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Impact of Renewable and Non-Renewable Energy Consumption on Economic Growth in Mexico: A RALS-EG Cointegration Test Approach

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Yenilenebilir ve Yenilenemez Enerji Tüketiminin Meksika'da Ekonomik Büyüme Üzerindeki Etkisi: Bir RALS-EG Eşbütünleşme Testi Yaklaşımı

Öz

Meksika 1990 yılında enerji ihracatçısı iken, 2019 yılında enerji ithalatçısı olarak 1990 yılına göre enerji ithalatını %1766 oranında artırmıştır. Bu çalışmada 1990-2019 döneminde yıllık verilerle Meksika için yenilenebilir ve yenilenemez enerji tüketiminin ekonomik büyüme üzerindeki etkisi araştırılmaktadır. Bütün değişkenler birinci farkta durağan olduğu için uzun dönemli ilişki Engle-Granger ve literatüre Lee vd. (2015) tarafından kazandırılan RALS-EG eşbütünleşme testiyle araştırılmıştır. Uzun dönem ilişkinin büyüklüğü için tahmin edilen model sonuçlarına göre Yenilenemeyen enerji dışındaki diğer değişkenlerin katsayıları pozitiftir. Granger-Nedensellik testi sonuçlarına göre ise Meksika için büyüme hipotezi geçerlidir.

Anahtar Kelimeler: Yenilenebilir ve Yenilenemez Enerji Tüketimi, Büyüme, RALS-EG Eşbütünleşme, Meksika

JEL Kodları: Q2, Q3, Q4

Impact of Renewable and Non-Renewable Energy Consumption on Economic Growth in Mexico: A RALS-EG Cointegration Test Approach

Abstract

While Mexico was an energy exporter in 1990, it increased its energy imports by 1766% as an energy importer in 2019 compared to 1990. In this study, the effect of renewable and non-renewable energy consumption on economic growth for Mexico is investigated with annual data for the period 1990-2019. Since all variables are stationary at the first difference, the long-run relationship was investigated with Engle-Granger and the RALS-EG cointegration test introduced by the literature by Lee et al. (2015) to the literature. According to the model results estimated for the size of the long-term relationship, the coefficients of the variables other than non-renewable energy are positive. According to the Granger-Causality test results, the growth hypothesis is valid for Mexico.

Keywords: Renewable Energy Consumption, Non-Renewable Energy Consumption, Growth, RALS-EG Cointegration, Meksika

JEL Codes: Q2, Q3, Q4

Araştırma ve Yayın Etiği Beyanı	Bu çalışma bilimsel araştırma ve yayın etiği kurallarına uygun olarak hazırlanmıştır.
Yazarların Makaleye Olan Katkıları	Çalışmanın tamamı yazar tarafından oluşturulmuştur.
Çıkar Beyanı	Yazar açısından ya da üçüncü taraflar açısından çalışmadan kaynaklı çıkar çatışması bulunmamaktadır.

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1. Introduction

The fastest-growing energy source in the world has been the renewable energy source. According to the calculations made by us with the data obtained from the International Energy Agency (IEA), the world fossil fuel consumption has an average annual growth rate of 1.59% (natural gas 2.44%, coal 1.97%, and oil 1.19%) in the 1990-2018 period. renewable energy use, on the other hand, became the fastest-growing energy source in the world with an annual average increase rate of 3.93% (wind, solar, etc. 7.63% and hydro 2.45%). Mexico, on the other hand, had an annual average growth rate of 1.43% for fossil fuels (3.89% for coal, 0.12% for oil, and 3.77% for natural gas), and 5.65% for nuclear. For renewable energy use, it has an annual average increase rate of 0.33% (hydro 1.18%, wind, solar, etc. -0.14%). This shows that the energy source with the lowest growth rate for Mexico, which is among the emerging economies, is the renewable energy source. In addition, the average annual increase rate of 10.80% in total energy imports in the same period causes Mexico to rapidly progress towards becoming a net energy importer country. Among the imported energy sources, natural gas takes the lead with an annual average increase of 18.05%, followed by coal with 12.33% and oil with 9.00%.

Mexico imports energy at a very high rate on average in the 1990-2018 period. On the other hand, the fact that Mexico's GDP has an average annual growth rate of 3.91% shows the extent to which energy imports curb the growth rate. The reason for this is the increase in the need for foreign exchange for energy imports and the formation of the current account deficit. In addition, the fact that the total energy losses experienced during the distribution, transmission, and transportation of energy in the same period had an annual average increase rate of 4.16% also shows that this economy does not have sufficient technology in the field of energy. Therefore, the energy resources used for Mexico are used intensively/inefficiently. On the other hand, the fact that Mexico's energy imports are mostly fossil fuels causes carbon dioxide (CO2) emissions, which occurred in the same period, to have an annual average increase of 2.06%. Therefore, the high economic growth experienced in Mexico results in more energy imports, more fossil fuel use, more energy losses, more CO2 emissions, and more environmental pollution. In addition, the high economic growth experienced in Mexico brings with it more energy imports, more energy costs, more foreign exchange needs, more current account deficit, more foreign dependency, and a more fragile economy. Therefore, for Mexico, which imports high amounts of energy, it is expected that the increase in the use of renewable energy will have a positive effect on economic growth as well as reduce foreign dependency. On the other hand, the decrease in the use of fossil fuels with the increase in the use of renewable energy will not only reduce foreign dependency but will also have a positive impact on environmental quality.

The subject of this study is a subject that will keep up to date throughout the world / especially in Mexico. The reason for this is that the share of fossil fuels among the world's total energy use in 2018 still has a high rate of 81% (31.49% oil, 26.88% coal, and 22.84% natural gas). On the other hand, the fact that the world renewable energy share has a very low rate of 4.54% (hydro 2.54%, excluding hydro 2.01%), makes this issue very important. In addition, as a result of the high use of fossil fuels, the temperature change in the world increased by 131.6% in 2019 compared to 1990 (FAOSTAT, 2022). This situation causes climate changes that are very difficult or impossible to compensate for. Increasing temperatures as a result of the use of fossil fuels also threaten hydro resources, which have a 55.84% share among the world's renewable energy resources in 2018 (IEA, 2022). In addition, droughts that occur as a result of increasing temperatures cause many forest fires. This situation increases the threat of hydro energy sources by causing more use of water, which is very important in the fight against fires. In addition, while 2 billion tons of CO2 gas emission were realized in the world at the beginning of the 1900s, this rate increased by approximately 1600% in 2018 as a result of increasing fossil fuel use and reached 36.2 billion tons of gas emissions (Gurler et al., 2020). In addition, population increases will further increase the energy demand and thus the fossil fuel demand. In addition to all these negativities, fossil fuel reserves have a lifespan of 51 years in oil, 53 years in natural gas, and 114 years in coal (ETBK, 2017). These situations increase the importance of the use of renewable energy for the whole world and especially for economies such as Mexico, which imports very high energy. Therefore, after the COVID-19 epidemic, environment and health-oriented energy policies have revealed that the use of renewable energy is no longer an option but a necessity for the World/Mexican economy. Because the increasing use of fossil fuels threatens a clean world with climate change, it is very important for human health.

The Mexican economy's inability to meet the energy it needs to achieve high growth figures with its resources makes this economy more foreign-dependent in the field of energy. Therefore, it becomes very important for Mexico to understand the relationship between renewable energy consumption and non-renewable energy consumption and economic growth to achieve sustainable, reliable, and environmentally oriented growth. The difference between this study from previous studies is to search for the Mexican economy, which imports energy and generally realizes this import as fossil fuel. Because the fossil fuel reserve life in the world is decreasing, the environmental quality is declining rapidly and Mexico is among the countries that are the primary addressee of renewable energy use due to high energy losses and higher energy costs. Secondly, the results to be obtained for energy importing countries such as Mexico will provide very important concrete contributions to policymakers. Thirdly, in the study, the effect of non-renewable energy consumption as well as renewable energy consumption is investigated and in addition to these, a production model is used by including labor and capital variables. Fourth, the results obtained are in line with the theoretical expectation and are supported by hypotheses. Fifth, RALS techniques, which have recently been introduced to the literature, will be used.

In this context, the effect of renewable energy consumption and non-renewable energy consumption on economic growth for Mexico in the period 1990-2019 is empirically tested. In the following section, the literature is given within the framework of energy use and economic growth hypotheses. Afterward, empirical models, methods, and findings are presented. Finally, evaluations will be made in light of the findings, and policy recommendations will be presented.

2. An overview of the literature within the framework of energy use and growth hypotheses

There are many studies in the literature investigating the relationship between energy consumption and economic growth. Due to the importance of this relationship, it is a research that is constantly up-to-date as it is researched by changing country groups in almost every period. The causal relationships related to the effect of energy consumption on economic growth in the literature are generally based on four basic hypotheses. These are growth, conservation, feedback, and neutrality hypotheses.

The growth hypothesis: In cases where the growth hypothesis is valid, there is a unidirectional causal relationship from renewable energy consumption to economic growth. In other words, it is the situation where energy consumption affects economic growth directly or together with labor and capital. In such a case, any policy to reduce energy consumption will harm the economic growth of the economy.

Decreasing fossil fuel reserves, increasing environmental degradation, and climate changes with the release of CO2 to the environment have recently increased the importance of renewable energy use. Therefore, the relationship between renewable energy consumption and economic growth has been investigated in many studies recently.

Bowden and Payne (2010) investigated the relationship between renewable energy consumption and output in the residential sector in the USA during the 1949-2006 period. Research findings showed that there is a one-way causality relationship from renewable energy consumption to economic growth in the housing sector for the USA in the relevant period. Similarly, Payne (2011) found that there is a unidirectional causality running from biomass energy consumption to economic growth for the USA in the 1949-2007 period. In the study by Fang (2011), it was found that there is a unidirectional causal relationship from energy consumption to economic growth for China in the 1978-2008 period. Similarly, Lin and Moubarak (2014) found that the growth hypothesis was valid for China in the 1977-2011 period. On the other hand, Alam et al. (2012) for Bangladesh economy during 1972-2006, Alshehry and Belloumi (2015) for Saudi Arabia during 1971-2010, Boontomea et al. (2017) for the Thai economy during 1971-2013, and Khoshnevis Yazdi and Shakouri (2017) for the German economy found that the growth hypothesis was valid for the in the 1975-2014 period. Also, Ohler and Fetters (2014) and Chen et al. (2020) For a group of 20 OECD countries, Chang et al. (2015) for the group of G7 countries, and Saidi and Omri (2020) for the 15 countries that consumed the most renewable energy found that growth hypothesis was valid. Also, Bhattacharya et al. (2016) revealed that renewable energy use had a significant positive effect on economic growth for 57% of 38 countries that consumed the most renewable energy in the period 1991-2012.

The conservation hypothesis: In cases where the conservation hypothesis is valid, there is a unidirectional causal relationship between economic growth to renewable energy consumption. In other words, it is a situation where energy consumption is determined according to economic growth. Therefore, in an economy where the conservation hypothesis is valid, any policy of change in energy consumption will not affect economic growth.

Menyah and Wolde-Rufael (2010) obtained a unidirectional causal relationship from economic growth to renewable energy consumption for the United States during the 1960-2007 period. Support and Aslan (2017) obtained that the protection hypothesis is valid for the

BRICS countries in the 1980-2012 period. Similarly, Alsaleh and Abdul-Rahim (2019) found that economic growth has a significant impact on bioenergy in their study of European continental countries in the 2005-2013 period.

The feedback hypothesis: In cases where the feedback hypothesis is valid, there is a causal relationship between economic growth to renewable energy consumption and similarly from energy consumption to economic growth. So there is a two-way relationship. Therefore, any policy of change in energy consumption will have different effects on economic growth.

Apergis and Payne (2010) investigated the effect of energy consumption on economic growth for 20 OECD countries during the 1985-2005 period. Research findings showed that there is a mutually causal relationship between energy consumption and economic growth for 20 OECD countries in the relevant period. Apergis and Payne (2011) found a bidirectional causality relationship between renewable energy consumption and economic growth for 6 Central American countries during the 1980-2006 period. Apergis and Payne (2012) investigated the effects of renewable energy consumption and non-renewable energy consumption on economic growth for OECD countries over the period 1990-2007. Findings It has been seen that there is a bidirectional causality relationship between renewable energy consumption and non-renewable energy consumption and economic growth for OECD countries. Similarly, Ohlan (2016) for the country of India in the period 1971-2012, Adams et al. (2018) for 16 emerging economies in the period 1980-2012, Tuğcu and Topçu (2018) for the G7 economies in the period 1980-2014, and Muhsin et al. (2019) found that there was a bidirectional causal relationship between economic growth and energy consumption for the Pakistani economy in the 1997-2015 period.

The neutrality hypothesis: In cases where the neutrality hypothesis is valid, there is no causal relationship between economic growth to renewable energy consumption and similarly from energy consumption to economic growth. So there is no bidirectional relationship. Therefore, any policy that reduces or increases energy consumption will not have a negative or positive effect on economic growth. Similarly, any negative impact on economic growth will not affect energy consumption.

Payne (2009) investigated the relationship between renewable energy consumption and economic growth for the USA during the 1949-2006 period. Research findings showed that there is no causal relationship between renewable energy consumption and economic growth. Similarly, Menegaki (2010) for 27 European countries in the 1997-2007 period, Omri et al. (2014) 17 For developed and developing countries in the period 1990-2011, Chang et al. (2015) for Canada, Italy, and the USA in the 1990-2011 period, Narayan and Doytch (2017) for 89 economies in the 1971-2011 period, Bulut, and Muratoglu (2018) for Turkey in the 1990-2015 period, Ozcan and Ozturk (2019) for 17 emerging economies in 1990- 2016 period, Fan and Wao (2020) for 31 Chinese provinces in 2000-2015 period, and Razmi et al. (2020) obtained that the neutrality hypothesis is valid between energy consumption and economic growth for the Iranian economy in the period 1990-2014.

Therefore, there is a very large literature in the literature with different results between renewable energy consumption and economic growth for different country groups in different periods.

3. Model, Data, Methodology and Empirical Results

In this section, renewable energy consumption and the relationship between non-renewable energy consumption and economic growth are discussed empirically for Mexico. The cointegration relationship will be investigated with the Residual Augment Least Squares-Augment Dickey-Fuller (RALS-ADF) and Residual Augment Least Squares-Eangle Granger (RALS-EG) approaches using annual data for the period 1990-2019 and Granger causality analysis will be performed.

3.1. Model and Data

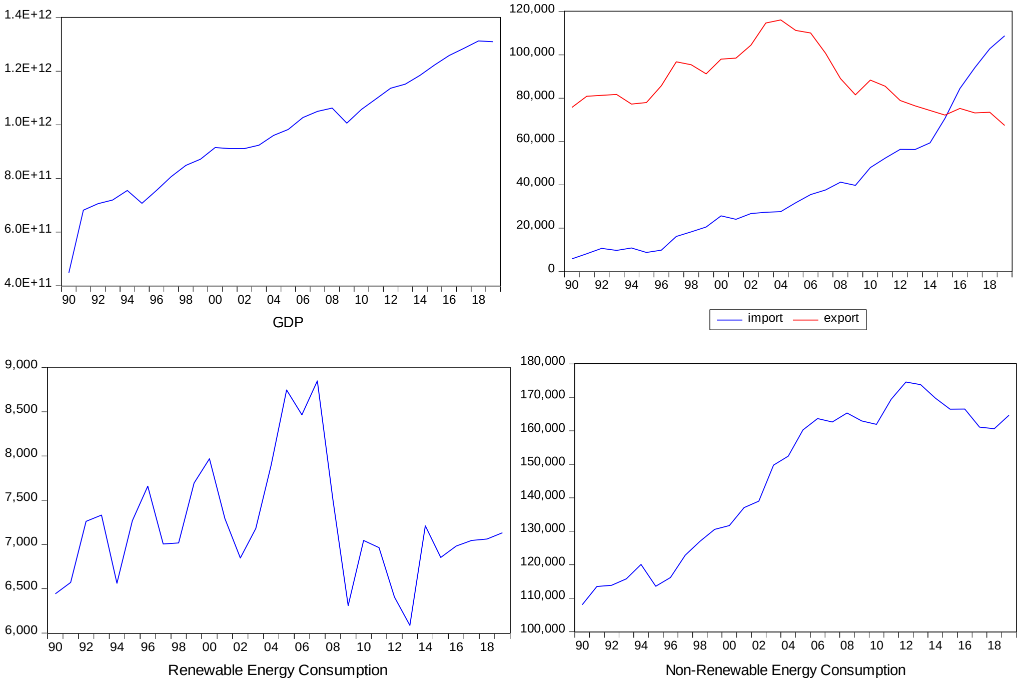
In this study, the effects of renewable energy consumption, non-renewable energy consumption, real gross capital, and labor force on economic growth in Mexico for the period 1990-2019 will be investigated. The model to be used for this is in the form of

$$lnGDP_t = \beta_0 + \beta_1 REN_t + \beta_2 FOS_t + \beta_3 CPTL_t + \beta_4 LBR_t + u_t$$

Where GDP, REN, FOS, CPTL and LBR stand for Real GDP, real gross fixed capital formation, labor force and renewable energy consumption, respectively. Real GDP (GDP) in constant 2010 US dollars, real gross fixed capital formation (CPTL) in constant 2010 US dollars, labor force (LBR) in millions and renewable energy consumtion (REN) in kilotonnes of oil equivalent (hydro, power generation from solar PV, solar TH, tide, wind, heat pump, boiler, chemistry heat, and others (ktoe)) and non-renewable energy consumption (FOS) in kilotonnes of oil equivalent (coal, oil and naturalgas (ktoe)). Real GDP, real gross fixed capital formation, and labor force data are from the World Bank, and renewable energy consumption and non-renewable energy consumption data are from the International Energy Agency (IEA). Natural logarithms of all variables were used.

The dependent variable in the study is economic growth and real GDP. So GDP=Log (Real GDP (in constant 2010 US dollars)) has been taken. Figure 1 shows the economic growth, energy import-export, renewable and non-renewable energy consumption trends of the Mexican economy, which is among the emerging economies in the 1990-2019 period. The fact that Mexico has fluctuating economic growth shows how sensitive it is to energy imports, renewable-non-renewable energy use, and other factors.

Figure 1: GDP, Energy import-Export, Renewable-Non-Renewable Energy Use for Mexico (1990-2019)



Source: GDP World Bank, https://databank.worldbank.org/ ,Energy import-export and renewable-no-renewable International Energy Agency (IEA) https://www.iea.org/

3.2. Methodology and Emprical Results

Before proceeding to the analysis, the stationarity of the series will be investigated. For this purpose, descriptive statistics for each series are given in Table 1 to decide on the method to be used in the stationarity test.

Table 1: ADF and RALS-ADF Unit Root Test Results

	GDP	REN	FOS	CPTL	LBR
Mean	11.975	3.857	5.159	11.298	7.631
Median	11.987	3.851	5.194	11.293	7.634
Maximum	12.118	3.947	5.242	11.434	7.762
Minimum	11.652	3.784	5.034	11.057	7.475
Std. Dev.	0.105	0.039	0.070	0.108	0.085
Skewness	-0.896	0.554	-0.456	-0.403	-0.180
Kurtosis	4.045	3.150	1.611	2.137	1.842
Jarque-Bera	5.382	1.561	3.449	1.744	1.839
Probability	0.068	0.046	0.017	0.042	0.040
Observations	30	30	30	30	30

When Table 1 is examined, it is seen that the mean of the series is positive and quite far from zero. On the other hand, it is seen that the volatility of the other series is almost close to each other, except for the use of renewable energy. In addition, the skewness and kurtosis values of the series give clues that the series does not have a normal distribution. Another test for normality is the Jarque-Bera test. Jarqua-Bera probability values of the series show that the series does not have a normal distribution. Therefore, in cases where the assumption of normal distribution of the residues is not valid, RALS-based stationarity tests will be used, which gives reliable results.

3.2.1. Unit Roots Test

In the ADF test, no assumptions are made about the stability of the residuals. That is, the residuals do not need to be stationary when applying the ADF unit root test. This is because there is no such assumption. However, these tests can be used whether the residuals are stationary or not. Because the ADF test has its critical values. Therefore, there is no need to make any assumptions about the residuals. However, Lee et al. (2015) stated in their study that the non-normality of the residuals is important. In other words, they stated that the relevant test may be more effective and stronger, depending on whether the residuals are normally distributed or not.

In the RALS technique, the information that the residuals are not normally distributed is added to the least-squares model that is run. For this, the residuals of the relevant model are taken and a new series is obtained from them and included in the relevant model. In this way, the relevant test becomes stronger and more effective.

In the traditional ADF unit root test, the

$$\Delta y_t = a_1 + \beta y_{t-1} + \sum_{j=1}^{\rho} \delta_j \Delta y_{t-j} + e_t$$

shaped model is taken into account. In this model, the stability of the y_t series is investigated by testing the significance of y_{t-1} under the main hypothesis. Im et al. (2014), on the other hand, suggested extending the unit root test they brought to the literature with residuals. In this way, stronger and more effective results will be obtained by using the information contained in normal residuals. This is done with the help of the equation

$$\Delta y_t = a_1 + \beta y_{t-1} + \sum_{j=1}^{\rho} \delta_j \Delta y_{t-j} + \widehat{w}_t'\gamma + e_t$$

Where $\widehat{w}_t$

$$\widehat{w}_t = h(\hat{e}_t) - \widehat{K} - \hat{e}_t\widehat{D}_t, t = 1,2, \dots, T$$

Where $h(\hat{e}_t) = [\hat{e}_t^2, \hat{e}_t^3]'$, $\widehat{K} = \frac{1}{T}\sum_{t=1}^{T} h(\hat{e}_t)$ and $\widehat{D}_t = \frac{1}{T}\sum_{t=1}^{T} h'(\hat{e}_t)$. The $\widehat{w}_t$ term can be represented as $m_j = \frac{1}{T}\sum_{t=1}^{T} \hat{e}_t^j$ as follows

$$\widehat{w}_t = [\hat{e}_t^2 - m_2, \hat{e}_t^3 - m_3 - 3m_2\hat{e}_t]'$$

Where $\hat{e}_t^2 - m_2$ is related to the constant variance condition in the least-squares method. That is, it is about the variance of the residual being constant along the regression line. Using this term increases the efficiency of the estimator when the error terms are asymmetrically distributed. $\hat{e}_t^3 - m_3 - 3m_2\hat{e}_t$ increases the efficiency unless $m_4 = 3\sigma^4$ is present. In other words, as long as the average of the 4th power of the residuals is not 3 times the 4th power of the variance, it increases the efficiency of the estimator. In other words, unlike the ADF unit root test, the $\widehat{w}_t'$ series carries the information that the residuals of the ADF unit root test are not normally distributed. In other words, the ADF unit root test is run and the errors are obtained and included in the ADF test equation again. The basic hypothesis here is that the series has a unit root, as in the ADF test.

Under the basic hypothesis, the limit distribution of the RALS-ADF t-statistic is

$$\tau_{RALS-ADF} = \rho\tau_{ADF} + \sqrt{1-\rho^2}z$$

where τ_{ADF} is the t-statistic of the standard ADF unit root test statistic. Z is a standard normally distributed variable. ρ^2 is the correlation between the RALS-ADF and the residuals from the ADF regressions. When $\rho^2 = 1$, RALS-ADF and ADF test statistics will be equal. To use the critical values here, it is necessary to calculate the correlation coefficients between the ADF and RALS-ADF unit root tests. So $\hat{\rho}^2 = \hat{\sigma}_A^2/\hat{\sigma}^2$. Here, $\hat{\sigma}_A^2$ denotes the error variance from RALS-ADF, while σ̂ denotes the error variance obtained from the ADF.

In the first part of the study, traditional ADF and RALS-ADF unit root tests were used to test the stationarity of the variables, and the results are shown in Table 2.

Table 2: ADF and RALS-ADF Unit Root Test Results

Level	**ADF**	**RALS-ADF**	ρ^2	**Lag Length**
GDP	-1.982	-1.975	0.731	4
REN	-2.932	-2.374	0.835	0
FOS	-1.926	-2.461	0.921	0
CPTL	-2.629	-2.631	0.983	5
LBR	-1.536	-1.143	0.939	2
First difference	**ADF**	**RALS-ADF**	ρ^2	**Lag Length**
ΔGDP	-5.290***	-6.400***	0.723	3
ΔREN	-5.720***	-5.821***	0.921	1
ΔFOS	-4.416***	-4.385***	0.959	0
ΔCPTL	-6.700***	-6.511***	0.893	4
ΔLBR	-3.342***	-4.766***	0.764	0

Note: *** is the significance level at the 1% level. ADF critical values are -3.724, -2.986 and -2.633 at 1%, 5% and 10% significance levels, respectively. RALS-ADF Critical values for $\rho^2 = 0.7$ are -3.246, -2,846, -2.619 at 1%, 5% and 10% significance levels, respectively. For $\rho^2 = 0.8$ are -3.213, -2.851,-2.657 at 1%, 5% and 10% significance levels, respectively. For $\rho^2 = 0.9$ are -3.099, -2.846 and -2.657 at 1%, 5% and 10% significance levels, respectively[2].

When Table 2 is examined, it is seen that all variables have unit roots in their level values according to both ADF and RALS-ADF test results and become stationary after taking the first difference. Therefore, all series are I(1).

[2] Horrace and Sickles (2014) edited the book "Festschrift in Honor of Peter Schmidt Econometric Methods and Applications" for RALS-ADF stability testing. In this book, Im et al. (2014) The critical values in the section titled "More Powerful Unit Root Tests with Non-normal Errors" in Chapter 10 have been taken into account.

3.2.2. Cointegration Test

The main criticism directed at the Engle and Granger (1987) (EG) test is that it is weak compared to alternative tests. The RALS-EG cointegration test is the test in which the RALS method proposed by Im and Schmidt (2008) is used instead of the EKK to increase the power of the EG test introduced to the literature by Lee et al. (2015). They stated in their study that high moments of non-normally distributed residuals will contain information about the nature of these residuals. It states that stronger cointegration tests can be derived if this information is used. In this proposed test, there is no need to predetermine a specific density function or functional form.

In the Engle cointegration test, firstly, residuals are obtained by establishing a model between the dependent variable and the independent variables. ADF unit root test is applied to these residuals. RALS-EG makes the first stage like EG. However, in the second stage, the ADF unit root test is applied to the residuals and the residuals of this model are taken to obtain $\widehat{w}_t$, ie high moments. Then, by including these moments in the ADF unit root test, the RALS technique is applied. In this way, stronger test statistics are obtained. It is

$$\widehat{w}_t = h(\hat{e}_t) - \widehat{K} - \hat{e}_t\widehat{D}_t, t = 1,2, \dots, T$$

Where $h(\hat{e}_t) = [\hat{e}_t^2, \hat{e}_t^3]'$, $\widehat{K} = \frac{1}{T}\sum_{t=1}^{T} h(\hat{e}_t)$ and $\widehat{D}_t = \frac{1}{T}\sum_{t=1}^{T} h'(\hat{e}_t)$. The $\widehat{w}_t$ term can be represented as $m_j = \frac{1}{T}\sum_{t=1}^{T} \hat{e}_t^j$ as follows:

$$\widehat{w}_t = [\hat{e}_t^2 - m_2, \hat{e}_t^3 - m_3 - 3m_2\hat{e}_t]'$$

Where $\hat{e}_t^2 - m_2$ is formed depending on the assumption of constant variance $E[(e_t^2 - \sigma_t^2)y_{t-1}] = 0$ moment. Efficiency is ensured with this condition as long as the residuals are not symmetrical. $\hat{e}_t^3 - m_3 - 3m_2\hat{e}_t$ is only related to the determination condition $\mu_j = E\left(e_t^j\right)$ and $\mu_4 = 3\sigma^4$ provided when the distribution of interest is normal. If there is no normal distribution, this condition causes a stationary term to be derived. This hinders the derivation of more powerful tests.

The following regression can be obtained by adding the $\widehat{w}_t$ term to the ADF regression model, which is in the second stage of the EG cointegration test:

$$\Delta\hat{u}_t = a_0 + \rho\hat{u}_{t-1} + \sum_{i=1}^{k} a_i \,\Delta\hat{u}_{t-1} + \widehat{w}_t'\gamma + v_t$$

The basic hypothesis ($\rho = 0$) showing that there is no long-term relationship between the related variables can be tested with the standard t-statistic. There is a relationship between the RALS-EG method test statistic and the EG test statistic as follows:

$$t^* \to \rho t + \sqrt{1-\rho^2}z$$

Where t^* denotes RALS-EG test statistic, t EG test statistic, z a standard normally distributed random variable. ρ represents the long-term correlation between the residuals e_t from the EG equation and the residuals v_t from the RALS-EG equation. Lee et al. (2015) recommended using the non-parametric estimation method proposed by Hansen (1995) for the estimation of ρ on which the cointegration tests estimated with RALS-EG are based.

In the next stage of the study, the cointegration relationship will be investigated for the series that become stationary after taking the first difference. For this, EG and RALS-EG cointegration tests were applied and the results are shown in Table 3.

Table 3: EG and RALS-EG cointegration Test Results

	Test statistic	k	rho
EG	-7.720***	0	-
RALS-EG	-5.028***	0	0.997236

Note: k represents the appropriate lag length obtained by the general-to-specific t-significance method. The critical values of the EG test are 5.41, 4.76, and 4.42 at 1%, 5%, and 10% significance levels, respectively. The critical values of the RALS-EG test are -5.15776, -4.53874, -4.22293 at 1%, 5%, and 10% significance levels, respectively[3].

Table 3 shows that there is a long-term relationship between the series at a 1% significance level according to both EG and RALS-EG test results. Therefore, for Mexico, there is a cointegration relationship between renewable energy consumption and non-renewable energy consumption and economic growth in the relevant period.

3.2.3. Estimation of cointegration coefficients

For Mexico, the coefficient estimation will be made after the cointegration relationship between the economic growth and the independent variables in the relevant period is found. For this, long-short term coefficient estimation will be made using Fully Modified Ordinary Least Squares (FMOLS) developed by Philips and Hansen (1990) and Canonical Cointegrating Regressions (CCR) estimators developed by Park (1992). The FMOLS estimator is an important estimator for the relationship between the explanatory variables and the residuals and for eliminating the deviations that may occur due to the internality problem. The CCR estimator, on the other hand, eliminates the internality problem arising from the correlation that may occur in the long run, asymptotically. Therefore, FMOLS and CCR estimators were used for long-term coefficient estimates and are given in Table 4.

Table 4: FMOLS and CCR Long-Term Coefficient Estimation Results

Dependent Variable	FMOLS				CCR			
	REN	FOS	CPTL	LBR	REN	FOS	CPTL	LBR
GDP	0.246**	-0.271*	0.239**	1.055***	0.238**	-0.231	0.251**	1.021***
	(0.090)	(0.153)	(0.093)	(0.136)	(0.101)	(0.158)	(0.118)	(0.162)

Note: *, ** and *** indicate the statistical significance at 10%, 5% and 1% levels, respectively.

When Table 4 is examined, it is seen that renewable energy consumption (REN), real gross fixed capital (CPTL), and labor force (LBR) have a positive effect on economic growth (GDP) in Mexico in the long run. On the other hand, it is seen that non-renewable energy consumption (FOS) has a negative relationship with economic growth (GDP).

According to FMOLS results, non-renewable energy consumption (FOS) is statistically significant at 10%, renewable energy consumption (REN) and real gross fixed capital (CPTL) at 5%, and labor force (LBR) at a 1% significance level. According to the CCR results, renewable energy consumption (REN) and real gross fixed capital (CPTL) were statistically significant at 5% and labor force (LBR) 1%, while non-renewable energy consumption (FOS) was found to be statistically insignificant. Since the variables have natural logarithms, they will be interpreted

[3] The critical values of the RALS-EG cointegration test were obtained by Yilanci and Aydin (2018) by simulation. Critical values, on the other hand, were taken into consideration in the appendix of the authors' study titled " The Impact Of Female College Enrollment On Economıc Growth In Turkey: A Rals-Eg Coıntegratıon Test Approach".

as elasticity coefficients. Therefore, according to FMOLS estimation results, a 1% increase in renewable energy consumption (REN), real gross fixed capital (CPTL), and labor force (LBR) in the relevant period for Mexico, which is among the emerging economies, will increase economic growth by approximately 0.25%, 0.24%, and 1.06%, respectively. On the other hand, a 1% increase in non-renewable energy consumption (FOS) creates an approximately 0.27% decrease in economic growth (GDP).

On the other hand, according to the CCR estimation results, a 1% increase in renewable energy consumption (REN), real gross fixed capital (CPTL), and labor force (LBR) in the relevant period for Mexico, which is among the emerging economies, increased the economic growth by approximately 0.24%, 0.25%, and 1.02% increase. respectively. Therefore, the findings show that the increase in the use of renewable energy has a positive effect on economic growth, while the increase in the use of non-renewable energy is negative.

Short-term coefficient estimation was made in the model, followed by FMOLS and CCR error correction model, and the results are shown in Table 5.

Table 5: FMOLS and CCR Short-Term Coefficient Estimation Results

	FMOLS					CCR				
Dependent Variable	ECTt-1	ΔREN	ΔFOS	ΔCPTL	ΔLBR	ECTt-1	ΔREN	ΔFOS	ΔCPTL	ΔLBR
	-0.603**	0.300**	0.537	0.178*	0.377	-0.797***	0.389**	0.702	0.198	0.243
ΔGDP	(0.249)	(0.125)	(0.395)	(0.091)	(0.981)	(0.164)	(0.164)	(0.503)	(0.174)	(1.239)

Note: *, ** and *** indicate the statistical significance at 10%, 5% and 1% levels, respectively.

Error correction coefficient (ECT), which expresses the long-term relationship between errors, was found by the theoretical expectation, was negative and statistically significant. Therefore, this confirms that there is a long-run relationship between economic growth and explanatory variables. The error correction term (ECT) indicates the correction rate and shows how quickly the variables return to equilibrium in the long run. Thus, the coefficient of the term ECT indicates that, according to the FMOLS (-0.603) and CCR (-0.797) models, approximately 0.60% and 0.80% of a variant in the t-1 period will be corrected in the t period (within a period or year), respectively.

3.2.4. Granger Causality Test

The fact that the past and literal values of two variables with time-series properties provide useful information for the next period at time t is called the Granger cause of each other. This causality test is widely used in the literature because it is easy in terms of practicality. The variables to be used for Granger causality need to be stationary, but not necessarily cointegrated to the same degree. The important thing is the selection of the appropriate lag length.

The causality between economic growth, renewable energy consumption, and non-renewable energy consumption for Turkey has been investigated and the results are shown in Table 6.

Table 6: Granger Causality Test Results

Direction of causality	Statistic	Probability	Direction of causality	Statistic	Probability	lag length
$lnREN \rightarrow lnGDP$	8.200***	0.004	$lnGDP \rightarrow lnREN$	0.001	0.994	2
$lnFOS \rightarrow lnGDP$	10.295***	0.001	$lnGDP \rightarrow lnFOS$	0.315	0.574	2
$lnCPTL \rightarrow lnGDP$	0.014	0.907	$lnGDP \rightarrow lnCPTL$	1.341	0.247	2
$lnLBR \rightarrow lnGDP$	96.469***	0.000	$lnGDP \rightarrow lnLBR$	0.083	0.774	2
$lnREN \rightarrow lnFOS$	1.165	0.559	$lnFOS \rightarrow lnREN$	7.680**	0.022	2

Note: ** and *** indicate the statistical significance at 5% and 1% levels, respectively.

When Table 6 is examined, there is a unidirectional causality running from renewable energy consumption, non-renewable energy consumption, and labor force to economic growth. On the other hand, there is a unidirectional causality running from non-renewable energy consumption to renewable energy consumption.

As a result, while the use of renewable energy affects economic growth positively for the Mexican economy in the relevant period, the use of non-renewable energy affects negatively. In addition, the results of the research on the Mexican economy showed that the growth hypothesis is valid. The findings obtained in this study differ from the results of the feedback hypothesis in the studies conducted by Tuğcu and Topçu (2018) for G7 economies and Apergis and Payne (2012) for OECD countries. The reason for this is generally the high share of renewable energy among the total energy resources of developed economies. In this way, there is a decrease in renewable energy costs and it is preferred more. On the other hand, the findings of this study are similar to Lin and Moubarak (2014) for China and Alam et al. (2012) are similar to the results of the growth hypothesis in the study. The reason for this is that while the Chinese economy was an energy exporter in 1990, like the Mexican economy, it became an energy importer in 2019. In addition, considering that the economies of China and Bangladesh are in the emerging economy group and are energy importing economies, renewable energy is important for these economies for energy independence and sustainable growth. Therefore, the increase in energy imports brings with it more foreign dependency, more foreign exchange needs, more current account deficit, and a more fragile economy the Mexican economy. Renewable energy offers very important opportunities to reduce energy costs, which bring the most important cost in energy import and production. Therefore, while renewable energy offers significant opportunities for the Mexican economy, reducing non-renewable energy is also important.

4. Conclusion and Policy Implications

Emerging economies have a special position among developing countries with their high growth rates, high energy consumption, and increasing populations. Mexico's economy is among the emerging economies. While the country of Mexico obtained additional income by exporting its energy surplus in 1990, its energy was only sufficient for itself in the future, and then it ceased to be a self-sufficient country in the field of energy. And it could no longer meet the energy it needed with its own resources and became a foreign-dependent country in the field of energy. Increasing economic growth has brought with it an increase in energy imports. The fact that most of these imports are fossil fuels has harmed environmental quality and human health with more CO2 emissions. Due to its insufficient technological infrastructure in the field of energy, it has caused high energy losses. Therefore, the country of Mexico has realized more energy imports, more fossil fuel demand, more energy loss, more energy use, more CO2 emissions, and more environmental degradation, along with high growth figures in the last 29 years. On the other hand, with the high growth figures in Mexico, more energy imports, more energy use, more energy loss, more energy demand, more energy costs, more foreign exchange need, more current account deficit, and more foreign dependency. making the economy more fragile.

Renewable energy consumption, on the other hand, significantly reduces the cost of carbon reduction by developing more economical and more efficient technologies, in creating employment worldwide/Mexico specific Bulavskaya and Reynès (2018), environmental protection, and sustainable development (Chen et al., 2019; Akal, 2015). Popp (2012), having a significant impact on regional development Miguez et al. (2006), providing great opportunities for the future Robertson et al. (2020), giving hopeless hope for energy soon Chang et al. (2003). In addition, it still has a high share of fossil fuel is used in the share of total energy use. The fact that fossil fuel reserves will run out soon is of great concern. In addition, the increase in harmful gases released to the environment causes negativities such as global warming and climate change. On the other hand, the emerging global epidemic of Covid-19 increases the severity of the need for a livable world for a cleaner, healthier, and the more livable world and occupies the world agenda more. Mexico's total GDP increased by 192.19% in 2019 compared to 1990. Mexico uses energy while achieving this increase. It realizes this energy with energy imports, which increased by 1765.97% in 2019 compared to 1990. The fact that these imports are mostly fossil fuels caused the fossil fuel use to increase by 52.39 percent (201.07% for natural gas, 187.23% for coal, and 2.95% for oil) in the same period. Increasing energy demand has created energy losses as it will increase the distribution, transmission, and transportation of energy. In the same period for Mexico, the energy loss during the distribution, transmission, and transportation of energy increased by 234.55%. These losses cause more energy consumption, resulting in an increase of 77.08% in CO2 emissions.

In this study, the effect of renewable energy consumption and non-renewable energy consumption on economic growth for Mexico, which is among the emerging economies, was investigated with current period data. The difference of this study from other studies is that more observations, calculation techniques, and non-renewable energy consumption are added to renewable energy consumption, including recent periods with current period data. Researching the relationship between renewable energy and non-renewable energy and economic growth will be very important for the Mexican economy. Therefore, these situations make the results obtained from this study wider, more consistent, and healthier.

Traditional ADF and RALS-ADF unit root tests, EG and RALS-EG cointegration tests, and Granger causality tests were used while performing the analyses. First of all, stationarity tests were performed for the series and it was shown that the series were stationary after taking the first difference. EG and RALS-EG cointegration tests were applied and a cointegration relationship was found, considering that all variables were stationary after taking the first difference and that there could be a cointegration relationship between the variables. Finally, the Granger causality test was applied for the variables with a long-term relationship. According to the results obtained, the increase in renewable energy consumption and the decrease in non-renewable energy support the growth hypothesis that the Mexican economy will have a positive impact on its economic growth. Therefore, any negativity to be experienced in renewable energy consumption for the Mexican economy in the relevant period and an increase in the use of non-renewable energy will cause negative effects on economic growth in this economy as well as human welfare.

In the light of the results obtained in the study, policymakers have important duties for the country of Mexico included in the analysis. For the high growth figures to be sustainable, reliable, clean, and environmentally oriented, policies to reduce the costs of renewable energy installations can be implemented, R&D activities can be increased, equipment to be used in the field of renewable energy can be produced locally, financing or credit facilities can be provided in the field of renewable energy, tax reductions and With tax exemptions, subsidies can be applied, new buildings or business centers can be constructed by renewable energy, environmental conditions can be improved for the transmission, transportation and storage of the energy obtained, renewable energy usage areas can be increased, bureaucratic obstacles can be reduced. In other words, it is very important to switch to domestic energy to meet the energy needs of countries with their own resources and reduce their dependence on foreign energy. In addition, to use renewable energy, governments need to create policies on energy with incentives, deterrent laws, sanctions, inspections, measures, accurate information, and training.

In the studies following this study, renewable energy for the Mexican economy and the relationship between non-renewable energy and economic growth can be studied in a larger data set. In addition, the use of current methods will also make important contributions to the literature. In the study, the relationship between renewable energy and economic growth at the general economy level was investigated. Sectoral research is also thought to reveal more detailed findings.

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