



The Effect of Renewable Energy Consumption on Economic Stability: Panel Data Analysis on Selected Countries

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Abstract

This study aims to investigate the effect of renewable energy consumption on economic stability. In this regard, covering the period of 1990-2016, data of 35 countries, 19 of which are developed and 16 of which are developing, were used. The cointegration analysis results reveal that, there is a long-term relationship between the two variables in developed and developing countries. According to panel coefficient estimators, the effect of renewable energy consumption on economic stability is positive and statistically meaningful in Germany, Denmark, Italy, Switzerland, and Sweden, which are developed countries, and also in Egypt, Turkey, Taiwan, Pakistan, and Indonesia, which are developing countries. However, the effect is negative and significant in contrast to expectations in England and Belgium, which are developed countries, and in India and the Philippines, which are developing countries.

Keywords: Energy, Renewable Energy, Non-Renewable Energy, Economic Stability, Political Stability



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I. Introduction*

The concept of energy, defined as the ability to produce jobs in physics, is linked to many disciplines such as economics, ecology and engineering. With the industrial revolution, the demand for energy continued increasingly due to the acceleration in factors such as globalization, technological progress, and population growth. In order to meet the increasing demand for energy, which is a very important input for production activities, it is important to use the existing energy sources efficiently and to provide energy diversity by turning to alternative energy sources.

Energy sources are generally classified as non-renewable energy sources and renewable energy sources. Non-renewable energy sources consist of fossil origin sources such as oil, natural gas, coal and nuclear energy. Renewable energy sources include solar, wind, geothermal, hydroelectric, biomass and wave energy. Non-renewable energy sources are discussed in many ways. The main basis of this debate is the fact that oil shocks that occurred in the 1970s caused serious imbalances in economic indicators and external costs such as environmental pollution and health problems, threatening energy supply security and sustainability in terms of limited reserves. On the other hand, it is possible to summarize the advantages offered by the use of renewable energy resources in the form of contributions to sustainable growth and development, reducing energy price uncertainty and risks, ensuring energy supply security, socioeconomic contribution, reducing environmental damage and positive effects on climate change. In addition, increasing the share of renewable energy resources in total energy demand is expected to have a positive impact on economic stability and social welfare.

Economic stability implies an economy with an acceptable level of change in economic indicators, free from risks and uncertainties. In this sense, it can be said that economic shocks, economic fluctuations and economic crises may adversely affect economic stability. Therefore, an energy-induced shock, fluctuation or crisis

can disrupt the balance in the economy, leading to instability. From this point of view, it is stated that the use of clean and sustainable alternative energy resources produced domestically is in an important position in ensuring economic stability by reducing possible imbalances in economic indicators.

The aim of this study is to examine the effect of renewable energy consumption on economic stability. The importance of the study is an effort to make a contribution to this field, as studies on sustainable growth and economic stability are less common in the energy literature.¹ The feature that distinguishes the study from its peers is the use of a more comprehensive index that includes basic macroeconomic indicators representing economic stability. The rest of the study is organized as follows: Following the introduction part where the concepts of energy and economic stability are introduced, the relationship between renewable and non-renewable energy sources and economic stability is discussed in the theoretical discussion section. In the section where the current literature is examined, the previous studies are summarized and grouped in the context of economic stability indicators. Following the explanations about the data set and model, method and empirical findings were shared in the panel data analysis section. In the conclusion part, the policy recommendations are evaluated by evaluating the findings.

II. Theoretical Discussion

Among the main studies examining the relationship between energy and economic activities are Hudson and Jorgenson (1974), Allen et al. (1976), J. Kraft and A. Kraft (1978), Hitch (1978), Akarca and Long (1980), Eden and Hwang (1984). In these studies, the relations among fossil, nuclear energy sources and economic activities were discussed. On the other hand, after the oil crises in the 1970s, the energy economy has preserved its place in the economy until today, and has made progress in two major literature axes since then. While the first main literature is formed within the framework of the relationship between energy and growth, the second is shaped by the effect of energy prices on economic performance. The pioneer of the first literature, J. Kraft and A. Kraft (1978), is considered to be the pioneer of the second literature, Hamilton (1983).

Energy is regarded as an important factor for economic stability and sustainable growth. The reason is that, the effect of shocks experienced in energy prices on economic fluctuations is a generally accepted issue. On the other hand, when the economy is exposed to economic shocks caused by energy price increases and supply cuts, deteriorations may occur in the environment of economic stability and sustainable growth (Aguiar-Conraria and Wen, 2006; Nkomo, 2005). In general, it is argued that energy-induced shocks and fluctuations

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¹The literature investigating the relationship between energy consumption and economic growth has improved greatly in the last decade. However, it is stated that studies investigating the effect of renewable energy on sustainable and stable economy are not sufficient in the literature (Bhattacharya et al., 2016: 734).

distort both the internal and external stability of economies, and significantly affect the countries that export and import energy without making a distinction between developed and developing economies (Chaudhry et al., 2015). However, it is stated that the move towards renewable energy can prevent the economic instability caused by the shocks and volatility mentioned above. The reason is that, with the dissemination of renewable energy, integration of national markets with alternative energy markets may decrease the possibility of economic instability caused by fossil energy by increasing energy diversity (Van de Ven and Fouquet, 2017).

The widespread use of renewable energy sources encourages economic growth thanks to efficiency gains, creates new employment sources and reveals a more competitive structure especially in the production and manufacturing sectors (WEF, 2019). On the other hand, towards the Sustainable Development Goals,² it reduces environmental concerns, serves energy security, provides foreign currency savings to countries, current account deficit and socioeconomic, etc. contributes positively to factors (Hanff et al., 2011). When evaluated as a whole, it can be said that renewable energy is associated with a sustainable and stable economic structure and has a key role in establishing economic stability.

In general, while the current literature examines the relationship among renewable energy and the economic variables, the difference of this study is that the energy is analyzed from a wider perspective, ie, the economic stability index covering macroeconomic variables. It is thought that this research will contribute to the literature and offer a different perspective.

III. Data Set and Econometric Model

Economic stability index (ECO), renewable energy consumption (REC), non-renewable energy consumption (NREC) and political stability index (POL) variables were used in the study. These variables are included in the analysis by taking their logarithms and expressed as LECO, LREC, LNREC and LPOL. The study period covers the period of 1990-2016. Economic stability index data were calculated by the authors following the “International Country Risk Methodology (ICRG)” of the PRS group.³ Renewable energy

²Sustainable development is a broad concept that evaluates economic, social and environmental factors together, including long-term equilibrium in the economy, efficient use of the factors of production and transfer of resources to future generations (Pearce, 1988).

³The International Country Risk Guide (ICRG) consists of 22 sub-components in three main stability / risk categories: Political, economic and financial. The economic stability / risk index consists of five sub-components: GDP per capita, growth rate, inflation rate, the share of the budget balance in GDP and the share of the current balance in GDP. The general purpose of this index is to determine whether a country is economically at risk / stable by addressing its strengths and weaknesses. These strengths and weaknesses were

consumption data were obtained from the "Economic Development and Cooperation Organization (OECD)" database, and non-renewable energy consumption data from the official website of "British Petroleum (BP)". Political stability index data were accessed from the official website of the ICRG.⁴ General explanations of the variables are presented in Table 1.

Table 1: General Explanations of Variables

Variable	Definition	Explanation	Resource
ECO	Economic Stability Index	Economic stability index data were created by the author following the ICRG methodology.	PRS-ICRG
REC	Renewable Energy Consumption	Renewable energy consumption data consist of the sum of solar, wind, hydroelectric, geothermal, wave and tide, as well as other liquid biofuels, biogas and municipal waste. It is expressed in thousand tons of oil equivalent.	OECD
NREC	Non-Renewable Energy Consumption	Non-renewable energy consumption data represent the sum of consumption data for fossil origin sources such as oil, coal and natural gas. It is calculated in thousand tons of oil equivalent.	BP
POL	Political Stability Index	Political stability index was calculated by taking the simple average of 12 political stability indicators.	PRS-ICRG

The countries included in the study were selected among 40 countries listed according to the "Renewable Energy Country Attractiveness Index (RECAD)". Due to the data constraint, analyzes were carried out on 35 countries in total. These countries are classified as developed countries and developing countries. In the classification of countries, the WESP (2019) report of the United Nations was used. The countries included in the analysis are given in Table 2.

Table 2: Countries Included in the Analysis

Developed Countries			
USA	England	Italy	Greece
France	Netherlands	Belgium	Sweden
Australia	Denmark	Ireland	Norway
Germany	Canada	Portugal	Finland
Japan	Spain	Switzerland	-
Developing Countries			
China	Morocco	Turkey	Pakistan
India	Egypt	South Korea	Thailand
Argentina	Brazil	Philippines	Peru
Chile	Mexico	Taiwan	Indonesia

determined by assigning risk / stability points, called economic risk / stability components, to each factor. The lower the total score (0-50), the more avoid the economic stability is the existence of an economy. On the other hand, the higher the total score, the greater the economic stability of the country concerned is expressed (PRS-ICRG, 2018: 2-14).

⁴ The purpose of the political stability / risk index is to evaluate the political stability of the countries covered by the ICRG comparatively. This index consists of 12 subcomponents: Government stability, socioeconomic conditions, investment profile, internal conflict, external conflict, corruption, military in politics, religious tension, law and order, ethnic tension, democratic accountability and bureaucracy quality. The index gets scores ranging between 0-100. As total value gets close to 100 points, political stability increases, and as it converges to 0, political risk increases (PRS-ICRG, 2018: 2-7).

In the study, Kaldor (1976), Kissel and Krauter (2006), Leblond (2006), Chang et al. (2009), Bhattacharya et al. (2016), Maradin et al. (2017), Maji and Sulaiman's (2019) studies were examined and the estimation model was created as in equation number 1:

$$LECO_{it} = \alpha_0 + \beta_1 LREC_{it} + \beta_2 LNREC_{it} + \beta_3 LPOL_{it} + u_{it} \quad (1)$$

$i=1, \dots, N; t=1, \dots, T$

One of the variables in the model is $LECO_{it}$; Economic stability index of country i at time t , $LREC_{it}$; The renewable energy consumption of country i at time t , $LNREC_{it}$; The non-renewable energy consumption of country i at time t , $LPOL_{it}$; It represents political stability index of country i at time t . u_{it} is the error term of country i at time t . The indices i and t indicate the cross section size ($N = 19$ for developed countries, $N = 16$ for developing countries) and time dimension ($T = 27$), respectively.

Since $LREC$ and $LNREC$ variables are important input positions for economic activities, their impact on the economic stability index variable is expected to be positive. The $LPOL$ variable is one of the important determinants for economic stability, and its expected impact on economic stability is also positive. Eviews 10, Stata 16 and Gauss 19 package programs were used for panel data analysis in the study.

In the study, the order of econometric method is formed as follows:

- BP (1980) LM and Pesaran (2004) CDLM tests for cross-sectional dependence,
- Pesaran and Yamagata (2008) homogeneity test for testing the homogeneity of slope coefficients,
- Pesaran (2007) CADF panel unit root test without structural break for detection of unit root presence,
- Westerlund and Edgerton (2007) LM Bootstrap and Westerlund (2008) Durbin-Hausman tests without structural break for testing the existence of the cointegration relationship,
- Eberhardt and Teal (2010) AMG coefficient estimator test without structural break for estimation of cointegration coefficients,
- Emirmahmutoglu and Köse (2011) panel causality test for testing the causality relationship.

Panel Data Analysis

Cross-Sectional Dependence Test and Results

It is expected that, it will affect other countries due to the shock experienced in any country because of developments such as globalization, technological progress and free foreign trade. Such a situation may cause inter-unit correlation, that is, cross-sectional dependence (Menyah et al., 2014: 389). In the study, Breusch and Pagan (1980) LM and Pesaran (2004) CDLM tests are used to determine the cross-sectional dependence.

Breusch and Pagan (1980) LM test statistics are calculated as follows:

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{p}_{ij}^2 \quad (2)$$

Based on the OLS estimate in the p_{ij} equation, it is an example estimate of the bidirectional correlation of the error term for each i . The LM test is valid for panels where N is relatively small and T is large enough. For large panels with $T \rightarrow \infty$ and $N \rightarrow \infty$, Pesaran (2004) suggests the scale version of the LM test as follows:

$$CD_{LM} = \left(\frac{1}{N(N-1)} \right)^{1/2} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T \hat{p}_{ij}^2 - 1) \quad (3)$$

CD_{LM} test shows normal distribution with $(N-1) / 2$ degree of freedom and asymptotic chi-square properties. It can be applied when N and T are large. However, if N is large and T is small, it is likely to show significant distortions.

Considering the time dimension and section size of the study ($T > N$), it is stated that LM and CD_{LM} cross-sectional dependence tests are suitable tests. In Table 3, the results of the cross-sectional dependence of the model are reflected.

Table 3: Cross-Sectional Dependence Results

MODEL (CD TEST)	Developed Countries	Developing Countries
BP (2004) LM	1291.29 [0.000]*	233.76 [0.001]*
PESARAN (2004) CD_{LM}	60.57 [0.000]*	3.39 [0.000]*

Notes: * represents 1% significance level. Values in square brackets reflect probability values. Lags is determined as 3. H_0 : No cross-sectional dependence; H_A : There is a cross-sectional dependence.

According to Table 3, null hypotheses for developed countries and developing countries is rejected at the level of 1% significance in the LM and CD_{LM} tests. Thus, there exists a cross-sectional dependence for both country panels.

Slope Coefficient Homogeneity Test and Results

Testing the homogeneity of slope coefficients goes back to Swamy (1970). Standardized distribution statistics of Pesaran and Yamagata (2008) $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$ tests are formulated as follows:

$$\tilde{\Delta} = \sqrt{N} \left(\frac{N-1\tilde{s}-k}{\sqrt{2k}} \right) \quad (4)$$

With the condition $(N, T) \rightarrow \infty, \sqrt{N/T} \rightarrow \infty$ and as long as the error terms have a normal distribution, the test of $\tilde{\Delta}$ is asymptotic standard normally distributed. $\tilde{\Delta}$ test is a test statistic with small sampling characteristics. The $\tilde{\Delta}_{adj}$ test statistics, adapted to the large sample properties, is organized in the form below:

$$\tilde{\Delta}_{adj} = \sqrt{N} \left(\frac{N^{-1}S - E(\tilde{z}_{iT})}{\sqrt{\text{var}(\tilde{z}_{iT})}} \right); \quad E(\tilde{z}_{iT}) = k, \text{var}(\tilde{z}_{iT}) = \frac{2k(T-k-1)}{T+1} \quad (5)$$

Table 4 shows the homogeneity test results of developed countries and developing countries.

Table 4: Homogeneity Test Results

Developed Countries	Delta ($\tilde{\Delta}$)	Delta Adjusted ($\tilde{\Delta}_{adj}$)
MODEL	7.05 [0.000]*	7.78 [0.000]*
Developing Countries	Delta ($\tilde{\Delta}$)	Delta Adjusted ($\tilde{\Delta}_{adj}$)
MODEL	7.95 [0.000]*	8.77 [0.000]*

Notes: * represents 1% significance level. H₀: Slope coefficients are homogeneous; H_A: Slope coefficients are heterogeneous.

In Table 4, according to the model results of $\tilde{\Delta}$ and $\tilde{\Delta}_{adj}$ tests, null hypothesis for developed countries and developing countries is rejected at 1% significance level and it is determined that both groups of countries have a heterogeneous structure. In other words, it is observed that the slope coefficients specific to the sections forming the model have changed between the units.

Panel Unit Root Test and Results

Pesaran (2007) developed the CADF (Cross-Sectionally Augmented Dickey-Fuller) test by including the lagged cross-section averages in the ADF regression. It is used in case of T > N and N > T. In addition, this test gives reliable results even if T and N are small.

The dynamic heterogeneous panel data model discussed in the test process is as follows:

$$y_{it} = (1 - \phi_i)\mu_i + \phi_i y_{i,t-1} + u_{it}, \quad i=1,2,\dots,N; \quad t=1,2,\dots,T \quad (6)$$

The error term with a single factor structure is shown as follows:

$$u_{it} = \gamma_i f_t + \epsilon_{it} \quad (7)$$

When equations 6 and 7 are evaluated together, equation 8 is composed as follows:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i f_t + \epsilon_{it}, \quad (8)$$

CADF regression is shown in the form below:

$$\Delta y_{it} = \alpha_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + \epsilon_{it} \quad (9)$$

CIPS (Cross-Sectionally IPS) panel unit root statistics are obtained by averaging the unit root statistics of each cross-section in CADF regression.

$$CIPS(N, T) = t\text{-bar} = N^{-1} \sum_{i=1}^N t_i(N, T) \quad (10)$$

CADF testing is a test method that takes into account cross-sectional dependence and heterogeneous structure of cross-sections. CIPS statistics are reached by averaging the CADF statistics. In Table 5, CIPS test statistics, which represent the overall panel, are shared in constant & no trend and constant & trend model forms.

Table 5: CIPS Panel Unit Root Test Results (Level)

Developed Countries	LECO	LREC	LNREC	LPOL
Constant & No Trend	-2.084	-2.119***	-1.797	-2.351**
Constant & Trend	-2.194	-2.534	-3.177*	-3.137*
Developing Countries	LECO	LREC	LNREC	LPOL
Constant & No Trend	-2.088	-1.161	-1.786	-1.893
Constant & Trend	-2.487	-1.985	-1.733	-2.169

Notes: *, ** and *** represent 1%, 5% and 10% significance levels, respectively. The maximum lag is set at 3. CIPS statistics critical values for developed countries are -2.38 (1%), -2.20 (5%) and -2.11 (10%) for the constant & no trend model. For the constant & trend model, it is -2.88 (1%), -2.72 (5%) and -2.63 (10%). The critical values of CIPS statistics for developing countries are -2.45 (1%), -2.25 (5%) and -2.14 (10%) for the constant & no trend model. For the constant & trend model, it is -2.96 (1%), -2.76 (5%) and -2.66 (10%). H₀: Panel has a unit root; H_A: Panel has not a unit root.

According to Table 5, the LECO variable is stationary in the constant & no trend and the constant & trend model forms in developed countries. While the LREC variable is stationary in the constant & no trend model form, it contains unit root in the constant & trend model form. While the LNREC variable has a unit root in the constant & no trend model form, it has a stationary structure in the constant & trend model form. The LPOL variable displays a stationary character in both model forms. When it comes to developing countries, it is determined that all variables contain unit roots in both model forms. In summary, while all variables are unit rooted in developing countries, unit root / stationary results differ according to variables and model forms in developed countries.

Panel Cointegration Test and Results

While the Durbin-Hausman panel cointegration test takes into account the cross-sectional dependence, it does not take into account the prior knowledge of the cointegration degrees of the variables. Instead, common factors are taken into account. In this test, although the dependent variable is I(1), it does not matter whether the independent variables are I(0) or I(1), but DH-p and DH-g test statistics can be used according to the homogeneous and heterogeneous structure of the panel coefficients (Westerlund, 2008: 205).

First, the group average statistic is shown as follows:

$$DH_g = \sum_{i=1}^n \hat{S}_i (\hat{\theta}_i - \hat{\theta}_i)^2 \sum_{t=2}^T e_{it-1}^2 \quad (11)$$

Hypotheses of group average statistics;

H₀: $\theta_i = 1$ for all i's,

H_A: $\theta_i < 1$ it is expressed in this way for some i.

Panel statistics are formulated as follows:

$$DH_p = \widehat{S}_n(\widehat{\theta} - \widehat{\theta})^2 \sum_{i=1}^n \sum_{t=2}^T e_{it-1}^2 \quad (12)$$

The hypotheses of panel statistics are indicated below;

$$H_0: \theta_i = 1 \text{ for all } i\text{'s,}$$

$$H_A: \theta_i = \emptyset \text{ ve } \emptyset < 1 \text{ created this way for all } i\text{'s.}$$

The alternative hypothesis of the group average statistics differs from the alternative hypothesis of panel statistics, with the expression "for some i". The reason for this is that, in panel statistics, individual terms (n) are collected before being put together. In group statistics, firstly, various terms are multiplied and then summed up (Westerlund, 2008: 203).

Westerlund and Edgerton (2007) LM panel cointegration test is a cointegration test based on the McCoskey and Kao (1998) Lagrange test multiplier. The power of the test has been increased with bootstrap and it has been proved by the simulations that it gives more successful results on the small sample. Cointegration equation is obtained from equation number 13.

$$y_{it} = \alpha_i + x'_{it}\beta_i + z_{it}, t=1, \dots, T; i=1, \dots, N \quad (13)$$

x_{it} represents the independent variables that are assumed to be K-dimensional random walk property.

$$z_{it} = u_{it} + v_{it}, \text{ however, is shown as } v_{it} = \sum_{j=1}^t \eta_{ij},$$

$$\eta_{ij} \sim IID, \eta_{ij} = \sigma_1^2.$$

The vector $w_{it} = (u_{it}, \Delta x'_{it})'$ indicates a linear process.

$$w_{it} = \sum_{j=1}^{\infty} \alpha_{ij} e_{it-j} \quad (14)$$

e_{it} assumes that the mean zero errors along t and α_{ij} provide the usual summability conditions of its parameters.

One of the important features of this test is that, the alternative hypothesis asserts there is no cointegration in response to the null hypothesis that assumes cointegration. Hypotheses are presented as follows:

$$H_0 = \sigma_i^2 = 0 \text{ for all } i\text{'s,}$$

$$H_A = \sigma_i^2 > 0 \text{ it is expressed in format for}$$

some i's.

In the case of cross-sectional independence stated in the study of McCoskey and Kao (1998), the test statistics equation is formed as follows:

$$LM_N^+ = \frac{1}{NT^2} \sum_{i=1}^N \sum_{t=1}^T \widehat{\omega}_i^{-2} S_{it}^2 \quad (15)$$

Due to the unit root characteristics of the variables of developed countries,⁵ the long-term

⁵In the developed countries, While the LPOL variable is stationary at the level, other independent variables, the LREC and the LNREC differed according to the model forms. Therefore, the final decision regarding the unit root / stationary process of the LREC and the LNREC variables could not be reached.

relationships between them are analyzed with the Durbin-Hausman panel cointegration test. Table 6 shows the results of the Durbin-Hausman panel cointegration test analysis.

Table 6: Durbin-Hausman Panel Cointegration Test Analysis Results

Developed Countries	Durbin-Hausman Testi	
	Test Stastic	p-value
DH-g (Group)	4.158	0.000*
DH-p (Panel)	0.408	0.342

Notes: * represents 1% significance level. Durbin-Hausman panel statistics are used in homogeneous models and group statistics are used in heterogeneous models. Newey-West method was preferred in bandwidth. H_0 : There is no cointegration relationship for all units; H_A : There is a cointegration relationship for some units.

Considering the heterogeneous structure of the model, DH-g (group) test statistics should be taken as basis for Durbin-Hausman panel cointegration test analysis results. The null hypothesis is rejected, because the probability value for the group statistics is less than 1%. Alternative hypothesis is accepted for some units, stating that there is a cointegration relationship. As a result, it has been proved that the variables act together in the long term, that is, cointegrated in developed countries.

Long-term relationships between variables in developing countries are investigated using Westerlund and Edgerton panel cointegration testing without structural break. In Table 7, structural unbreakable cointegration test analysis results are given.

Table 7: Westerlund and Edgerton LM Panel Cointegration Test Analysis Results

Developing Countries	Constant & No Trend			Constant & Trend		
	Test Statistics	Asymptotic p-value	Bootstrap p-value	Test Statistics	Asymptotic p-value	Bootstrap p-value
LM_N^+ TEST	1.866	0.031	0.998	7.418	0.000	0.364

Notes: Bootstrap probability values are obtained from 1000 replicate distribution and asymptotic probability values are obtained from standard normal distribution. H_0 : There is a cointegration relationship; H_A : There is no cointegration relationship.

In Westerlund and Edgerton (2007) panel cointegration test, asymptotic p value is used for the model without cross-sectional dependence and bootstrap p value for the model with cross-sectional dependence. Therefore, since the presence of cross-sectional dependence is detected in developing countries, the bootstrap p value is taken as the basis.

According to the results of LM test analysis in Table 7, the null hypothesis could not be rejected in both the constant and no trend and the constant and trend model form according to the bootstrap p value. In other words, the null hypothesis was accepted in the developing countries, which means that variables act together in the long term, that is, they are cointegrated.

Long Term Panel Cointegration Coefficient Estimator Test and Results

The long-term "Augmented Average Group" (AMG) estimator, which allows cross-sectional dependence with the addition of the common dynamic effect to the regression, also takes into account the heterogeneity of slope coefficients. On the other hand, the AMG estimator method can be used in the case of internality, which assumes the relationship between independent variables and error terms. This test statistics is subject to a two-step testing process. In the first step, the operation of the OLS (FD-OLS) regression model, whose first difference is taken, is discussed and this process is explained as follows (Eberhardt & Bond, 2009; Eberhardt & Teal, 2010):

$$\Delta y_{it} = b' \Delta x_{it} + \sum_{t=2}^T c_t \Delta D_t + e_{it} \quad (16)$$

$$\Rightarrow \hat{c}_t = \hat{\mu}_t^*$$

The first step is carried out on the pooled regression model with the primary difference process. It is suggested that non-stationary and hidden variables deviate from pooled regression estimation results in this step. Therefore, a standard difference estimator (FD-OLS) regression is introduced with the T -1 year dummy, where the dummy coefficients re-labeled as $\hat{\mu}_t^*$ are summed. In the second step, the AMG estimator test statistics is shown as follows:

$$y_{it} = a_i + b' x_{it} + c_i t + d_i \hat{\mu}_t^* + e_{it} \quad (17)$$

$$\Rightarrow \hat{b}_{AMG} = N^{-1} \sum_i \hat{b}_i$$

In the second step, this variable (β) is included in each of the N standard country regressions, including linear trend terms, to capture neglected peculiar processes that develop linearly over time.

Table 8 and Table 9 report the AMG cointegration coefficient estimator results for developed and developing countries, respectively. Thanks to the results of the AMG coefficient estimator analysis, it is possible to discuss country-specific discussions on which variables affect the LECO dependent variable for both groups.

Table 8 shows the AMG cointegration coefficient estimator results for developed countries.

Table 8: AMG Cointegration Estimator Test Results

LECO (Dependent Variable)	LREC		LNREC		LPOL	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Developed Countries						
USA	-0.048	0.195	-0.299	0.025**	0.104	0.331
France	0.036	0.553	0.187	0.114	0.305	0.057***
Australia	0.092	0.378	-0.148	0.169	0.569	0.000*
Germany	0.113	0.001*	0.551	0.187	-0.224	0.413
Japan	-0.105	0.217	-0.803	0.000*	0.122	0.704
England	-0.022	0.065***	-0.015	0.898	0.42	0.015**
Netherlands	-0.002	0.861	0.141	0.350	-0.265	0.136
Denmark	0.030	0.096***	0.040	0.556	-0.236	0.128
Canada	-0.384	0.403	0.707	0.131	0.023	0.971
Spain	0.051	0.138	-0.151	0.097***	0.624	0.003*
Italy	0.046	0.000*	0.009	0.883	0.263	0.024**
Belgium	-0.029	0.000*	0.334	0.000*	0.074	0.65
Ireland	-0.017	0.450	-0.317	0.064***	0.059	0.882
Portugal	0.038	0.487	-0.257	0.056***	0.177	0.377
Switzerland	0.214	0.021**	0.053	0.818	-0.06	0.851
Greece	0.024	0.625	-0.298	0.063***	0.830	0.005*
Sweden	0.306	0.014**	0.240	0.257	1.256	0.000*
Norway	-0.033	0.620	0.200	0.065***	0.194	0.441
Finland	0.020	0.754	0.420	0.003*	1.130	0.000*
PANEL	0.060	0.217	0.110	0.304	0.265	0.000*

Notes: *, ** and *** represent 1%, 5% and 10% significance levels, respectively. The t statistics was calculated using the Newey-West heteroskedasticity standard errors.

According to the AMG coefficient estimator results shared in Table 8, the effect of the LREC variable on the LECO variable has been found to be significant and positive, as expected in Germany, Denmark, Italy, Switzerland and Sweden. It has been observed that a 1% increase in renewable energy consumption caused an increase in the economic stability index by 0.113% for Germany, 0.030% for Denmark, 0.046% for Italy, 0.214% for Switzerland and 0.306% for Sweden. On the other hand, contrary to what is expected in England and Belgium, the effect of renewable energy consumption on the economic stability index is negative and statistically significant. A 1% increase in renewable energy consumption in England and Belgium reduces the level of economic stability index in these countries by 0.022% and 0.029% respectively. It is thought that some factors come into prominence as the cause of the negative relationship. In general, these factors include that the facility, parts and maintenance services required for renewable energy production contain high costs and incentives create additional burden on the budget. There is not enough qualified workforce in this field. Traditional energy lobby activities are active. Also, financing renewable energy incentives are reflected on household electricity bills. Such factors can lead to imbalances in economic activities, causing economic instability.

Belgium, Norway and Finland are the countries with statistically significant and positive relationships between the LNREC variable and the LECO variable. The 1% increase in non-renewable energy consumption in these countries increases the economic stability index by 0.334% in Belgium, 0.200% in Norway and 0.420% in Finland. In USA, Japan, Spain, Ireland, Portugal and Greece, the relationship between the variables is negative. It has been determined that, an increase of 1% in non-renewable energy consumption in these countries cause a decrease in the economic stability index by 0.299% in USA, 0.803% in Japan, 0.131% in Spain, 0.317% in Ireland, 0.257% in Portugal and 0.298 in Greece. Considering the results that arise contrary to the

expectations, external costs such as energy shocks, chronic current account deficit, environment and health are suggested as the reasons of the negative relationship. Considered as a whole, it can be said that dependence on foreign energy causes imbalances in economic indicators through current account deficit and often causes external costs that are not taken into account.

It has been determined that the LPOL variable is positive and statistically significant as expected on the LECO variable in France, Australia, England, Spain, Italy, Greece, Sweden and Finland.

Table 9 shows the AMG cointegration coefficient estimator results for developing countries.

Table 9: AMG Cointegration Estimator Test Results

LECO (Dependent Variable)	LREC		LNREC		LPOL	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Developing Countries						
China	-0.232	0.219	0.077	0.081***	-0.270	0.055***
India	-0.517	0.039**	0.302	0.001*	0.136	0.018**
Argentina	0.143	0.484	0.863	0.007*	0.766	0.034**
Chile	0.111	0.167	0.179	0.018**	0.609	0.001*
Morocco	0.260	0.111	-0.114	0.620	0.042	0.858
Egypt	0.349	0.062***	-0.319	0.000*	0.307	0.000*
Brazil	-0.148	0.687	1.067	0.011**	1.387	0.113
Mexico	0.072	0.822	0.957	0.000*	-0.336	0.361
Turkey	0.405	0.051***	0.769	0.000*	0.067	0.764
South Korea	0.026	0.380	0.221	0.000*	-0.262	0.446
Philippines	-0.490	0.013**	0.479	0.000*	-0.076	0.374
Taiwan	0.092	0.081***	0.067	0.327	0.148	0.660
Pakistan	1.863	0.005*	-0.616	0.031**	0.060	0.575
Thailand	0.296	0.273	0.174	0.119	-0.038	0.914
Peru	-0.237	0.540	0.420	0.177	1.328	0.000*
Indonesia	1.730	0.005*	-0.291	0.204	0.389	0.001*
PANEL	0.232	0.164	0.265	0.028	0.266	0.041**

Notes: *, ** and *** represent 1%, 5% and 10% significance levels, respectively. The t statistics was calculated using the Newey-West heteroskedasticity standard errors.

According to the test results in Table 9 presented by the AMG coefficient estimator, the impact on the LREC variable of the LECO variable is positive and significant in Egypt, Turkey, Taiwan, Pakistan and Indonesia. However, it is negative and statistically significant in India and Philippines. Accordingly, a 1% increase in renewable energy consumption, economic stability index increases by 0.349% in Egypt, 0.405% in Turkey, 0.092% in Taiwan, %1.863 in Pakistan and %1.730 in Indonesia. However, in India and Philippines, economic stability index reduces by 0.517% and 0.490% respectively.

Amongst developing countries, in China, India, Argentina, Chile, Brazil, Mexico, Turkey, South Korea and the Philippines, it has been observed that there is a positive and statistically significant relationship between the LNREC and the LECO variables. In these countries, when a 1% increase in consumption of non-renewable energy is observed, the index of economic stability increases by 0.077% in China, 0.302% in India, 0.863% in Argentina, 0.179% in Chile, 1.067% in Brazil, 0.957% in Mexico, 0.769% in Turkey, 0.221% in South Korea and 0.479% in Philippines. However, in Egypt and Pakistan, a negative and significant relationship has been found between the variables. It has been determined that, 1% increase in non-renewable energy consumption in Egypt and Pakistan cause a decrease by 0.319% and 0.616% in the economic stability index, respectively.

While the relationship between the LPOL and the LECO variables is positive in India, Argentina, Chile,

Egypt, Peru and Indonesia, this relationship is negative only in China, contrary to expectations. This relationship emerging in China is thought to stem from China's distinctive socioeconomic structure.

Panel Causality Test and Results

Emirmahmutoğlu and Köse (2011) panel causality test is a Granger causality test based on the Toda-Yamamoto (1995) test. Considering the heterogeneous structure of the panel and the dependence between the sections, this test can be applied on stationary series of different degrees. It can also be used in the absence of a cointegration relationship.

The process of this test is summarized as follows (Emirmahmutoğlu and Köse, 2011: 871-873): First, the heterogeneous panel VAR (k_i) model with p variables is expressed as follows:

$$z_{i,t} = \mu_i + A_{i1}z_{i,t-1} + \dots + A_{ik_i}z_{i,t-k_i} + u_{i,t}, \quad i=1,2,\dots,N; t=1,2,\dots,T, \quad (18)$$

The symbol i indicates the section size, and the symbol t indicates the time dimension. The term μ_i is a p-dimensional vector of fixed effects. A_{i1}, \dots, A_{ik_i} is the constant (p × p) matrix of parameters allowed to change between units. $u_{i,t}$ is defined as a column vector of the error terms p.

In the VAR model, the variables containing unit roots cause non-standard asymptotic distributions containing coefficient problems in Wald statistics. In this case, the Granger causality test ceases to be valid for non-stationary variables. To eliminate this problem, Toda and Yamamoto (1995) developed the LA-VAR model as an alternative approach to test the coefficient constraint of the VAR model. In heterogeneous mixed panels, the $(k_i + d \max_i)$ model is estimated as follows:

$$z_{i,t} = \mu_i + A_{i1}z_{i,t-1} + \dots + A_{ik_i}z_{i,t-k_i} + \sum_{l=k_i+1}^{k_i+d \max_i} A_{il}z_{i,t-l} + u_{i,t}, \quad (19)$$

$$i=1,2,\dots,N; t=1,2,\dots,T$$

To test the hypothesis that there is no Granger causality in heterogeneous panels, Fisher (1932) test statistics are used. Fisher test statistics are shown as follows:

$$\lambda = -2 \sum_{i=1}^N \ln(p_i), \quad i=1,2,\dots,N \quad (20)$$

The term p_i represents the p value corresponding to the Wald statistics of the section. This test statistic has a chi-square distribution at 2N degrees of freedom. It is stated that the test is valid only when N converges $T \rightarrow \infty$.

In heterogeneous mixed panels, the $(k_i + d \max_i)$ lagged VAR model is formulated as follows:

$$x_{i,t} = \mu_i^x + \sum_{j=1}^{k_i+d \max_i} A_{11,ij}x_{i,t-j} + \sum_{j=1}^{k_i+d \max_i} A_{12,ij}y_{i,t-j} + u_{i,t}^x \quad (21)$$

$$y_{i,t} = \mu_i^y + \sum_{j=1}^{k_i+d \max_i} A_{21,ij}x_{i,t-j} + \sum_{j=1}^{k_i+d \max_i} A_{22,ij}y_{i,t-j} + u_{i,t}^y \quad (22)$$

In equations 21 and 22, dm_{ax}_i show the highest level of integration suspected for each i in the system. While causality from x to y is tested in equation 22, causality from y to x in equation 21 is tested using a similar procedure.

Table 10 shows the results of Emirmahmutoğlu and Köse panel causality test analysis for developed countries.

Table 10: Emirmahmutoğlu and Köse Panel Causality Test Analysis Results

Developed Countries	LREC=>LECO		LECO=>LREC	
	Wald Statistics	p-value	Wald Statistics	p-value
USA	0.911	0.34	0.224	0.636
France	4.377	0.036**	4.513	0.034**
Australia	3.055	0.081***	0.742	0.389
Germany	10.503	0.015***	2.585	0.460
Japan	0.212	0.645	0.663	0.416
England	0.851	0.356	0.012	0.912
Netherlands	0.254	0.614	1.711	0.191
Denmark	0.971	0.324	0.936	0.333
Canada	0.001	0.972	0.223	0.637
Spain	0.100	0.751	2.705	0.100***
Italy	0.051	0.821	1.684	0.194
Belgium	0.305	0.581	0.019	0.892
Ireland	0.062	0.803	0.176	0.675
Portugal	0.091	0.763	1.038	0.308
Switzerland	0.021	0.885	0.905	0.942
Greece	1.601	0.206	1.210	0.271
Sweden	0.464	0.793	0.065	0.968
Norway	28.241	0.000*	0.548	0.76
Finland	1.842	0.175	0.448	0.503
PANEL FISHER	67.116**		35.445	

Notes: *, ** and *** represent 1%, 5% and 10% significance levels, respectively. The maximum lag is taken as 3. Schwarz information criterion was used. Panel bootstrap critical values (LREC => LECO); 1%, 5%, 10% are 79.134, 64.822, 58.473 respectively. Panel bootstrap critical values (LECO => LREC); 1%, 5%, 10% are 80.495, 67.305, 60.167 respectively. H_0 : LREC is not the Granger cause of LECO (Renewable energy consumption is not the Granger cause of the economic stability index); H_0 : LECO is not the Granger cause of LREC (Economic stability index is not the Granger cause of renewable energy consumption).

In Table 10, according to the panel Fisher test statistic, which represents the overall panel, “LREC is not the Granger cause of LEKO”, null hypothesis is rejected, while “LECO is not the Granger cause of LREC”, null hypothesis could not be rejected. In other words, an alternative hypothesis is accepted for the panel of developed countries, which suggests that the economic stability index is the Granger cause of renewable energy consumption. On the other hand, the null hypothesis could not be rejected stating that the renewable energy consumption is not the Granger cause of the economic stability index. As a result, based on the one-way relationship from renewable energy consumption to economic stability index, it has been revealed that there is a “growth hypothesis” for the panel in developed countries.

Considering country-based causality relations, the direction of causality in Australia, Germany and Norway is from renewable energy consumption to economic stability index, while the direction of causality in Spain is from economic stability index to renewable energy consumption. In France, however, it is determined that there is a two-way relationship. As a result, within

the framework of the period and countries analyzed, it has been proved that the “growth hypothesis” for Australia, Germany and Norway, “conservation hypothesis” for Spain and “feedback hypothesis” for France are valid.

Table 11 shows the results of Emirmahmutoğlu and Köse panel causality test analysis for developing countries.

Table 11: Emirmahmutoğlu and Köse Panel Causality Test Analysis Results

Developing Countries	LREC=>LECO		LECO=>LREC	
	Wald Statistics	p-value	Wald Statistics	p-value
China	3.411	0.182	2.227	0.328
India	5.435	0.066***	0.709	0.702
Argentina	0.056	0.813	0.003	0.958
Chile	0.015	0.902	0.000	0.998
Morocco	3.23	0.199	0.935	0.627
Egypt	2.567	0.109	5.767	0.016***
Brazil	0.673	0.412	0.007	0.933
Mexico	3.319	0.068***	1.334	0.248
Turkey	0.146	0.702	0.495	0.482
South Korea	0.062	0.803	0.359	0.549
Philippines	3.45	0.063***	2.27	0.132
Taiwan	0.271	0.603	2.806	0.094***
Pakistan	0.483	0.487	0.208	0.648
Thailand	0.539	0.463	0.025	0.875
Peru	8.328	0.004*	0.038	0.846
Indonesia	0.057	0.811	0.007	0.935
PANEL FISHER	46.431		28.159	

Notes: *, ** and *** represent 1%, 5% and 10% significance levels, respectively. The maximum lag is taken as 3. Schwarz information criterion was used. Panel bootstrap critical values (LREC => LECO); 1%, 5%, 10% are 69.983, 54.204, 48.885 respectively. Panel bootstrap critical values (LECO => LREC); 1%, 5%, 10% are 63.437, 53.881, 48.656 respectively. H_0 : LREC is not the Granger cause of LECO (Renewable energy consumption is not the Granger cause of the economic stability index); H_0 : LECO is not the Granger cause of LREC (Economic stability index is not the Granger cause of renewable energy consumption).

In Table 11, according to the panel Fisher test statistic, which represents the overall panel, “LREC is not the Granger cause LECO” and “LECO is not the Granger cause of the LREC”. Null hypotheses is not rejected. In other words, no statistically significant relationship has been found for the panel of developing countries, both from renewable energy consumption to economic stability index and from economic stability index to renewable energy consumption.

When the causality results of the countries are evaluated, statistically significant relationships have been observed in India, Mexico, Philippines and Peru from renewable energy consumption to the economic stability index. On the other hand, it has been determined that there is a significant causal relationship only in Egypt and Taiwan from the economic stability index to renewable energy consumption. As a result, the "growth hypothesis" in India, Mexico, the Philippines and Peru and the "conservation hypothesis" in Egypt and Taiwan have been proved to be valid among developing countries in the context of the period and country panel.

IV. Conclusion and Recommendations

Considering that energy is an important input for economic activities, alternative energy sources are significant in meeting energy demand. In this way, it is stated that a more balanced process will be followed in economic activities by providing energy resource diversity. In this context, renewable energy consumption is expected to reduce imbalances in economic indicators and contribute to economic stability as a whole. In the study, the effect of renewable energy consumption on economic stability has been examined in the context of developed countries and developing countries, and cross-sectional dependence and heterogeneity have been determined for both country groups. After the unit root test, the cointegration test results reveal that variables in both country groups act together in the long term. According to the long-term coefficient estimator, results contrary to expected ones have been reached in some countries and the reasons for this have been discussed. Finally, causality relationships have been interpreted in terms of hypotheses.

According to the long-term coefficient estimator results, as expected, a positive and significant relationship has been determined on the economic stability index of renewable energy consumption in Germany, Denmark, Italy, Switzerland and Sweden. However, contrary to what is expected in England and Belgium, a negative and significant relationship has been found. The reasons for the negative relationship determined in these two countries are thought to be the methods of financing renewable energy incentive mechanisms and the production of insufficient capacity energy due to climate caused imbalances. Amongst developing countries, in Egypt, Turkey, Taiwan, Pakistan, Indonesia, positive and significant effect of the renewable energy consumption on economic stability index has been found. Contrary to expectations, negative and statistically significant results have been detected in India and the Philippines. It is considered that high costs, the activities of the traditional energy lobby and the high rate of low qualified labor force are thought to be effective in explaining this negative relationship occurring in these two countries.

Considering the results of causality relations analysis in developed countries, a one-way relationship has been determined from renewable energy consumption to economic stability index in Australia, Germany and Norway, and from economic stability index to renewable energy consumption in Spain. In France, it has been detected that bilateral relationship exists. Within the framework of the analyzed period and country group, it has been proved that the "growth hypothesis" in Australia, Germany and Norway, "conservation hypothesis" in Spain and "feedback hypothesis" in France are valid. In developing countries, there is a causality relationship from renewable energy consumption to economic stability index in India, Mexico, Philippines and Peru, and from economic stability index to renewable energy consumption in Egypt and Taiwan. As a result, the "growth hypothesis" for India, Mexico, the Philippines and Peru and the "conservation hypothesis" for Egypt and Taiwan have been proven to be valid in the context of the period and country group discussed. Any causality could not be reached for Turkey. However, according to the long-term

coefficient estimator, renewable and non-renewable energy consumption have been found to be positive and statistically significant on the economic stability index. But, it can be stated that the consumption of non-renewable energy is more effective over the economic stability index, and this result is expected for countries where a large portion of energy demand supplied from fossil resources are observed in countries such as Turkey.

In the study, some suggestions are made in the context of renewable energy policies and practices in general. These suggestions are summarized as follows: The proper planning of the methods of financing high costs of production, installation, parts and maintenance services of renewable energy, the decent analysis of the suitability of the climate characteristics of the renewable energy installation regions to the relevant renewable energy type, increasing the efficiency of R&D expenditures in the field of renewable energy technology, improving the storage possibilities of electricity from renewable energy, making well-equipped workforce planning for the renewable energy sector, and preventing the cartel and lobbying activities that occur in the fossil fuel sector and cause imbalances in the market.

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