching approximately $9,945.78 by 2018. These figures reflect the country's economic progress during this period, marked by advances in various sectors and an improvement in the population's standard of living.

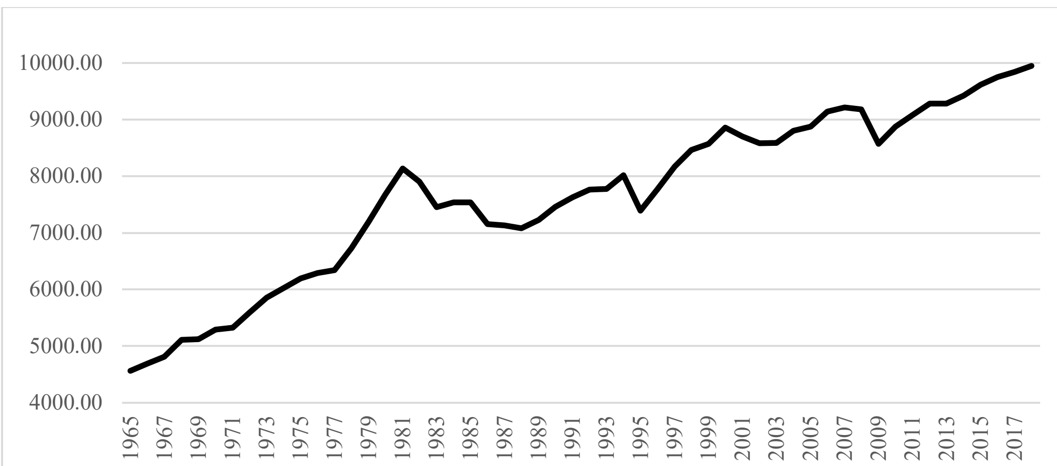

Figure 4. GDP per capita
Source: Own elaboration using data from INEGI.

The industrial value added in Mexico saw significant growth, as reflected in Figure 5. Industrial value added consistently increased over the years. This ongoing growth led to a substantial rise in the country's industrial output. The data indicate the development and expansion of the Mexican industry during this period, which contributed to economic growth and strengthened Mexico's industrial sector.

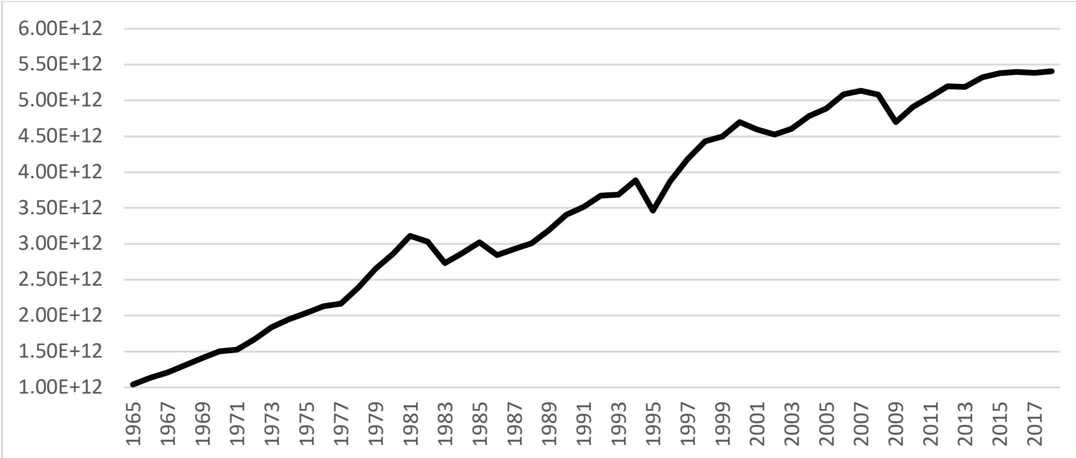

Figure 5. Industrial Value Added
Source: Own elaboration using data from INEGI.

Before constructing the regression model, correlation tests were performed to evaluate the relationships between the independent variables and the dependent variable. These tests helped identify whether statistically significant connections existed among the variables, which is crucial for confirming the suitability of a linear regression model.

The Pearson correlation coefficient was used to assess the linear relationship between quantitative variables. Pearson's correlation is a statistical tool that gauges the linear connection between two quantitative variables. This coefficient ranges from -1 to 1, where 1 indicates a perfect positive correlation, 0 signifies no correlation, and -1 reflects a perfect negative correlation. Essentially, Pearson's correlation measures both the direction and strength of the linear relationship between two variables, helping us determine if changes in one are associated with changes in the other (Fiallos, 2021).

The results of the correlation analysis show a strong positive relationship among the variables. The Pearson correlation coefficient between GDP per capita and Industrial Value Added is 0.9788, while the coefficient between GDP per capita and CO_2 emissions (kt) is 0.9733. Additionally, a significant correlation of 0.9805 was found between Industrial Value Added (constant LCU) and CO_2 emissions. These findings suggest that as GDP per capita and Industrial Value-Added increase, CO_2 emissions tend to rise substantially.

The Alternating Least Squares (ALS) method may be more appropriate in this case than the Ordinary Least Squares (OLS) method due to the strong correlations among the independent variables. In regression analysis using OLS, it is assumed that the independent variables are linearly independent and not highly correlated with each other. However, in this situation, the correlations among GDP per capita, Industrial Value Added, and CO_2 emissions are very high.

When the independent variables are highly correlated, a multicollinearity problem can occur in OLS regression. Multicollinearity can make the estimated coefficients unstable and difficult to interpret, and it can also decrease the accuracy of the model's predictions.

ALS is a technique that better handles multicollinearity by iteratively including independent variables into the model, enabling the regression method to select the most relevant variables and lessen the influence of highly correlated predictors.

Since GDP per capita, Industrial Value Added, and CO_2 emissions are highly correlated, using the ALS method can help prevent multicollinearity issues and provide more stable, reliable estimates in the regression model. This makes ALS a better choice in this case.

The decision to use ALS instead of OLS is justified by the presence of strong multicollinearity among the explanatory variables. When regressors exhibit near-linear dependence, OLS estimates become unstable, highly sensitive to small changes in the data, and difficult to interpret. Similarly, del Valle and Guerra (2012) demonstrate that multicollinearity inflates the variance of OLS coefficients, undermining their statistical reliability and limiting the validity of inference. These studies also note that alternative estimation procedures—such as component-based or iterative methods—provide more stable estimates under severe multicollinearity.

3. Results

The results of the model using ALS, generated with Gretl®, are shown in the following table:

Table 5. ALS Results

Model: ALS, using observations 1965-2018 (T = 54)					
		Dependent variable: CO2 Emissions			
	coefficient	**Std. Error**	**t-Statistic**	**p-value**	
const	−131366	41384.8	−3.174	0.0025	***
GDPper	30.4907	11.1337	2.739	0.0085	***
Industry	5.80E-08	1.27E-08	4.58	3.03E-05	***
Dependent vble median.		306793.6	Dep. vble. Std. Dev.		127980.9
Sum absolute resid.		918910	Sum squared resd.		3.18E+10
Log-likelihood.		−617.4958	AIC		1240.992
BIC		1246.958	HQC		1243.293

Source: Own elaboration with data from INEGI, processed in Gretl® software.

Based on the model results shown in Table 5 (above), the coefficients indicate a positive relationship between the independent and dependent variables. In other words, as both GDP per capita and Industrial Value-Added increase, higher economic growth is associated with greater CO_2 emissions. Regarding the t-statistics, both coefficients are significantly different from zero, with values of 2.739 and 4.580 for GDP per capita and Industrial Value Added, respectively. This indicates that both variables are statistically significant in predicting CO_2 emissions. The associated p-values are below the commonly accepted significance level (0.05), confirming the statistical significance of the coefficients.

Regarding the goodness of fit, the model has a log-likelihood of approximately -617.4958, and the information criteria (Akaike, Schwarz, and Hannan–Quinn) suggest the model's adequacy compared to other possible specifications.

Performing a normality test on the residuals shows that they do not follow a normal distribution, which could pose a problem in regression analysis. It is important to consider this non-normality when interpreting the model estimates and to explore possible solutions, such as data transformations or testing alternative models. The test results are displayed in the following table.

Table 6. Normality Test of Residuals

Frequency distribution for uhat7, observations 1-54							
Number of bins = 7, Mean = 6014.68, Std. Dev.=24180.8							
Interval			**Midpoint**	**Frequency**	**Relative**	**Cumulative**	
	<	-20325	-30159	4	7.41%	7.41%	**
-20325	-	-655.83	-10490	21	38.89%	46.30%	*************
-655.83	-	19013	9178	18	33.33%	79.63%	************
19013	-	38682	28848	4	7.41%	87.04%	**
38682	-	58351	48517	5	9.26%	96.30%	***
58351	-	78020	68186	1	1.85%	98.15%	
	>=	78020	87854	1	1.85%	100.00%	
Null hypothesis of Normal distribution test:							
Chi-squared (2) = 13.683 with p-value 0.00107							

Source: Own elaboration based on INEGI data using Gretl® software.

The frequency distribution results suggest that the residuals do not follow a normal distribution, as the relative and cumulative frequencies across the intervals do not align with the expected pattern. The normality test confirms this conclusion. The very low p-value (0.00107) provides strong evidence against the null hypothesis that the residuals are normally distributed.
However, within the scope of this research, the absence of normality in the residuals may not be as critical for several reasons: (i) An important factor when evaluating residual normality is the sample size. In our case, we have 54 observations. As the sample size increases, residuals tend to approach a normal distribution because of the Central Limit Theorem. Although normality is not fully achieved with our sample, the relatively large size helps alleviate concerns about non-normal residuals. (ii) Regression estimators, like ALS, are robust to certain assumption violations, including the normality of residuals. This means that even if residuals are not normally distributed, the estimators can still be consistent and efficient in estimating the model's parameters. (iii) Since the main goal of this research is to understand the causal relationship between the independent variables and the dependent variable (e.g., the impact of GDP per capita and Industrial Value Added on CO_2 emissions), the lack of residual normality becomes less critical. What matters most is whether the independent variables are significant and how they relate to the dependent variable.
Although the lack of normality in residuals is an important issue in statistics, it may not be as critical for our research and model because of the sample size, the robustness of the estimators, and the nature of our approach.

4. Discussion

The results from the ALS estimation reveal a statistically significant positive relationship between GDP per capita, Industrial Value Added, and CO_2 emissions in Mexico from 1965 to 2018. Both explanatory variables have positive coefficients, with t-statistics of 2.739 and 4.580 respectively, confirming their role in explaining the trend of national emissions. These findings align with previous research documenting the link between economic growth and environmental degradation (Stern, 2004; Ang, 2007; Lean and Smyth, 2010; Jalil and Mahmud, 2009; Pao and Tsai, 2010). The magnitude of the estimated coefficients in Mexico is comparable to those found in BRIC countries (Pao and Tsai, 2010) and ASEAN nations (Lean and Smyth, 2010), though in the Mexican case, the values indicate a higher dependence on carbon-intensive economic activities.

The results contrast with findings from Antonakakis et al. (2017), where advanced economies show a partial decoupling between growth and emissions. Unlike those cases where technological change and regulation have reduced emissions intensity, the Mexican data show that industrial expansion remains tightly linked to fossil fuel use, consistent with findings from recent consumption-based accounting studies (He et al., 2021). This contrast highlights the ongoing challenges in aligning Mexico's growth with climate goals.

A methodological aspect of this study is the use of ALS instead of the more common OLS. The correlations among explanatory variables were very high (above 0.97), indicating multicollinearity, which can impact the stability of estimates. This issue has been addressed in econometrics through methods such as Principal Component Regression (Jolliffe, 1982), Ridge Regression (Hoerl and Kennard, 1970), and LASSO (Tibshirani, 1996). ALS, by iteratively including variables, provided stable coefficients under these conditions, making it a suitable alternative for this case.

Another relevant point concerns the lack of residual normality identified through the χ^2 test ($p = 0.00107$). Although this could influence inference, previous studies suggest that estimators remain consistent under non-normality when using appropriate methods, such as heteroskedasticity-robust standard errors (White, 1980), autocorrelation-robust estimators (Newey and West, 1987), or quantile regression approaches (Koenker and Bassett, 1978). Additionally, with 54 annual observations, the Central Limit Theorem lessens the impact of non-normality on asymptotic inference. Therefore, even though the test rejects normality, the main conclusions of the model are still interpretable within these methodological considerations.

From a policy perspective, the findings show that both GDP per capita growth and industrial development are linked to higher CO_2 emissions. This aligns with earlier discussions in the

Environmental Kuznets Curve (EKC) literature (Stern, 2004; Jalil and Mahmud, 2009) but shows a stronger relationship in Mexico compared to other emerging economies (Pao and Tsai, 2010). These results highlight the importance of policies that decouple economic growth from emissions increase, such as promoting renewable energy and enhancing industrial efficiency (Shahbaz et al., 2013; Antonakakis et al., 2017).

García-Lara et al. (2017) show that environmental degradation in Mexico has intensified in regions where economic and demographic pressures exceed the adaptive capacity of terrestrial ecosystems. Their analysis demonstrates that biodiversity loss and land-use stress are closely associated with intensified production systems, reinforcing the conclusion that Mexico's growth trajectory remains environmentally burdensome. Similarly, Gavito et al. (2017) highlight that the country's current technological and institutional frameworks are insufficient to support a transition toward sustainable production models, particularly in sectors that depend heavily on fossil fuels and resource-intensive activities. Together, these studies corroborate the strong dependence of Mexico's economic expansion on carbon-intensive processes, as reflected in the ALS results.

Ramírez and Delgado (2017), through a multisectoral assessment of ecological risks, document how industrial intensification has increased pressure on ecosystems and contributed to long-term environmental vulnerability. Furthermore, Ríos-Orozco and Cárdenas (2017) show that resource overuse and land degradation are strongly correlated with patterns of regional economic specialization, particularly in agricultural and extractive zones. Their findings underscore that Mexico's environmental challenges are embedded in the composition of its productive structure, which limits the country's capacity to decouple economic growth from emissions—fully consistent with the emission–growth relationship identified in this study

Finally, the results of this study raise important questions regarding the effectiveness of Mexico's current mitigation policies under the Paris Agreement. While evidence from various countries shows that well-designed regulatory and technological measures can reduce emissions without compromising economic performance (Lean and Smyth, 2010; He et al., 2021), the empirical findings for Mexico suggest that deeper structural reforms are required to decouple growth from carbon-intensive activities. Future research could broaden the analytical framework by incorporating sector-specific panel data or nonlinear dynamics to evaluate heterogeneous policy impacts over time.

5. Conclusions

Mexico's development trajectory remains fundamentally carbon-intensive, reflecting persistent environmental trade-offs embedded in the country's industrial and economic structure. Throughout the period analyzed, increases in GDP per capita and Industrial Value Added were consistently accompanied by higher CO_2 emissions, indicating that the dynamics of growth have yet to decouple from fossil-fuel dependence.

This pattern carries important implications for Mexico's ability to meet its international climate commitments. Despite the adoption of mitigation measures and updates to its NDC framework, the evidence suggests that these efforts have not altered the underlying link between economic activity and emissions, raising concerns about the sufficiency of current strategies to achieve long-term climate goals.

Addressing this challenge will require a more explicit policy focus on mechanisms that enable structural decoupling. Priorities include accelerating the use of renewable energy, enhancing industrial energy efficiency, and progressively internalizing the environmental costs of production. Advancing these measures would help place Mexico on a more sustainable emissions trajectory while preserving economic performance.

More broadly, the findings underscore the need for economic and environmental planning to evolve in tandem. Embedding sustainability considerations into Mexico's development strategy is essential not only for meeting international obligations but also for strengthening ecological resilience and promoting long-term social well-being.

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