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Investigation of the Relationship Between Economic Growth and use of Fossil and Hydroelectric Energy Resources by ARDL Boundary Test: 1971-2018 Iraq Case

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Abstrak. Energi memberikan peran yang sangat penting bagi perekonomian. Dalam konteks ini, banyak negara telah melakukan penelitian untuk meneliti bagaimana energi mempengaruhi ekonomi mereka. Selain itu, hubungan antara energi dan pertumbuhan ekonomi merupakan indikator penting dalam memandu kebijakan ekonomi. Dalam penelitian ini pengaruh Produksi Energi dari Sumber Fosil dan Produksi Energi dari Sumber Listrik Tenaga Air terhadap Pertumbuhan Ekonomi (PDB) untuk Irak dianalisis dengan uji Kointegrasi ARDL. Data Irak yang digunakan dalam penelitian ini diambil dari alamat web resmi Bank Dunia antara tahun 1971-2018. Hubungan yang signifikan dan positif telah ditemukan antara sumber daya energi yang dibahas dalam studi dan pertumbuhan ekonomi. Selain itu, menurut analisis kausalitas Toda-Yamamoto, ditemukan hubungan kausalitas dari penggunaan sumber daya energi fosil terhadap pertumbuhan ekonomi. Demikian pula, hubungan kausalitas telah ditemukan dari penggunaan sumber daya energi hidroelektrik terhadap pertumbuhan ekonomi.

Keywords:
ARDL, Cointegration, Causality, Economic Growth, Energy Resources.

Abstract. Energy is an important input for economies. In this context, many countries have conducted studies to examine how energy affects their economies. In addition, the relationship between energy and economic growth is an important indicator in guiding economic policies. In this study, the effect of Energy Production from Fossil Sources (EPFS) and Energy Production from Hydroelectric Sources (EPHS) on Economic Growth (GDP) for Iraq was analyzed with the ARDL Cointegration test. The data of Iraq used in the study were taken from the official web address of the World Bank and covers the years between 1971-2018. A significant and positive relationship has been found between the energy resources discussed in the study and economic growth. In addition, according to the Toda-Yamamoto causality analysis, a causality relationship from the use of fossil energy resources to economic growth was found. Likewise, a causality relationship has been found from the use of hydroelectric energy resources to economic growth.

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1. Introduction

Access to energy is critical to people's well-being, economic development, and poverty reduction. Ensuring everyone has adequate access to energy is an ongoing and increasingly important challenge to global development efforts. Hence, the difficulty of keeping the balance between development and the environment requires that they have access to a sufficient amount of sustainable energy sources while having a sufficiently high standard of living.

However, the environmental impact of our energy systems is also of great importance. Historically and today's energy systems have been based on fossil fuels (coal, oil and natural gas). These produce carbon dioxide and other greenhouse gases - which are the main drivers of global climate change. If we want to meet global climate targets and avoid the dangers of climate change, the world needs to take a deep-rooted and global review of its energy resources.

Hydroelectric energy means the production of electrical energy by using flowing water. Hydroelectric energy, such as geothermal energy, biomass energy, wind energy and solar energy, is also a renewable, sustainable energy source. In this context, hydroelectric power plants called HEPPs are established. Electricity can be generated at all times thanks to the continuous flow of water. The amount of energy produced varies according to the strength of the flowing water. The higher the water flowing from the river, the greater the amount of energy produced. Expressed as environmentally friendly during their activities, HEPPs can cause great damage to the environment during the construction process. During the construction phase, the stream to be built on it is drained in another direction with canals, and during this process, damage to the surrounding forests is in question. The life of the creatures living in the stream built on it is intervened, in this case, it causes the death of those creatures. In addition, although the HEPP causes serious damage to the area where it is located, it is a very costly system. The aim of this study is to determine the effect of fossil and hydroelectric energy production on economic growth in Iraq with the ARDL boundary test.

The relationship between economic growth and energy consumption has been tested using different methods in the literature. The first of these methods; are studies based on production function. However, the weak point of the production function-based studies is that while growth encourages energy use due to the loud correlation between energy consumption and economic growth, it points to the conclusion that energy use may not be necessary for economic growth [1].

One of the other methods used is causality analysis. The first study in which the method was used in [2]. In this study, the relationship between energy consumption and GDP was investigated by using Sim's causality test for the USA between 1950-1970. In the study, it was decided that there is a one-way positive causality from Gross Domestic Product to energy consumption.

The results obtained in the studies in which the relationship between production factors were tested also differ. While Brendt and Wood in [3] concluded that there is a substitution relationship between these two production factors in econometric studies on the determination of the relationship between energy and capital, the author in [4] results differ in terms of cross-section and time series in parallel with the series used, but in the long run energy and they concluded that there is a substitution relationship between the capital and a more complementary relationship in the short run.

The authors in [5] studied, between the years 1960-2003 industry for Turkey, and total residential energy consumption, industrial added value and annual real GDP data was used, cointegration and Granger causality tests were conducted. As a result of the study, it was concluded that there is a neutral relationship between total energy consumption and real GDP and industrial energy consumption and industrial value added.

The aim of this study is to examine the relationship between economic growth and energy produced from fossil fuels and hydroelectricity for Iraq with ARDL bounds test. For this purpose, after the necessary data were obtained, analyzes were made and the results were examined in detail. The materials and methods used for the study and the results are given in detail below.

2. Methods

In practice, the effect of Energy Production from Fossil Sources (EPFS) and Energy Production from Hydroelectric Sources (EPHS) on Economic Growth (GDP) for Iraq was analyzed with the ARDL Cointegration test. This data set belonging to Iraq and between the years 1971-2018 was obtained from the internet address of the World Bank and the necessary analyzes were made with Eviews 9 package program. The methods used in the analysis are detailed under the headings below.

2.1. Stationary Tests in Time Series

If the mean and variance do not change over time in a time series, it is accepted as stationary. If a time series satisfies the stationary condition, it is stated that in the long run, this time series fluctuates around the average and tends to return to the average. In cases where the effect of a one's unit shock applied to the series is temporary, series that are stationary tend to return to the mean [6]. The presence of unit root in variables means that the series cannot be stationary. It was determined that the analyzes performed with non-stationary data did not give reliable results and caused a relationship called spurious regression [7]. In order to solve the pseudo-regression problem, it is one of the many different methods recommended to regress these differences by taking the differences of these series instead of these non-stationary series [8].

In this study, using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, it has been tried to determine whether there is unit root in the series.

2.2. Augmented Dickey Fuller Unit Root Test (ADF)

Autocorrelation problem was ignored in the unit root test developed in [9]. Later, Dickey and Fuller in [10], the unit root test assumed that the error terms in the model were autocorrelated, and the lagged terms of the dependent variable were included in the model to solve the autocorrelation problem. In [20] The relationship between petroleum price and real exchange rate was examined by ADF unit root test, Johansen-Juselius cointegration test and Granger causality analysis. The authors in [10] used the critical values they developed for the unit root test in the unit root test (ADF), which they expanded on. They used criteria such as the Schwarz information criterion (SIC) or the Akaike information criterion (AIC) to decide the appropriate number of delayed terms in the extended test. While AIC gives stronger results in finite samples, SIC gives more reliable results in large samples.

In order to overcome the autocorrelation problem, equations with AR (p) process have been developed in the ADF unit root test.

$$Y_t = Y_{t-1} + Z_t \qquad t = 2,3,\dots n \tag{1}$$

$$Z_t = \theta_1 Z_{t-1} + \theta_2 Z_{t-2} + \dots + \theta_p Z_{t-p} + \varepsilon_t \tag{2}$$

$$Y_t = \rho Y_{t-1} + \sum_{i=1}^{p} \theta_i (Y_{t-i} - Y_{t-1-i}) + \varepsilon_i \tag{3}$$

$$Y_t = \alpha + \beta \left[t - \frac{1}{2}(n - p + 1)\right] + \rho Y_{t+p-1} + \sum_{i=1}^{p} \theta_i Z_{t+p-i} + \varepsilon_{t+p} \tag{4}$$

H_0: $\rho = 1$ or $\delta = 0$ (The series unit contains roots, so the series is not stationary)
H_1: $\rho < 1$ or $\delta < 0$ (The serial unit does not contain a root, series is stationary).

2.3. Phillips Perron Unit Root Test

Phillips and Perron in [11] introduced a non-parametric test that corrects the autocorrelation between error terms. In this non-parametric test, models are created using the autoregressive-moving average process (ARMA). Phillips and Perron (1988) is a unit root test developed against the weakness of DF and ADF tests in the stationary analysis of time series. This test gives stronger results than DF and ADF unit root tests in the stationary analysis of trend time series. Phillips Perron test is shown by equation (5) or (6).

$$y_t = \hat{\mu} + \hat{\alpha} y_{t-1} + \hat{\varepsilon}_t \tag{5}$$

$$y_t = \tilde{\mu} + \tilde{\beta}\left(t - \frac{1}{2}T\right) + \tilde{\alpha} y_{t-1} + \tilde{\varepsilon}_t \tag{6}$$

Here, T is the number of observations, ε is the error term, and μ, α and β are the least squares regression coefficients.

H_0: ρ=1 or δ=0 (The series unit contains roots, so the series is not stationary)
H_1: ρ<1 or δ<0 (The serial unit does not contain a root, series is stationary).

2.4. Cointegration Test

The number of studies investigating the possible relationships between economic time series has been increasing in recent years. Cointegration analysis is used to reveal these relationships. These analyzes are widely used in econometrics and form the basis of time series analysis. Cointegration analysis method was developed by Granger and Engle [12,13]. It has been widely used since its development and has become very popular today. The authors in [13] demonstrated that an analysis with non-stationary time series may not reflect the real relationship, in other words, the relationship may be false. The existence of a long-term relationship between variables and their common stochastic trend is defined as cointegration. It is stated that in such a situation, they cannot act independently from each other [14].

2.5. The Distributed Delay Autoregressive Model (ARDL) Boundary Test Approach

One of the important advantages of the ARDL approach is that some variables become level stationary I (0) and value variables become stationary I (1) at the first difference, in other words, variables that are differently integrated are used to test whether they are integrated in the long run. The ARDL approach based on the Least Squares (OLS) method, which Peseran and Shin [15] and Peseran, Shin and Smith [16] have introduced to the literature, is used to explain the dynamic (autoregressive) relationship structure between variables. In the regression analysis using time series, if the model includes not only the current values of the independent variables but also the delayed values, this model is called the distributed lag model. If the model contains one or more delayed values of the dependent variable among its independent variables, this model is called a cascading model. These two models are shown by equations (7) and (8), respectively.

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \varepsilon_t \tag{7}$$

$$Y_t = \alpha + \beta X_t + y Y_{t-1} + \varepsilon_t \tag{8}$$

Hypotheses for determining the cointegration relationship in ARDL bounds test approach:

H_0: $y_1 = y_2 = \ldots = 0$, There is no cointegration relationship,
H_1: $y_1 \neq y_2 \neq \ldots \neq 0$, There is a cointegration relationship.

Thus, when the calculated F statistic is greater than the upper bound critical value, the H_0 hypothesis is rejected and it is said that there is cointegration between the variables, while it can be said that there is no cointegration between the variables by accepting the H_0hypothesis when the lower bound is less than the critical value. If the calculated F statistic is between the lower and upper bound critical values, a decision cannot be taken about cointegration.

2.6. Toda-Yamamoto Causality Test

The Granger causality test is generally used in empirical studies in the literature. However, in order to use this test, the series must be stationary or integrated in the same degree. But it is possible to come up with causality between degree-integrated series as well. The reason for choosing the Toda-Yamamoto test is that the variables in the model are not required to be stationary to the same degree. In the analysis of Toda – Yamamoto [17] the standard vector autoregressive model (VAR) was first established based on the levels of the series, regardless of their degree of integration. In the following steps, the degree of the VAR model is artificially changed by adding the actual degree (k) to the maximum degree of integration (dmax) (k + dmax). However, the coefficients of the terms added to the model later are ignored. In this causality procedure, there is a condition that the maximum degree of integration (dmax) should not exceed the true degree (k) of the VAR model [18]. In this respect, it can be stated that the Toda-Yamamoto Causality Test gives more consistent results compared to the Granger Causality Test. Causality analysis developed by Toda and Yamamoto [17] shows an improvement over the Granger test, which uses a standard asymptotic distribution test statistic on standard Granger causality analysis [19].

3. Analysis and Findings

ADF and PP unit root tests were used to analyze the stationary of the variables, the analysis results of ADF are given in table 1 and the analysis results for PP are given in table 2.

Table 1. ADF Unit Root Test Results

Variables	I(0)				I(1)			
	Constant		Constant+Trend		Constant		Constant+Trend	
	t-bar	p-value	t-bar	p-value	t-bar	p-value	t-bar	p-value
GDP	-2.134	0.004	-3.201	0.005				
EPFS	-2.370	0.230	-3.416	0.396	-2.251	0.001	-3.203	0.001
EPHS	-2.478	0.413	-3.378	0.401	-2.301	0.001	-3.004	0.020

$p<0.05$

ADF unit root test results for both fixed and constant + trend models by taking the level (I (0)) and first order differences of the variables (I (1)) are given in Table 1. When Table 1 is examined, it can be said that the H_0 hypothesis is accepted for the EPFS and EPHS series in both the fixed and the constant + trend model at the level (p> 0.05) and thus these variables are not stationary at the 5% significance level, that is, they contain unit root. For GDP, it is seen that the series is stationary in level (p <0.05). For GDP, the H_0 hypothesis is rejected and the series does not contain a unit root. In order to stabilize the non-stationary EPFS and EPHS series, their first order differences are taken. After taking the first order differences, the variables were analyzed according to both the fixed and the fixed + trend model. H_0 hypothesis was rejected for EPFS and EPHS variables in both models (p <0.05). Thus, after taking the first-order differences of these variables, it can be said that at the 5% significance level, they are stabilized, that is, they do not contain unit roots.

Table 2. PP Unit Root Test Results

Variables	I(0)				I(1)			
	Constant		Constant+Trend		Constant		Constant+Trend	
	t-bar	p-value	t-bar	p-value	t-bar	p-value	t-bar	p-value
GDP	-2.214	0.001	-3.127	0.002				
EPFS	-2.235	0.410	-3.631	0.381	-2.617	0.001	-3.410	0.001
EPHS	-2.271	0.398	-3.701	0.390	-2.304	0.001	-3.301	0.002

p<0.05

PP unit root test results for both fixed and constant + trend models by taking the level (I (0)) and first order differences of the variables (I (1)) are given in Table 2. Table 2 shows the t statistics and probability values calculated separately for three variables whose level and first-order differences are taken using both fixed and fixed + trend models. According to Table 2, the H_0 hypothesis is accepted for both models at the level (p> 0.05) and thus, it can be said that EPFS and EPHS are not stationary at the 5% significance level, that is, they contain unit root. For GDP, it is seen that the series is stationary in level (p <0.05). For GDP, the H_0 hypothesis is rejected and the series does not contain a unit root. Necessary analyzes were made by taking the first order differences of the non-stationary EPFS and EPHS series and these series were made stationary. According to the analysis results, the H_0 hypothesis was rejected for both the fixed and the fixed + trend model for the variables of EPFS and EPHS (p <0.05). Thus, after taking the first order differences of these variables, it can be said that they are stationary at the 5% significance level and according to the PP unit root test, that is, they do not contain unit roots.

The use of ARDL cointegration analysis is more suitable for cointegration analysis due to the fact that the variables discussed in the study are stationary at different levels, as stated in the literature.

Table 3. ARDL Cointegration Bound Test

Number of Independent Variables (k)	F statistic Value	Significance Level	Critical Values	
			Lower Limit	Upper Limit
		1%	1.83	2.903
2	19.4256	5%	*2.13*	*3.59*
		10%	2.61	3.63

Whether there is cointegration between variables at 1%, 5% and 10% significance level is shown in Table 3. As seen in Table 3, the calculated F statistic value is greater than the upper limit critical value at the 5% significance level. Therefore, it is determined that there is cointegration between variables by accepting the H_1 hypothesis. After determining a long-term relationship between variables with the F test, the parameters of this relationship were estimated with the ARDL model based on the Least Squares (OLS) method and the results are given in Table 4.

Table 4. ARDL (1, 2, 2) Model

Variables	Coefficients	Standard Error	t- statistic	Probability Value (p)
Constant (c)	0.017893	0.001478	6.571362	0.031
GDP (-1)	0.103647	0.078312	-2.741693	0.013
EPFS (-1)	0.136402	0.032147	-2.317895	0.025
EPFS (-2)	0.112365	0.036415	-2.017852	0.031
EPHS (-1)	0.127853	0.063219	-2.378901	0.019
EPHS (-2)	0.107524	0.001436	-2.368710	0.021

p<0.05

Table 4 gives the values of the variables in the ARDL (1, 2, 2) model. As seen in Table 4, t all three variables have significant and positive coefficients ($p < 0.05$).

One of the important elements that should not be ignored in the analyzes made with the ARDL model is the basic assumptions of the EKK. The results of the basic assumptions of EKK are given in table 5.

Table 5. ARDL Diagnostic Tests

Diagnostic Tests	Test Statistics	Probability Value (p)
R^2	0.750136	
Adjusted R^2	0.716520	
F- Statistics	12.143026	0.001
Breush-Godfrey LM Test	0.540367	0.348
ARCH Test	2.390172	0.281
Jargue-Bera Normality Test	0.493075	0.432
Ramsey-Reset Test	1.801637	0.601

The basic test results for the basic assumptions of the EKK are given in Table 5. The coefficient of determination (R^2) expressed as a percentage varies between 0 and 1 and shows how much of the variance in the dependent variable is explained by the independent variables. Thus, it is seen that approximately 75% of the GDP is disclosed by EPFS and EPHS. If the model was generalized with the corrected R^2 and obtained from the model population, approximately 71% of the variation in GDP would have been explained by EPFS and EPHS. The changing variance problem is tested with the Breush-Godfrey LM test. When the Breush-Godfrey LM test probability value is greater than its critical value, it is assumed that there is no variance problem. According to the Breush-Godfrey LM test probability value ($p > 0.05$) in Table 5, it can be said that there is no variance problem. Whether there is autocorrelation in the estimated model is determined by ARCH test. Autocorrelation is assumed when the probability value of the ARCH test is greater than the critical value. According to the ARCH test probability value in Table 5 ($p > 0.05$), it was determined that there was no autocorrelation. The Jargue-Bera normality test tests whether the errors have a normal distribution or not. When the probability value of the Jargue-Bera normality test is greater than the critical value, the errors are considered to have a normal distribution. According to Table 5 ($p > 0.05$), it is observed that the errors have a normal distribution. The Ramsey-Reset test analyzes whether there is a model building error or not. When the Ramsey-Reset test probability value is greater than the critical value, it is concluded that there is no modeling error. According to the Ramsey-Reset test probability value in Table 5 ($p > 0.05$), it was determined that there was no modeling error.

Table 6. Long Term ARDL Cointegration Results

Variables	Coefficients	Standard Error	t	p
Constant	0.108349	0.003621	5.104562	0.023
EPFS	0.118632	0.027369	-2.214690	0.002
EPHS	0.012470	0.014785	-2.163147	0.002

Table 6 shows the values of the parameters calculated with the long-term ARDL model. In this way, the state of the long-term relationship between variables can be determined. In the study, GDP shows the dependent variable, and EPFS and EPHS show the independent variables. According to Table 6, a positive and significant ($p < 0.05$) relationship was determined between GDP and EPFS and EPHS. In addition, a one-unit increase in EPFS causes an increase of 0.118 units in GDP and a one-unit increase in

EPHS causes an increase of 0.012 units in GDP. Thus, when comparing the effects of EPFS and EPHS variables on GDP, it can be said that for Iraq, the effect of EPFS is greater.

The stability of the ARDL model was investigated by determining whether there is any structural break in the variables. For this purpose, CUSUM and CUSUMQ graphs that exploit backward error term squares and investigate structural breakage in variables. In CUSUM and CUSUMSQ graphs, if the variables are within the critical limits, it is determined that the ARDL model is stable and thus the model coefficients are stable.

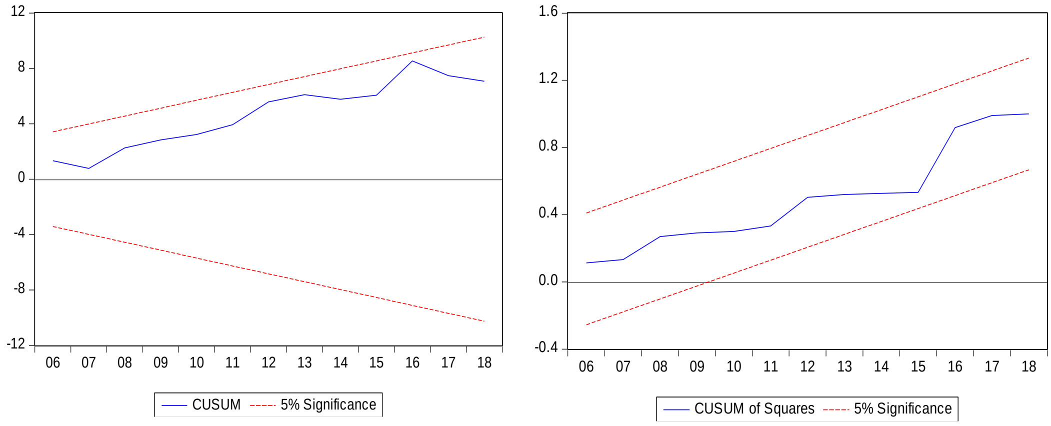

Figure 1. CUSUM and CUSUMQ results

Figure 1 shows the stability of the estimated ARDL model. When the CUSUM and CUSUMSQ graphs were examined, it was determined that the variables were between the critical limits at the 5% significance level. Thus, it was observed that there was no structural break in the variables and the long-term coefficients calculated by the ARDL boundary test were stable.

After performing the ARDL cointegration test, Toda-Yamamoto Causality Test was used to determine the causality direction among variables. First, the appropriate lag length was determined in the VAR Model, and then the Toda-Yamamoto Causality Test was performed.

Table 7. Selection of the lag length of the VAR model

Lag	LR	FPE	AIC	SC	HQ
1	41.01547*	2915.2713*	19.06270*	23.28041*	21.03715*
2	49.34782	3124.016	21.10419	27.07614	25.00143
3	51.04861	3361.179	21.50793	29.10083	25.70391
4	53.07126	3641.061	22.16820	30.00731	26.00617

As seen in Table 7; LR test statistics, FPE (Final prediction error), AIC (Akaike information criterion), SIC (Schwarz information criterion) and HQ (Hannan-Quinn information criterion) statistics were obtained as 1 (*). It can be said that the series do not have varying variance, serial correlation problem, and have normal distribution, because all values provide the same optimum delay.

The results of the Toda-Yamamoto Causality Test applied after determining the optimum lag length are given in detail in Table 8 below.

Table 8. Toda-Yamamoto Causality Test Results

Causality Direction	Test Statistics Value	p-probability value
GDP → EPFS	2.731	0.091
EPFS → GDP	2.045	0.021
GDP → EPHS	2.731	0.004
EPHS → GDP	2.976	0.001

As seen in Table 8, it is seen that GDP does not cause EPFS ($p>0.05$) but EPFS causes GDP ($p<0.05$). In this case, it is seen that there is a causality relationship from EPFS to GDP. It is seen that GDP causes EPHS ($p\leq 0.05$) in the same way that EPHS causes GDP ($p\leq 0.05$). In this case, there is a bidirectional causality relationship between GDP and EPHS.

4. Conclusion

New econometric techniques are used every day in the modeling and testing of economic theories. More realistic results are obtained by making economic analysis using these techniques. It is expected that many economic variables exhibit asymmetrical behaviors in economic theory. Therefore, it is thought that the relationships between economic variables can be modeled correctly by using nonlinear methods.

Energy use varies according to the energy resources of countries and their state of development. It is stated in the literature that there is a tendency to use renewable energy resources especially in developed countries. In addition to the damage caused by fossil-based energy types to the environment, their depletion is among the important reasons affecting the orientation towards renewable energy sources. Iraq is a country rich in oil resources. It is also in the middle level human development category according to the 2020 Human Development Index Report. In the light of this information, the fact that fossil resources are generally used in Iraq in terms of energy production supports the studies in the literature. The aim of this study is to determine the effect of fossil and hydroelectric energy production on economic growth in Iraq with the ARDL boundary test.

In the study, GDP shows the dependent variable, and EPFS and EPHS show the independent variables. According to Long Term ARDL Cointegration Results, a positive and significant ($p <0.05$) relationship was determined between GDP and EPFS and EPHS. In addition, a one-unit increase in EPFS causes an increase of 0.118 units in GDP and a one-unit increase in EPHS causes an increase of 0.012 units in GDP. Thus, when comparing the effects of EPFS and EPHS variables on GDP, it can be said that for Iraq, the effect of EPFS is greater. According to Toda-Yamamoto Causality Test Results, GDP does not cause EPFS ($p>0.05$) but EPFS causes GDP ($p<0.05$). In this case, it is seen that there is a causality relationship from EPFS to GDP. It is seen that GDP causes EPHS ($p\leq 0.05$) in the same way that EPHS causes GDP ($p\leq 0.05$). In this case, there is a bidirectional causality relationship between GDP and EPHS.

It is in the analysis and findings section that the study has similar results with the studies in the literature. Especially in the energy consumption of Iraq, it is seen that the types of energy it has have a high rate. Among these energy types, fossil fuel energy use has the highest rate. Seeking new energy alternatives due to the damage caused by fossil fuel energy types to the environment and their depletion will result in healthier results. New policies should be developed especially for the use of renewable energy sources and investments should be made in these energy types. The fact that the study has not been studied or studied less with this method for Iraq makes the study different. In addition, we believe that this study will contribute to the literature for Iraq.

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