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Renewable Energy Consumption: The Effects on Economic Growth in Mexico

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ABSTRACT

This study will demonstrate, through an econometric approach, the renewable energy consumption-economic growth effects in Mexico over the period 1990-2017. After a premise where we describe the situation of energy demand and consumption in Mexico and a summary of the economic literature, we have applied various econometric tests. Results about unit root tests describe a situation with all variables that aren't stationary except that in first differences. The Toda and Yamamoto approach is very important in our analysis: it highlights the existence of a unidirectional causal flow, running from renewable energy consumption to aggregate income. This situation respects the theory and hypothesis of economic growth.

Keywords: Renewable Energy Consumption, Economic Growth, Causality, Mexico
JEL Classifications: B22, C32, N54, Q43

1. INTRODUCTION

Renewable energy growth is an important factor for the economy as well as for the environment and society. This is because, among the determinants of growth, there are obviously economic conditions and technological innovation. However, these must be helped by policies that pay attention to pollution and climate change. The choice to go towards a change of new energy and widening the scope of application, will allow to reduce carbon emissions, but will improve the life of the society. In this way, it will be possible to create new jobs, to contribute to achieving the objectives of economic development and to guarantee a cleaner and more prosperous for future generations. The production of green energy is growing over the years: For example, starting in 2012, the new generation plants powered by renewable sources have produced more energy than that derived from conventional, non-renewable sources. In this situation,

Mexico is a special case study. Mexico can boast excellent wind resources and ideal for the construction of large parks. The temperature difference between the Gulf of Mexico and the Pacific Ocean creates one of the strongest and most constant wind tunnels in the Oaxaca region. In this region, there are areas with an annual average wind speed even higher than ten meters per second. In this way, an average load factor of >2500 h has been calculated for existing plants. The growth rate of wind capacity installed in 2016 was even higher than 100%. At the same time, the northernmost region of the country is characterized by an insolation index of 60% higher than that of Germany, the world leader in the photovoltaic sector and comparable to that of California and the deserts of North Africa. Therefore, wind and solar represent, without a doubt, the sectors with the highest growth expectations for the coming years, but they are certainly not the only ones. Mexico also boasts >10 GW of installed hydropower and just under 1 GW of geothermal. As for the latter source, the country is the world's fourth largest producer of installed power and the second, only after Indonesia, for geothermal resources available. Finally, in the last period, important projects in the biomass sector are also beginning to be registered. For these reasons, we will try to verify the effects of renewable energy consumption in Mexico on economic growth.

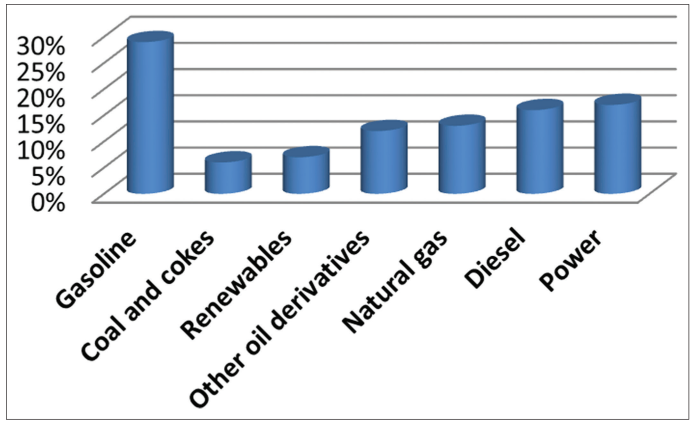
2. RECENT TRENDS IN RENEWABLES AND IN MEXICO'S TOTAL ENERGY SYSTEM

Mexico is a major producer of fossil fuels. Indeed, it is the tenth largest producer of oil and natural gas in the world. This situation is a determinant for Mexico' economic growth. However, in recent years, it increased research and development about renewable sources of energy. According to government sources, the Total Final Energy Consumption (TFEC) is 90% and it is, principally, fossil fuels; the total share of renewable energy was about 10% (Figure 1). In general, we can list the main sources for Mexico in future about renewable energy in: Wind (it's a potential to produce 92 TW h of electricity in future), solar pv (in a future could contribute 30 GW of power capacity) and bioenergy (for a future represent amount to around 4 GW of capacity).

With regard to consumption by sector, transport has been, for many years, the most important component of energy consumption. Today, however, this sector accounts for half of Mexico's TFEC, while it has grown the total energy demand of the building sector (about 35%), with consumption equal to 25% of Mexico' TFCE. The industrial sector, however, consumes energy to a value of 28%, while only 3% agriculture (Figure 2).

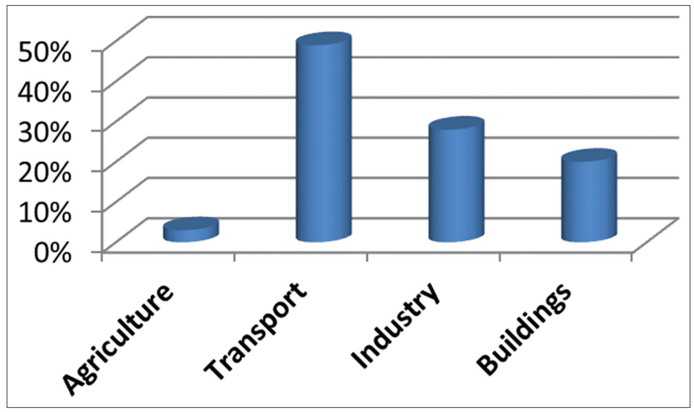
Now, according to REmap (2015) is possible to analyze growth projections about energy consumption and uptake of renewable energy technology, for a time series 2010-2030 in Mexico. These results are taken from paper "power sector perspectives" and affirm that in 2030 the TFEC will be equal to 7.4 EJ, that it is a 64% increase over 2010. This increase in consumption will particularly affect the transport sector for a value of 45%; consumption in the industrial sector will also increase four times in 2030. It will record a value of 33% compared to the total. The case of the building sector is interesting. In fact, the share of consumer demand, in 2030, will remain constant. In 2030 the energy demand will be met primarily by oil and electricity. Subsequently, we find gas and renewable energy (Figure 3).

Figure 1: Total final energy consumption Mexico composition



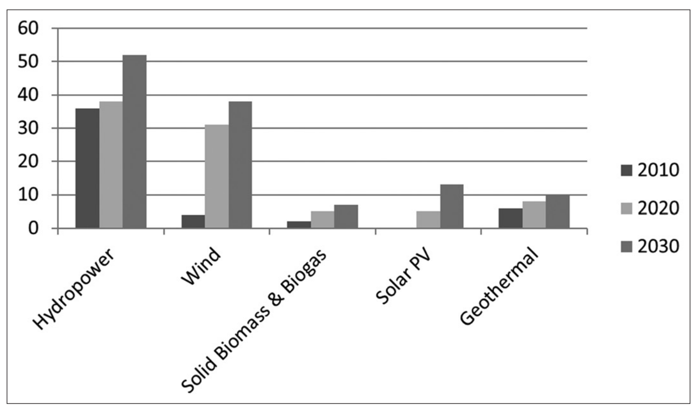
Source: National Energy Balance 2016

Figure 2: Total final energy consumption by sector



Source: National Energy Balance 2016

Figure 3: Renewable power generation growth, 2010-2030



Source: IRENA REmap, 2030

3. A BRIEF SURVEY OF THEORETICAL AND EMPIRICAL STUDIES

Studies examining the relationship between energy consumption and economic growth is enormous. Some studies (Apergis and Payne 2009, Apergis and Payne 2010, Apergis and Payne 2014) find a bidirectional relationship between renewable energy consumption and economic growth, especially about the China' case where the real GDP growth for a value of 0.12% with an increase in renewable energy consumption by 1%. Relatively to panel context, numerous have been those that have analyzed the case of the OECD countries (Sadorsky, 2009; Apergis and Payne, 2010; Tiwari, 2011; Tugcu et al., 2012; Kula, 2014; Bhattacharya et al., 2016; Jebli et al., 2016; Rafindadi and Ozturk, 2017; Benavides et al., 2017; Taher, 2017; Hassine and Harrathi, 2017).

With regard to technical studies on renewable energy in Mexico case, we can look Table 1.

So, for the literature review about social and environmental impact of the implementation of renewable energy projects in Mexico, we can follow the Table 2.

4. EMPIRICAL ANALYSIS

This study examines, now, the renewable energy consumption-economic growth nexus in Mexico over the period 1980-2017. We use Toda and Yamamoto tests (1995) and according to Apergis and Payne (2014), we estimate these equations in logarithm terms (1):

(1) $[LnY_t, LnRE_t, LnK_t, LnL_t] = A0 + A1\ [LnY_{t-1}, LnRE_{t-1}, LnK_{t-1}, LnL_{t-1}] + A2\ [LnY_{t-2}, LnRE_{t-2}, LnK_{t-2}, LnL_{t-2}] + A3\ [LnY_{t-3}, LnRE_{t-3}, LnK_{t-3}, LnL_{t-3}] + [\mathcal{E}LnY_t, \mathcal{E}LnRE_t, \mathcal{E}LnK_t, \mathcal{E}LnL_t]$

After we use a Granger causality analysis (1969) with the forecast error variance decomposition analysis. Y is GDP (constant 2000 US$), RE represent Combustible renewables and waste (% of total energy), K is Gross fixed capital formation (constant 2000 US$), L is Total labor force (Labor force statistics).

For the dataset, we use World Data Bank Development Indicators for Mexico, with time series 1980-2017.

To begin, we analyze the variables with the descriptive statistics in Table 3. As we can see: Mean present a positive value for GDP, Gross fixed capital formation and Total labor force. Renewable

Table 1: Main findings on the status and prospects of renewable energy sources in Mexico

Year	Author (s)	Key findings
2015	Hernández-Escobedo and Rodríguez	The authors evaluated solar resources in 5 states along the Gulf of Mexico. They found that the highest amount of solar energy recorded was >6.22 kW h/m² for day in July. Its effect on growth is positive and unidirectional
2015	García et al.	The authors analyzed 11 bioenergy options and had these results: By 2035, 16% of the final energy in Mexico. It could be replaced. Mexico has a potential technician for the production of sustainable biomass for 1713 PJ or 18.5% of the total primary energy used. The change will generate new jobs
2015	Grande et al.	Users can find benefits from using photovoltaics. Through this idea, they would stop using the energy provided by the network, obtaining two effects: Saving families and more disposable income. This situation would incentivize Keynesian income multipliers
2010	Hernández-Escobedo et al.	The authors carry out a detailed study on the effects of wind on renewable energy. They find that in some areas of northern Mexico it is possible to use this source to replace the network' energie
2014	Alemán-Nava et al.	The authors, starting from the fact that in Mexico about 16% of the power was generated from renewable sources, they study the support that there has been over time hydro-electric energy and biomass
2014	Mundo-Hernández et al.	The study addresses the hassle of the Mexican Fund resources for the energy transition. It mainly promotes the electrification using photovoltaic technology. Its use is an engine for economic growth
2011	Hernandez-Escobedo et al.	The authors study how to exploit the wind's potential in Mexico. They conclude that a minimum wind speed is required between 8:00 am and 4:00 pm and a maximum closing time at 24:00 h

Table 2: Social and environmental impact of renewable energy projects in mexico

Year	Author (s)	Key findings
2016	Huesca-Pérez et al.	The authors find the following positive effects: Lower negative impact on agricultural production; Creation of new jobs during the construction phase of renewable energy machinery; Increased transmission of information; Minor social conflicts
2016	Corona et al.	This paper evaluates the environmental performance of concentrating solar power plants. The plants are located in different countries (Spain, Chile, the Kingdom of Saudi Arabia, Mexico and South Africa). According to the authors, the main environmental impact of these technologies is due to the construction of heliostats, mainly with the use of steel
2015	Selfa et al.	This paper focuses on social sustainability in the biofuels sector in three Latin American countries (including Mexico). The authors' results were: Increase in workers' wages; higher disposable income for families, thanks to savings
2015	Agüero-Rodríguez et al.	This paper is a study on the effects of the transformation of national policy on the biofuels of the state of Veracruz in Mexico. The authors reveal that without proper regulation, the price increase can be intensified by mass production of biofuels in the area
2011	Pasqualetti	This paper studies the challenges and obstacles to the development of renewable projects (solar, wind, geothermal) in countries such as: Scotland, Mexico and the United States. It addresses the problem of the social impact of wind energy, specifically in the state of Oaxaca in Mexico
2010	García-Frapolli et al.	This article studies the economic benefits of using some stoves that use biomass in Michoacan, Mexico. The results regarding the social impact of this saved, improving the health of children and adults and reducing public health expenditure. Time saved, improving the health of children and adults and reducing public health expenditure
2007	Fernández-Valverde	The authors analyze hydrogen as one of the main sources of energy for Mexico. Among the results that suggest the use of hydrogen in Mexico are: The combustion of hydrogen produces water and a small amount of nitrogen oxides and therefore low environmental impact

Table 3: Descriptive statistics analysis

Variable	Mean	Median	SD	Skew ness	Kurtosis	10Trim	IQR
Y	11.4813	11.6251	0.2205	−0.1435	2.471	11.47	0.3621
RE	−0.1121	−0.1457	0.5941	−0.4253	3.4305	−0.11	0.4125
K	10.0742	10.0629	0.1856	0.047	1.7156	10.05	0.2413
L	10.0251	10.0354	0.1912	−0.4014	2.1174	10.01	0.0941

Table 4: Results for unit roots

Variable	Deterministic component	ADF	ERS	KPSS
Y	Contant, trend	−1.128	−0.405	0.422***
RE	Contant, trend	−2.1896	−3.015*	0.38**
K	Contant, trend	−4.261*	−4.157***	0.024
L	Contant, trend	−2.1478	−1.756	0.208***
ΔY	Constant	−4.742***	−4.369***	0.628***
ΔRE	Constant	−6.381***	−6.984***	0.041
ΔK	Constant	−4.108***	−4.324***	0.025
ΔL	Constant	−3.997***	−3.087***	0.198

***P<0.01, **P<0.05, *P<0.1

Table 5: Results about single structural break

Variable	OBP	k	t-stat	5% critical value
Y	1989	1	−2.157	−3.560
RE	2000	1	−2.741	−3.560
K	1990	2	−2.728	−3.560
L	1991	1	−1.71	−3.560
ΔY	1989	0	−5.764***	−3.560
ΔRE	1978	3	−6.846***	−3.560
ΔK	1989	2	−5.412***	−3.560
ΔL	1989	2	−3.108***	−3.560

***P<0.01, **P<0.05, *P<0.1

Table 6: Multivariate granger noncausality tests (TodaYamamoto approach)

Dependent variables	Independent variables			
	Y	RE	K	L
Y	(-)	17.611*** (0.000)	3.784 (0.157)	1.848 (0.426)
RE	4.6625 (0.108)	(-)	9.417 (0.013)	3.1496 (0.344)
K	1.8425 (0.475)	5.7421* (0.072)	(-)	2.0895 (0.394)
L	1.1608 (0.660)	12.245*** (0.002)	9.147** (0.017)	(-)

Wald tests (P values in parentheses), ***P<0.01, **P<0.05, *P<0.1

Energy consumption is negative; 10-Trim values are near the mean and the standard deviation, the inter-quartile range shows the absence of outliers.

Regarding the correlation analysis it show that, in our time series dataset, they are strongly correlated: Y-RE= 0.7814; Y-K= 0.9612; Y-L=0.9824; RE-K=0.8047; RE-L=0.8147; K-L=0.9128 with all significant variables (0.000). After, to study the stationary properties, we apply unit root processes in Table 4.

The results in Table 4 show: In relation to ocular inspection process all the value in time series dataset don't satisfy the stationary criterion. On the contrary, this is so when we use the first difference. We can say that the four series are integrated into I (1).

Now, in order to find the anomalous values, consistently with economic and historical theory, we apply in our analysis CMR tests. This approach is necessary to eliminate, in the estimate, the economic turbulence that characterized the time series 1980-2017 (Table 5).

The results obtained show how, despite the structural break and the tests at the first differences, we are unable to reject the null of unit root. We can confirm, therefore, that are I (1) processes.

After this situation we use to, estimate the causal link between the renewable energy consumption and economic growth effects in Mexico, Toda and Yamamoto Granger non-causality tests in Table 6.

The results of Toda and Yamamoto approach, in a multivariate Granger non-causality tests, shows that there is a link between Y and R: GDP is driven by renewable energy consumption. This result can be explained in the following way: When increases the energy consumption, also increases the use of the inputs used. This statement is also confirmed by the fact that there is a bidirectional causality between K and RE. Tests advise us also that we can reject the null hypothesis for: Y and RE, between K and RE. This situation is very interesting because renewable energy consumption Granger causes Real aggregate income and, also, capital formation.

5. CONCLUSION

The study addressed the problem about the relationship between renewable energy and economic growth for Mexico over the period 1980-2017. The growth in energy demand has fueled the search for renewable energy, in a country, rich in resources with an excellent environmental impact. The result about unit root tests describes a situation with all variables that aren't stationary except that in first differences. The results of multivariate Toda and Yamamoto allowed to isolate the causal links of the chosen variables: In fact, results show that real GDP is driven by renewable energy consumption. So, we can assert that econometrical analysis confirms the "growth hypothesis" in the Mexico case.

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