Tourism and the environment in Mexico: evidence of the relationship in the short and long term

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Abstract
Purpose – This study aims to examine the relationship between the environment and tourism flows, as well as the economic variables of the 32 states of Mexico for the period 1999–2019 based on data availability. The related literature studying tourism and environmental impacts is scarce at a national level, with most of them being local case studies. Some international studies find that if the relationship exists, it is weak or nonexistent, using CO2 as a proxy in most cases.

Design/methodology/approach – The present study uses panel data and cointegration panel methodologies, while also using geographic information systems to observe the distribution of variables at a state level between tourism and environmental variables.

Findings – The findings of the study are as follows: state gross domestic product, the inertia of environmental variables (i.e. volume of water treatment and solid waste), occupied rooms (proxy variable for tourism activity) and average temperature have an impact on the contemporary evolution of environmental variables; national and international tourist variables have no impact on the environment; the panels are integrated in such a way that there is a long-term equilibrium between states and some environmental care variables; and no conclusive evidence is found regarding the impact of tourism activity on the considered environmental variables.

Research limitations/implications – The main limitations and areas of opportunity of the work refer to the amount of data available over time and the precision of the measurement of the variables. The availability, temporality and frequency of the data are also limitations of the research. An example of this is the nonexistence of CO2 emissions at the state level. Additionally, studying other countries and regions for which there are limitations of data and applied studies is also a challenge.

Practical implications – The results are important for economies (in growth) and societies whose economic growth depends on tourism flows and have done little to reverse the damage that tourism has on the environment.

Social implications – The models can contribute to study the relation between tourism and environmental variables and could be extended to regions, states and provinces for decision-making on actions to be taken for the present and future.

Originality/value – The originality of the research is innovative for the region: Mexico, Central and Latin America. There are no works that have studied these problems with this methodology and these variables. In terms of originality, the classic models of panel data and cointegration of panel data are useful and easily replicable for others to use for different countries. The results are relevant because there is apparently no relationship between tourism and some environmental variables in the short run, but there exists a weak and strong long-run relation between some of them.

Keywords Environment, Economic growth, Tourism, SDGs, Panel data and cointegration

Paper type Research paper
Turismo y medio ambiente en México: evidencia de la relación en el corto y largo plazo

Resumen

Propósito: Se examina la relación entre medio ambiente y flujos turísticos, así como variables económicas de los 32 estados de México para el periodo 1999-2019 basado en la disponibilidad de datos. La literatura relacionada es escasa, siendo la mayoría de estudios de casos locales. Estudios internacionales no encuentran que la relación exista, es débil o inexistente, utilizan CO2 como un indicador en la mayoría de los casos.

Diseño/metodología/enfoque: Se utilizaron metodologías de datos de panel y cointegración de panel, así como sistemas de información geográfica para observar la distribución de variables a nivel estatal.

Resultados: i) El Producto Interno Bruto Estatal, la inercia de las variables ambientales (es decir, volumen de tratamiento de agua y residuos sólidos), habitaciones ocupadas (proxy de la actividad turística) y temperatura promedio tienen un impacto en la evolución contemporánea de las variables ambientales, ii) las variables turísticas nacionales e internacionales no tienen un impacto en el medio ambiente, iii) los paneles están integrados de tal manera que existe un equilibrio a largo plazo entre turismo, crecimiento económico y algunas variables ambientales, y iv) no se encuentra evidencia concluyente con respecto al impacto de la actividad turística en las variables ambientales consideradas.

Limitaciones/implicaciones de la investigación: Las principales limitaciones y áreas de oportunidad del trabajo se refieren a la cantidad de datos disponibles en el tiempo y a la precisión de la medición de las variables. La disponibilidad, temporalidad y frecuencia de los datos también son limitaciones de la investigación. Un ejemplo de ello es la inexistencia de emisiones de CO2 a nivel estatal. Además, el estudio de otros países y regiones para los que existen limitaciones de datos y estudios aplicados también es un reto.

Implicaciones prácticas: Los resultados son importantes para las economías (en crecimiento) y las soluciones cuyo crecimiento económico depende de los flujos turísticos y que han hecho poco por invertir los daños que el turismo produce en el medio ambiente.

Implicaciones sociales: Los modelos pueden contribuir a estudiar la relación entre el turismo y las variables medioambientales, y podrán extenderse a regiones, estados y provincias para la toma de decisiones sobre las acciones a emprender para el presente y futuro.

Originalidad/valor: El artículo proporciona un análisis innovador y exploratorio hacia una perspectiva futura que agrega valor al turismo y la planificación para la sostenibilidad. La relación entre turismo y medio ambiente se ha estudiado durante varios años. La UNTWO ha abordado las consecuencias del turismo en el medio ambiente, particularmente, más basura, mayor consumo de agua, emisiones de CO2 y otros aspectos. Pocos trabajos estudian la relación entre estas variables.

La originalidad de la investigación es innovadora para la región: México, América Central y América Latina. No existen trabajos que hayan estudiado estos problemas con esta metodología y estas variables.

En términos de originalidad, los modelos clásicos de datos de panel y cointegración de datos de panel son útiles y fácilmente replicables para que otros los utilicen en diferentes países. Los resultados son relevantes porque aparentemente no hay una relación entre el turismo y algunas variables ambientales a corto plazo, existe una relación débil y fuerte a largo plazo entre algunas de ellas.

Palabras clave: Medio ambiente. Crecimiento económico. Turismo. ODS. Datos de panel y cointegración

Tipo de papel: Trabajo de investigación
Introduction

Tourism is an important channel for generating accelerated endogenous growth because it provides a growing economy with foreign currency to finance the same sector and other economic activities, whether directly or indirectly (Brida et al., 2008; Neves and Campos, 2005; Balaguer and Cantavella-Jordá, 2002).

Existence of tourist areas, services and products, along with social, economic development and infrastructure elements, will generate tourist flows that will allow it to be a self-generating growth engine; however, its effects on environmental conditions are undeniable, such as an increased demand for water, energy, higher emissions, waste generation, deforestation due to infrastructure expansion.

In Mexico, positive evolution of tourism and its growth potential have increased in recent years, tourism has been proposed as a source of growth. Tourist activities are frequently considered key variables in economic growth at regional, national and international levels, as they particularly provide growing economies with income through currency, jobs and services generation, among others.

Available studies emphasize the role of tourism in growth, and there have been studies based on the effects on environment, through indiscriminate water use and emissions generated by pollutants from transportation, changes in land use resulting from investments in the sector (Adedoyin and Bekun, 2020; Adedoyin et al., 2021), solid waste generation (Khan et al., 2020).

It is not easy to separate the environmental impacts attributable to tourism from the effects of other economic activities or anthropogenic factors and non-anthropogenic causes. Challenges and goals society must meet the Sustainable Development Goals (SDGs) by 2030, the relationship between tourism and environmental care is more relevant than ever.

Tourism worldwide has led to greater questioning of its environmental effects (Holden, 2008). Pulido-Fernández et al. (2019) argue sustainable tourism has grown due to awareness of the availability of natural and cultural resources and negative aspects that tourism could have on the environment and society.

Tourism has negative externalities on environment such as pollution, water, garbage, resource use and tourist’s behavior toward the site they are visiting. Negative effects on environment include both physical and cultural aspects. These negative effects must be offset by economic benefits that tourism offers (Holden, 2008). Tourism should maintain or improve air, water and soil quality in destinations.

As a resource-dependent activity, tourism must compete for scarce resources to ensure its survival. Private sector dominates tourism-related activities, and investment decisions are primarily based on profit maximization. Unlike other industrial activities, tourism generates revenue by importing customers rather than exporting its product (McKercher, 1993).

We conduct a quantitative analysis of impact of tourism on environmental variables, using panel data methodologies and panel data cointegration to measure whether tourism flows in Mexico directly impact the preservation of natural resources and, secondly, whether tourism and environmental variables have a long-term relationship.

The aim is to study the relationship between tourism and the environment in Mexico. If tourism create greater economic growth, then it also tends to affect the natural resources or environmental variables available at the level of the 32 states that make it up. There is no conclusive evidence of the relationship between these variables. Research questions are as follows:

\textbf{RQ1.} To what extent do tourist flows in Mexico affect the environment?

\textbf{RQ2.} Is there a long-term relationship between tourist flows and environmental variables in Mexico?

\textbf{RQ3.} Can we test the hypothesis of tourism environmental disease for Mexico?
Methodologies and methods used include economic, social and environmental variables, recognizing their measurement may be imperfect or inaccurate. Panel data models and panel data cointegration allow to estimate the existing short-term relationship between variables, leveraging all available data over time and by state in a robust way and to analyze whether there is a long-term relationship between the variables considered.

**Literature review**

For years, the same question has been asked about the contribution of domestic tourism sector to economic growth (Gupta and Dutta, 2017). This relationship would allow the private and public sectors to plan and manage tourism activities with the aim of maximizing the gains derived from the activity. The general idea is the existence of tourist areas will generate visitor flows to drive economic growth. Among the effects considered to measure the impact of destination places, increase in foreign currency supply, generation of local income sources with externalities effects and growth of direct and indirect jobs stand out, among others (Balaguer and Cantavella-Jordá, 2002).

Disadvantages of tourism have been analyzed by the World Tourism Organization (World Tourism Organization, 2019a, 2019b). Tourism is facing a clear threat from environmental and climate change effects, natural disasters, water scarcity, changes in biodiversity and effects of pandemics. Undoubtedly climate change has affected tourism, and tourism has affected climate change as well. Thus, causality is something that should be demonstrated whenever possible.

Neves and Campos (2005) analyze the causality between economic growth and tourism using a panel data model for countries with a strong presence of tourism sector in their total economic activity, authors address this relationship from the perspective of time series or other analytical tools. For Latin American countries, it is found that a higher per capita flow of tourists generates greater growth in nations with low- and middle-income levels, whereas for richer economies, this relationship is not observed. Neves and Campos (2005) found that conditional impact of tourism is not significant, and in some subsamples, it appears as an unexpected negative impact, which confirms the results found in the complete sample.

The sign and significance of parameters related to the variables of the tourism sector are relevant in Africa and Latin America and in all variables for the subsample where a comparative advantage in the tourism sector is assumed; authors conclude tourism alone cannot contribute significantly to the high growth rates of those economies that specialize in tourism. The most surprising result of the study is that, in case there is a significant relationship between economic growth and tourism, the sign is negative.

Holzner (2011) analyzes “Beach Disease Effect” on countries dependent on tourism in the long term; it reviews whether economies characterized by being dependent on tourism show lower economic dynamics. One way to analyze the issue is by combining two aspects of the literature:

1. the relationship between tourism specialization and long-term economic growth; and
2. possible channels by tourism specialization can improve or worsen economic development.

Copeland (1991), Gylfason (2001) and Sachs and Warner (2001), methodology is modified to study dependence of the tourism sector and the development of countries in a panel.

Two facts are recognized in the literature:

- development of tourism is highly dependent on natural and cultural resources, and
- as the tourism industry expands, exploitation of natural resources increases the risk of pollution, erosion, habitat loss, among other environmental consequences (Wang and Wang, 2018).
Elimination of the harmful effects of tourism on the ecological balance and the future development of tourism are among the biggest challenges facing society (Ozturk et al., 2016; Mikayilov et al., 2019; Adedoyin et al., 2021; Gössling and Peters, 2015).

Paramati et al. (2017) studied the effect tourism has on economic growth and CO₂ emissions for countries in Eastern and Western Europe. Using a panel data cointegration methodology, the study found that there is a long-term relationship between variables. Results suggest that tourism has an adverse effect in Eastern Europe and not in the Western part. Authors conclude that tourism has positive effects on economic growth but the consequences on CO₂ emissions depend more on public policies (PP) and efficient management.

Kongbuamai et al. (2020) study the causal and long-term relationships between tourism, economic growth, natural resources and ecological footprint in association of Southeast Asian Nations (ASEAN) countries using cointegration, Westerlund and causality tests. Finding the existence of the environmental Kuznets curve (EKC), a negative relationship between tourism and environment with ecological footprint. This means that in ASEAN member countries, tourism and environment help improve environmental quality. Pulido-Fernández et al. (2019) study uses a structural equation model to show that improvements in environmental sustainability do not occur at the expense of the main variables of tourist growth; in fact, it is precisely the opposite. Results suggest that an improvement in policies and regulation will increase tourism growth, when tourism increases, so does environmental pollution, so relationship between tourism and environmental sustainability is bidirectional.

Mikayilov et al. (2019) studied the impact of tourism on ecological footprint for Azerbaijan during 1996–2019. They found that the coefficient of tourism development, which is the elasticity of environmental degradation, is invariant over time. Among the variables they used are trade and energy consumption as independent variables, which have a positive impact on the ecological footprint.

Long-term evidence on economic growth, international tourism, globalization, energy consumption and CO₂ emissions in organization for economic cooperation and development (OECD) countries during 1994–2014 is studied by Balsalobre-Lorente et al. (2020). Empirical analysis reveals that climate change is magnified by energy use, tourism and economic growth. They also find a U-shaped relationship (EKC) between international tourism and CO₂ emissions. Contribution of international tourism to climate change in the early stages of development is diminished by globalization in later stages; findings provide additional arguments for shaping regulatory frameworks aimed at reversing the current energy mix in OECD countries by facilitating energy efficiency and promoting renewable sources (Balsalobre-Lorente et al., 2020).

Khan et al. (2020) focuses on Pakistan, analyzing the relationship between economic growth, tourism, investment, CO₂ emissions, energy consumption and their direction of causality. Using unit root tests and an error correction model; they find evidence that economic growth influences tourism, which generates a greater demand for energy and a greater amount of CO₂ emissions, which in turn disincentivizes tourism. Authors conclude that PP are needed to increase foreign tourism that seeks sustainability, as well as regulations that promote environmental protection and the reduction of the use of nonrenewable energy.

Azam et al. (2018) analyzed the effects of tourist arrivals on environmental pollution in Malaysia, Thailand and Singapore, using unit roots and structural shocks. They found that tourism has a positive impact for Malaysia and a negative impact for Thailand and Singapore. Ahmad et al. (2019) studied middle-income economies in Southeast Asia, and by using unit root tests and structural breaks, the study confirms a negative impact of tourism on the environment for Indonesia and Philippines but a positive impact for Vietnam. This implies that the relationship varies for different countries in the same region, depending
on the specific characteristics of the country and the corresponding policies to protect the environment.

In Mexico, few studies address the relationship between economic growth, environment and tourism jointly and/or disaggregated at the state level. Brida et al. (2008) use quarterly data aggregated at the national level, through a Johansen cointegration analysis, confirm the hypothesis of tourism as a factor in economic growth. Gómez-López et al. (2011) seek to test the EKC for the 32 entities using panel data, they found that there is no relationship between economic growth and an increase in environmental variables, except for the volume of garbage collection and wastewater volume. They also found that the environment is not among the priorities of the Mexican economy according to the EKC hypothesis. Padilla (2015) analyzes environmental effects of tourism in Cancun (water, solid waste, air and noise pollution) and documents that after receiving two million tourists annually, hotels generate 95% of wastewater that goes beyond treatment plants in the city and a large portion of it reaches the sea contaminating the water. Regarding the generation of solid waste, it amounts to 329,000 tons per year, a quarter of which is generated by the hotel zone. Tousignant et al. (2012) review Puerto Vallarta, which receives an average of three million tourists annually and an average of 350 daily tons of garbage (half generated by tourists). Through surveys with residents, they found that the garbage dump has an impact on the quality of life of people living nearby, although it was considered a secondary effect of tourism.

Empirical evidence

The information used comes from various official sources of information. The relationship between socioeconomic variables and tourism flows on environmental variables are studied. The 32 states of Mexico are included in the period 1999–2019, owing to the limited availability of information for all variables. Information is as follows:

- domestic tourists (NacTourists);
- international tourists (IntTourists);
- State gross domestic product (GDP) (SGDP) at constant prices 2013;
- Tourism GDP (GDP_Tourism) at constant prices 2013;
- annual average temperature (AvgTemp); and
- exchange rate (ExRate).

As environmental variables, we use proxies for environmental care/degradation the number of planted trees (PlantedTrees), environmental licenses (EnvLic), water treatment plants (TreatPlants), reforested area (RefSurf), garbage collection volume (GarbRecVol) and water treatment volume (WatTreatVol). We use Occupied Rooms (OccupRooms) as a proxy for total tourists. In some cases, there are biannual variables, so some estimates have unbalanced panel data.

Figures 1 and 2 show scatter plots of the domestic and international tourist with environmental variables considered. It appears to be a positive relationship between tourists and the volume of garbage collection and water treatment. In Figure 3, we present, using geographic information systems, the distribution and concentration of the variables used in this study at the state level.

In the tourism flow variables [panels (a) and (b) Figure 3], Veracruz, Jalisco, Mexico City and Guerrero stand out with the highest flows of domestic tourists followed by Quintana Roo, Chiapas and Chihuahua. Panels (c)-(f) in Figure 3 show variables of garbage collection volume, water treatment volume, planted trees and reforested surface. No regularity is observed between tourist flows and environmental variables.
Georeferencing of the variables allows us to conclude that states that apparently have higher results in their environmental efforts do not coincide with states with the highest influx of tourists. According to the maps, the state concentrations are independent, meaning that there seems to be no relationship between tourist flows and environmental variables.
Methodology

We study the impact and relationship between socioeconomic variables and tourist flows on environmental variables. The 32 states of the Mexican Republic are included in the period 1999–2019. Previous relations do not allow us to a priori expect that the tourism sector could affect the considered environmental variables. We use panel data models and panel data cointegration, to explore the qualities of both cross-sectional data and time series data and to analyze whether there is a long-term equilibrium among the related variables. The methodology protocol is reported in Figure 4.
Panel data models

In panel data models, the evolution of variables is considered for each of the states in Mexico over time. Using these models (dimensions of \( N \) (states) and \( T \) (period)), results in more robust and conclusive tests than just applying time series. Annual evolution could help in forming “expectations” for the future. For environmental and tourism variables, heterogeneity is observed among the 32 Mexican states suggesting the relevance of observing individually for each variable and for each year in the sample period so it would be expected that each state would converge toward different stationary states. To eliminate bias in the measurement of variables, all of them are expressed in logarithms or alternatively in percentage changes.

Consider the following general panel data model:

\[
y_{it} = \alpha_i + \beta x_{it} + e_{it}
\]  

(1)

where \( \alpha_i \) is a random variable, the dependent variable \( y_{it} \) is explained by a set of independent or exogenous variables \( x_{it} \). Error term \( (e_{it}) \) is assumed to have constant variance \( (\sigma_{e}^{2}) \) and constant mean of zero \( (E(e_{it}) = 0) \).

Fixed effects panel assumes that differences between agents (states) are represented by the constant term. Random effects model considers the constant term \( \alpha_i \) as a random variable that represents the individual effects of the panel agents, and especially that they are distributed independently of the independent variables \( (x_{it}) \).

In the random effects model, values are different for each state, the constant is defined as follows: \( \alpha_i = \alpha + \epsilon_i \), where \( \epsilon_i \) is assumed to be independently distributed as a normal with mean zero and constant variance, \( N(0, \sigma^2) \). The equation to be estimated is therefore:

\[
y_{it} = \alpha + \beta x_{it} + \epsilon_i + u_{it}
\]

(2)
Hausman test is used, which contrasts the hypothesis of consistency of the estimator of the random effects model.

**Cointegration of panel data**

We included cointegration model to test whether the series have a long-term equilibrium relationship from 1999 to 2019. Panel data cointegration tests used in the literature consider three different models: Kao (1999), Pedroni (2000, 2004) and Westerlund (2008). The series for which we applied the three cointegration tests are those that were statistically significant in the panel data models for explaining long-term relationships, namely: international tourists, domestic tourists, state GDP at constant 2013 prices and environmental variables. Panel data cointegration tests were conducted based on data availability including reforested area, wastewater treatment volume and wastewater treatment volume.

Unit roots and cointegration in panel data has been fruitful by combining the advantages of receiving and leveraging information from time series with cross-sectional data, taking advantage of the $N$ and $T$ dimensions, more robust and conclusive tests can be conducted compared to only applying time series.

To establish whether the variables are cointegrated, the Kao test (1999) was used. Consider the panel data model of equation (1) where the variables $y_{it}$ and $x_{it}$ are I(1) and not cointegrated. For $z_{it} = \{\mu_{it}\}$, Kao (1999) proposed unit root tests of DF and augmented DF for $e_{it}$ as a test for the null hypothesis of no cointegration.

We establish is that the variables must be non-stationary in levels, but when we convert the variables to their first differences, they become stationary. In this way, the hypotheses that we establish in the Kao and Pedroni tests are the following:

- $H_0$: No cointegration among the panels
- $H_a$: All the panels are cointegrated

In the case of the Westerlund (2008) model, the hypotheses are as follows:

- $H_0$: No cointegration among the panels
- $H_a$: Some panels are cointegrated

**Results**

According to the panel data models, we estimate the following equation:

$$
I_{\text{Env}_{it}} = \alpha + \beta_1 \Delta \text{Env}_{it-1} + \beta_2 \Delta \text{NacTourists}_{it} + \beta_3 \Delta \text{IntTourists}_{it} + \beta_4 \Delta \text{Occ} \text{cup} \text{Rooms}_{it} \\
+ \beta_5 \Delta \text{GDP}_{it} + \beta_6 \Delta \text{TourGDP}_{it-1} + \beta_7 \Delta \text{AvgTemp}_{it} + \beta_8 \text{ExRate}_{it} + \epsilon_{it}
$$

(3)

where the variables of state $i$ in year $t$ are defined in the empirical evidence subsection. We refer to the environmental variable as $\text{Env}_{it}$, and $\Delta \text{Env}_{it}$ is the differencing operator for any variable $\text{Env}$. $\Delta$ represents the percentage changes in the variables considered in the model. The results are presented in Table 1.

Evolution of environmental variables for 32 federal entities in Mexico 1999–2019 in the proposed models is explained by four variables: GDP in constant pesos 2013, growth rate of the environmental variable with respect to the previous year, increase in the average temperature and, in four of the six environmental variables considered, the proxy variable for tourism, which is the number of occupied rooms. For average temperature, the sign is negative in most of the variables for which it is statistically significant, meaning that an increase of 1°C decreases the growth rate of the environmental variable. Results have the expected sign, and statistical
### Table 1: Panel data models for environmental variables in Mexico

<table>
<thead>
<tr>
<th>Variables</th>
<th>Constant</th>
<th>logEnv(_{i,t-1}) (\beta_1)</th>
<th>ΔNatTourists(_{i,t}) (\beta_2)</th>
<th>ΔIntTourists(_{i,t}) (\beta_3)</th>
<th>ΔOccupRooms(_{i,t}) (\beta_4)</th>
<th>ΔSGDP(_{i,t}) (\beta_5)</th>
<th>ΔTourGDP(_{i,t}) (\beta_6)</th>
<th>AvgTemp(_{i,t}) (\beta_7)</th>
<th>ExRate(_{i,t}) (\beta_8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PlantTrees(_{i,t})</td>
<td>16.0805 (1.928)</td>
<td>0.134380 (2.174)</td>
<td>-0.0009737 (-1.003)</td>
<td>-0.000814 (-0.5882)</td>
<td>0.00644711 (1.12)</td>
<td>-0.002154 (-0.4656)</td>
<td>0.0655051 (0.4754)</td>
<td>-1.39425 (-0.5053)</td>
<td>0.112970 (0.8797)</td>
</tr>
<tr>
<td>EnULicit(_{i,t})</td>
<td>2.62783 (2.798)</td>
<td>0.331030 (2.398)</td>
<td>0.00404923 (0.7742)</td>
<td>0.000793904 (0.8847)</td>
<td>-0.0084690 (-1.617)</td>
<td>-0.0022883 (-0.3626)</td>
<td>0.0137843 (3.027)</td>
<td>-0.102747 (-0.3406)</td>
<td>-0.14937 (-4.715)</td>
</tr>
<tr>
<td>GarbRecVol(_{i,t})</td>
<td>-12.167 (-0.907)</td>
<td>7.02077 (7.437)</td>
<td>-0.0013401 (-0.3803)</td>
<td>-0.002093 (-0.4586)</td>
<td>0.0244392 (2.728)</td>
<td>0.0291662 (3.568)</td>
<td>-0.00148702 (-0.4484)</td>
<td>-12.0983 (-2.326)</td>
<td>0.337548 (4.722)</td>
</tr>
<tr>
<td>TreatPlants(_{i,t})</td>
<td>-6.6737 (-2.856)</td>
<td>0.760106 (21.42)</td>
<td>-0.000250564 (-0.4938)</td>
<td>-0.00016752 (-0.3839)</td>
<td>0.0062883 (2.336)</td>
<td>0.00417764 (1.215)</td>
<td>1.67798 (2.333)</td>
<td>0.0653005 (0.166)</td>
<td>0.0016944 (1.127)</td>
</tr>
<tr>
<td>SupRef(_{i,t})</td>
<td>11.6313 (3.336)</td>
<td>0.316066 (2.348)</td>
<td>0.000578408 (0.2778)</td>
<td>0.00011215 (-1.542)</td>
<td>0.00640792 (1.803)</td>
<td>0.00068342 (0.7449)</td>
<td>0.028137 (-1.187)</td>
<td>0.0819820 (1.252)</td>
<td>0.0437004 (4.630)</td>
</tr>
<tr>
<td>WatTreatVol(_{i,t})</td>
<td>2.4341 (0.073)</td>
<td>0.792599 (20.26)</td>
<td>1.454866 (0.03162)</td>
<td>-0.0019803 (-0.2170)</td>
<td>-0.0019651 (-2.208)</td>
<td>0.0016944 (0.003)</td>
<td>0.016991 (4.630)</td>
<td>0.0032667 (-1.247)</td>
<td>0.0436704 (4.630)</td>
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<td>GLS (Random Effects)</td>
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<tr>
<td>PlantTrees(_{i,t})</td>
<td>7.18303 (2.754)</td>
<td>0.717860 (10.39)</td>
<td>-0.0031885 (-0.5380)</td>
<td>-0.0014821 (-1.084)</td>
<td>0.000469182 (0.07478)</td>
<td>-0.002158 (-0.5034)</td>
<td>-0.0019198 (-0.4936)</td>
<td>-0.043910 (-1.221)</td>
<td>-0.11625 (-0.708)</td>
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<tr>
<td>EnULicit(_{i,t})</td>
<td>1.18417 (1.547)</td>
<td>0.788383 (20.10)</td>
<td>0.00085899 (1.815)</td>
<td>0.00126276 (0.9942)</td>
<td>-0.0142949 (-2.338)</td>
<td>-0.008089 (-1.339)</td>
<td>0.144349 (2.513)</td>
<td>-0.328800 (-1.375)</td>
<td>0.002478 (0.6654)</td>
</tr>
<tr>
<td>GarbRecVol(_{i,t})</td>
<td>-7.0987 (-14.41)</td>
<td>1.03190 (38.86)</td>
<td>-0.0018832 (-0.4938)</td>
<td>-0.001875 (-0.8383)</td>
<td>0.0027952 (3.682)</td>
<td>0.0030850 (3.715)</td>
<td>-0.0015267 (-2.339)</td>
<td>-0.34164 (-3.416)</td>
<td>0.785682 (29.90)</td>
</tr>
<tr>
<td>TreatPlants(_{i,t})</td>
<td>-6.6737 (-2.856)</td>
<td>0.760106 (21.42)</td>
<td>0.000250564 (-0.4938)</td>
<td>-0.00016752 (-0.3839)</td>
<td>0.004775 (2.293)</td>
<td>0.00206988 (2.336)</td>
<td>0.00417764 (1.215)</td>
<td>1.67798 (2.333)</td>
<td>0.0653005 (0.166)</td>
</tr>
<tr>
<td>SupRef(_{i,t})</td>
<td>2.94653 (2.849)</td>
<td>0.690121 (10.65)</td>
<td>0.000569756 (0.2546)</td>
<td>-0.001328 (-1.530)</td>
<td>0.00011732 (2.560)</td>
<td>-0.0031736 (-0.9519)</td>
<td>-0.000702094 (-0.2660)</td>
<td>-0.081576 (-0.3154)</td>
<td>-0.00854 (-0.3465)</td>
</tr>
<tr>
<td>WatTreatVol(_{i,t})</td>
<td>0.570360 (2.947)</td>
<td>0.984678 (100.2)</td>
<td>3.535936 (0.07739)</td>
<td>0.000309849 (0.8366)</td>
<td>-0.0008748 (-0.8704)</td>
<td>-0.0019765 (-2.209)</td>
<td>0.00138243 (3.566)</td>
<td>-0.039817 (-0.7011)</td>
<td>-0.05974 (-1.195)</td>
</tr>
</tbody>
</table>

**Note:** t-statistic in parentheses

**Source:** Own elaboration/table by authors
significance is standard. Results are relevant because, there is no evidence that national or international tourist flows are related to positive environmental variables (e.g. reforested area or planted trees) or negative environmental variables (e.g. volume of garbage collected or volume of water treatment).

Occupied rooms summarize that the tourism activity is statistically significant. Garbage collection volume indicates that tourism has a positive impact on generating more garbage. This is one of the most relevant results in this work in quantitative terms. Environmental variables and their direct care, generation of garbage, use of water and emission of pollutants are the most direct. Given that only the first variable is available at the state level, it is the most direct result regarding the possible relationship between tourist flows and environmental care.

Domestic and international tourist flow variables are not statistically significant in the fixed effects model but are for the environmental license variable in the random effects model. In summary, panel data models show that the evolution of environmental variables in Mexico 1999–2019 is mainly explained by the inertial effect of the same variable measured through its growth, economic growth through state GDP, the increase in the average annual temperature and, in the case of garbage collection volume, environmental licenses and reforested area, the variable of occupied rooms as a proxy for the dynamics of both domestic and international tourism.

For all models, the Hausman test contrasts the hypothesis of the consistency of the estimator of the random effects model. In all cases, the consistent estimation is that of the fixed effects model were verified (upper panel in Table 1).

Results do not allow for robust conclusions regarding the incidence of tourism on the environment. The same applies to Mexico in this period with the available information: variables of tourism flow in Mexico fail to explain the care or deterioration of environmental variables for which we have information. Results of panel data models (Table 2) are consistent with several studies regarding the non-necessity of a relationship between tourism and the degradation of environmental variables, (Pulido-Fernández et al., 2019; Mikayilov et al., 2019).

Panel data cointegration models indicate that environmental variables, domestic and international tourists and state GDP at constant prices of 2013 are cointegrated in the long-term equilibrium. The most robust tests are Pedroni and Westerlund, as according to the results, the variables considered cointegrate for all or at least most of the panels. For Kao test, the results are ambiguous, however, the Dickey Fuller test is statistically significant at 95% confirming

<table>
<thead>
<tr>
<th>Test</th>
<th>Reforested surface area</th>
<th>Garbage collection volume</th>
<th>Water treatment plants</th>
<th>Water treatment plants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>p-value</td>
<td>Statistic</td>
<td>p-value</td>
</tr>
<tr>
<td>Kao test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified Dickey–Fuller</td>
<td>$-0.6428$</td>
<td>$0.2602$</td>
<td>$-0.7380$</td>
<td>$0.2303$</td>
</tr>
<tr>
<td>Dickey–Fuller</td>
<td>$-3.3127$</td>
<td>$0.0005$</td>
<td>$-3.4238$</td>
<td>$0.0003$</td>
</tr>
<tr>
<td>Augmented Dickey–Fuller</td>
<td>$-1.1567$</td>
<td>$0.1237$</td>
<td>$-1.2259$</td>
<td>$0.1101$</td>
</tr>
<tr>
<td>Unadjusted modified Dickey–Fuller</td>
<td>$-4.2445$</td>
<td>$0.0000$</td>
<td>$-4.2961$</td>
<td>$0.0000$</td>
</tr>
<tr>
<td>Unadjusted Dickey–Fuller</td>
<td>$-5.4193$</td>
<td>$0.0000$</td>
<td>$-5.4810$</td>
<td>$0.0000$</td>
</tr>
<tr>
<td>Pedroni test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modified Phillips–Perron</td>
<td>$3.8713$</td>
<td>$0.0001$</td>
<td>$3.7205$</td>
<td>$0.0001$</td>
</tr>
<tr>
<td>Phillips–Perron</td>
<td>$-1.9848$</td>
<td>$0.0236$</td>
<td>$-1.5198$</td>
<td>$0.0643$</td>
</tr>
<tr>
<td>Augmented Dickey–Fuller</td>
<td>$-0.9991$</td>
<td>$0.1589$</td>
<td>$-0.6747$</td>
<td>$0.2499$</td>
</tr>
<tr>
<td>Westerlund test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variance ratio</td>
<td>$-1.8581$</td>
<td>$0.0316$</td>
<td>$-1.9338$</td>
<td>$0.0266$</td>
</tr>
</tbody>
</table>

Source: Own elaboration/table by authors
the cointegration of panels in the variables considered. Results in both cases is that strong cointegration – where all panels cointegrate, and the weak cointegration – where some panels cointegrate, suggest the importance of PP aimed at strengthening the relationship between the variables studied. Table 3 summarizes qualitative results of models used.

Conclusions and recommendations

Is recognized the impact of tourism on the environment; many of these studies are qualitative and conducted at the national, local or tourist destination level. There are no such studies in Mexico at the national or state level. We analyzed the evolution of different variables for different macroeconomic agents, that is, panel data and panel data cointegration to provide evidence of short- and long-term relationships between tourist flows and environmental variables.

The main results are as follows: evolution of environmental variables in Mexico for the period 1999–2019 is explained by the lagged effect of the environmental variable measured through its growth, by economic growth through state GDP, growth in the average temperature and three environmental variables (reforested area, garbage collection volume and environmental licenses), and occupied rooms as a proxy variable for tourist flows. Tourist flow variables in Mexico do not explain the care or deterioration of environmental variables for which we have information, meaning that evidence of the relationship between the number of tourists and environment is weak but they are closely related. In conclusion,

Table 3 Qualitative results of panel and panel data cointegration models

<table>
<thead>
<tr>
<th>Model</th>
<th>Results</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel data</td>
<td>Variables explaining environmental degradation or care are:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. One-period lagged environmental variables (inertia)</td>
<td>Evolution of considered environmental variables is due the variable itself in relation to the previous year</td>
</tr>
<tr>
<td></td>
<td>2. Economic growth for waste collection variables (+), water treatment volume (−), reforestation area (−) and water treatment plants (+)</td>
<td>Garbage collection shows linear and increasing relationship with population and tourism</td>
</tr>
<tr>
<td></td>
<td>3. Occupied rooms for waste collection (+), reforestation area (+) and water treatment plants (+)</td>
<td>Economic growth and tourism positively and statistically significantly explain the increase in garbage, but not the average temperature, which explains it negatively</td>
</tr>
<tr>
<td></td>
<td>4. Average temperature for waste collection variables (−), water treatment volume (−), reforestation area (−) and water treatment plants (+)</td>
<td>Volume of water treatment is explained by inertia of variable, and negatively by average temperature</td>
</tr>
<tr>
<td></td>
<td>The greatest impact on evolution or change of environmental variable is in all cases the value of the variable in the immediate previous period</td>
<td>Reforested area is negatively explained by economic growth and average temperature, and positively by the tourism proxy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water treatment plants is positively explained by the same variable one period earlier, economic growth, the tourism proxy and the average temperature</td>
</tr>
<tr>
<td>Panel data cointegration tests:</td>
<td>Environmental variables, domestic and international tourists and state GDP have a long-term relationship over time with four environmental variables considered</td>
<td></td>
</tr>
</tbody>
</table>

Source: Own elaboration/Table by authors
the issue of tourist flows and the positive and negative relationship with environment is inconclusive and requires much future work; having more data for the study of the relationship between the growth and development of tourist activities and the deterioration and preservation of the environment will allow for better conclusions in this regard.

The contribution of this work is that we measured the short- and long-term impacts of the possible relationship between tourism and environmental variables. In the short term, there is no clear conclusion about the impact of tourism on environmental variables, but in the long term, the variables of tourism are related to the environmental variables considered. Implications are vital for the design of PP for the present and future. The inconclusive results in the short term but conclusive results in the long term provide possibilities for anticipating the actions that countries should take to preserve the environment in the face of tourist activities.

PP should focus on proposing, applying and verifying compliance so that tourism sector activities have a positive impact on preservation of environmental heritage (or at least no negative). Although empirical evidence is limited, in some cases, the signs of estimates and results are contrary to what should ideally happen, such as taking better care of water, generating less waste and improving air quality, among others.

Consequences for tourism sector and activities must be reconsidered for present and medium- to long-term future. The sector must be resilient to adapt to the current new conditions. Countries and society must make a greater effort to adapt to the new reality and take care of the natural resources which are more limited as time goes on. Beyond the SDGs, the world has given us an opportunity to look at the future more consciously.

The importance of this work lies in studying the relationship between tourism and the environment. There are many international studies that focus on this relationship. In Mexico, there is no work that studies these variables. Results are important for economies and societies whose economic growth depends on tourism flows and have done little to reverse the damage that tourism has on the environment.

Originality of the research is innovative for the region: Mexico, Central and Latin America. There are no works that have studied these problems with this methodology and these variables. The models of panel data and cointegration of panel data are useful and easily replicable for others for different countries.

Main limitations and areas of opportunity of the work refer to the amount of data available over time and the precision of the measurement of the variables. The availability, temporality and frequency of the data are also limitations of the research. An example of this is the nonexistence of CO₂ emissions at the state level.

References


Further reading


About the authors

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