RELATIONSHIP BETWEEN ENERGY SECURITY AND ECONOMIC GROWTH: A BOOTSTRAP PANEL GRANGER CAUSALITY ANALYSIS

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Abstract
This study is aimed to examine the relationship causality between energy security and growth for a total of 74 countries including 39 high-income countries, 23 upper-middle-income countries, and 12 lower-middle-income countries by using the Kónya´s (Kónya, 2006) Bootstrap Panel Granger Causality approach. According to the results obtained, it has been determined unidirectional causality relationship from energy security risk level to GDP for 14 countries and from GDP to energy security risk level for 20 countries. On the other hand, there is bidirectional causality between energy security risk level and GDP for 22 countries, while there is no causality between energy security risk level and GDP for 18 countries. Moreover, the results are also demonstrated that the rate of detection of a causality relationship increases as one moves from high-income group countries to lower-middle-income group countries. The results, which evidence the existence of a relationship between energy security risk level and economic growth for many countries, reveal the importance of the policies to be implemented in this direction.

Keywords: Energy security; economic growth; energy economics; energy policy; bootstrap panel causality
JEL Classification: C23; O13; O40; O47; Q43

Introduction

The increasing importance of energy for states and societies in the historical process has revealed the concept of energy security and has made energy security a national strategy issue. Energy security has been defined as the uninterrupted availability of energy sources at an affordable price by International Energy Agency-IEA (2020). The energy security issue, which was previously associated with the depletion of fossil fuels, has

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become an increasingly multi-dimensional concept with the oil crisis in the 1970s. Thus, the modern energy security perception has been shaped by expanding with dimensions expressed as 4A of energy security: availability, affordability, accessibility, and acceptability (Kartal, 2020 :82-85).

The "availability" dimension of energy security implies the existence of obtainable energy resources. Due to the geographically unequal distribution of resources, while some countries have energy resources, these resources in other countries are either non-existent or insufficient. In other words, the status in terms of the "availability" dimension of energy security in any country, also shapes the value and meaning of other dimensions of energy security, which are affordability, accessibility, and acceptability.

The "affordability" dimension of energy security implies access to energy resources at affordable prices. In this context, this dimension of energy security for self-sufficient countries in terms of energy resources is related to whether the costs such as the extraction, transportation, and refining of energy resources, are reasonable according to the market price (*i.e.*, price ≥ cost = profitability). On the other hand, this dimension of energy security in terms of countries obtaining these resources through imports is related to whether the price of imported energy is appropriate (in other words, whether is expensive). The most important risk factor in this dimension of energy security is price fluctuations. In this context, while the increase in energy prices in energy importing countries is a significant energy security risk factor, the decrease in energy prices is an important risk factor for energy-exporting countries.

The "accessibility" dimension of energy security implies uninterrupted access to energy resources. In this context, this dimension of energy security for self-sufficient countries in terms of energy resources is related to uninterrupted and safe access to existing resources. On the other hand, this dimension of energy security in terms of countries obtaining these resources through imports is related to the continuation of energy imports without interruption.

The "acceptability" dimension of energy security, which has gained importance recently, implies that energy consumption must be acceptable with its environmental impacts. This dimension of energy security is associated with intensive energy consumption endangering natural life and human life (such as climate change, air pollution, ecological deterioration, water pollution, soil pollution, and traffic jam), depletion of resources due to excessive consumption, and the accidents that have occurred/are likely to occur during the energy transport by sea, tanker or pipeline. This dimension of energy security represents sustainability in a sense and, it included factors such as preventing the use of the energy sources, which harm the environment, increasing the use of renewable energy sources, which are eco-friendly, and ensuring energy efficiency.

According to today's perception of energy security, ensuring energy security not only requires that to have energy resources (availability) or access these resources without interruption at the most affordable (accessibility and affordability), but also requires that these resources should be used in a way that does not harm to the environment. In this context, when IEA's definition of energy security is evaluated by considering the dimensions of energy security, it can be argued that the definition of IEA includes 3A of energy security, including availability, affordability, and accessibility. For these reasons, IEA's definition of energy security can be extended as follows: energy security is the uninterrupted availability of energy resources at an affordable price in an acceptable manner with its environmental effects.

Although the dimensions of energy security are expressed with 4A of energy security, it can also be expanded to include the provision of available, affordable, reliable, efficient, eco-friendly, properly governed, and socially acceptable energy services (Pasqualetti & Sovacool, 2012 :167). In this context, to ensuring energy security requires complex measures such as establishing self-sustaining national energy systems, building independent energy-transporting infrastructure, boosting energy production capacity, improving energy efficiency, and increasing the share of renewable energy sources in the consumption balance (Aminjonov, 2016 :1).

In measuring energy security, indexes obtained by combining many data on the dimensions of energy security are frequently used. One of these indexes is the Energy Security Risk Index published by the Global Energy Institute, which is used also in this study.

This study investigates the relationship between economic growth and energy security for 74 countries belonging to different income groups. Some statistical data of the countries subject to empirical analysis are given in Table 1. In this study, data from 74 countries, 39 of which are high income, 23 of which are upper-middle income, and 12 of which are lower-middle income, are used. Accordingly, while the three largest economies in terms of GDP are the United States, China, and Japan, the three smallest economies are Trinidad and Tobago, Bahrain, and Tunisia.

In the next part of this study, which examines the causal relationship between energy security and economic growth for 64 countries in different income groups, a literature review on the subject is included. Then, the data used in the study, the Kónya (2006) bootstrap panel causality approach utilized in causality analysis and the necessary pre-tests for using this approach are introduced. In the last section, results including the Kónya (2006) bootstrap panel causality test as well as cross-sectional dependence tests and heterogeneity tests are included.

Table 1: Some statistical data on countries in analysis

Country	GDP	Rank	ESRI	Rank	Country	GDP	Rank	ESRI	Rank
High-income countries					**Upper middle-income countries**				
Australia	1,434	13	805	69	**Argentina**	520	25	1,136	42
Austria	456	28	1,153	37	**Azerbaijan**	47	69	1,212	28
Bahrain	38	73	1,343	19	**Belarus**	60	66	1,924	3
Belgium	543	24	1,323	20	**Brazil**	1,885	9	1,059	50
Canada	1,716	11	802	70	**Bulgaria**	66	64	1,111	45
Chile	298	41	1,178	34	**China**	13,895	2	912	62
Croatia	62	65	1,181	32	**Colombia**	334	39	678	73
Czech Republic	249	45	1,024	55	**Ecuador**	108	61	1,042	54
Denmark	356	37	864	67	**Indonesia**	1,042	16	932	61
Finland	276	42	1,147	39	**Iran**	473	27	1,371	18
France	2,788	6	1,128	43	**Iraq**	224	49	1,191	30
Germany	3,950	4	1,085	47	**Kazakhstan**	179	55	889	63
Greece	218	51	1,076	49	**Libya**	53	67	1,526	10
Hungary	158	57	1,113	44	**Malaysia**	359	36	1,272	24
Ireland	383	32	1,048	52	**Mexico**	1,221	15	966	59
Israel	371	34	1,044	53	**Paraguay**	40	71	1,094	46
Italy	2,086	8	1,240	27	**Peru**	222	50	884	64
Japan	4,955	3	1,281	22	**Russian Federation**	1,657	12	875	65
Korea, Rep.	1,721	10	1,453	15	**South Africa**	368	35	1,156	36
Kuwait	141	58	1,645	6	**Thailand**	507	26	1,396	17
Netherlands	914	17	1,147	38	**Turkey**	771	19	1,267	25
New Zealand	208	52	757	71	**Turkmenistan**	41	70	1,894	4
Norway	434	29	869	66	**Venezuela**	208	53	988	56
Oman	79	63	1,731	5	**Lower middle-income countries**				
Poland	587	22	967	58	**Algeria**	174	56	1,251	26
Portugal	241	48	1,279	23	**Bangladesh**	274	43	1,139	41
Qatar	191	54	1,610	7	**Egypt**	251	44	1,407	16
Romania	242	47	676	74	**India**	2,713	7	1,144	40
Saudi Arabia	787	18	1,518	11	**Morocco**	118	60	1,498	12
Singapore	373	33	2,211	1	**Nigeria**	398	31	837	68

Table 1: Continuation

Country	GDP	Rank	ESRI	Rank	Country	GDP	Rank	ESRI	Rank
High-income countries					Lower middle-income countries				
Slovak Republic	106	62	1,178	33	**Pakistan**	315	40	1,211	29
Spain	1,420	14	1,189	31	**Philippines**	347	38	978	57
Sweden	555	23	1,084	48	**Tunisia**	40	72	1,498	13
Switzerland	705	20	1,050	51	**Ukraine**	131	59	1,463	14
Taiwan, China	608	21	1,314	21	**Uzbekistan**	53	68	1,569	8
Trinidad and Tobago	24	74	1,975	2	**Vietnam**	245	46	1,168	35
UAE	422	30	1,569	9					
United Kingdom	2,861	5	944	60					
United States	20,580	1	727	72					

Note: GDP data are in billions of dollars. The energy security risk ranking has made from the most risky country to the least risky country.

Source: World Bank (2020); Global Energy Institute (2020)

1. Literature Review

The fact that energy is one of the most strategic inputs of the modern world economy brings to a very important position energy security issue in many aspects -especially in economic, social, political, military, and international relations. In this direction, although the issue of energy security is also frequently examined in the economic literature, most of these studies focus on the definition of energy security, its dimensions, and the factors affecting energy security. In addition to these studies, there are studies examining energy security by using empirical methods. However, most of the empirical studies on energy security focus on the creation of indices on energy security to evaluate/compare the position of countries in terms of energy security, on the evaluation of countries in terms of the dimensions of energy security. Accordingly, Yao & Chang (2014) examine how China's energy security has changed over 30 years of reform and the opening period by constructing a framework quantitative for the 4A of energy security (the availability of energy resources, the applicability of technology, the acceptability by society, and the affordability of energy resources). Li *et al*. (2016) evaluate energy security in 4 East Asian countries (Singapore, South Korea, Japan, and Taiwan) in a three-level framework (vulnerability, efficiency, and sustainability) by using the PCA method. Yao *et al*. (2018)

is investigated how energy security is conceptualized in four resource-poor countries including Singapore, South Korea, Japan, and Taiwan. Bambawale & Sovacool (2011) are investigated the energy security concerns faced by China from the point of view of energy users working in government, university, civil society, and business sectors. Wang and Zhou (2017) is evaluated global national energy security by considering the three dimensions of energy security (security of energy supply – delivery dimension, safety of energy utilization dimension and, stability of political-socioeconomic environment dimension) for 162 countries. Song *et al*. (2019) is evaluated how China's energy security has changed over the years by creating the China Energy Security Index (CESI) including the energy supply dimension (nine indicators), economic-technical dimension (three indicators), and environmental dimension (six indicators) from the dimensions of energy security. In a study, which is a synthesized analysis of national energy security policies and performance by drawing from research interviews, survey results, a focused workshop, and an extensive literature review, by Sovacool & Mukherjee (2011) is claimed that energy security ought to be comprised of five dimensions, including availability, affordability, technology development, sustainability, and regulation. Zhang (2011) is focused on the importance of China's demand-side efforts to control the growth of oil demand and its dependence on imported oil for energy security. Kim *et al*. (2011) is analyzed the dependence of the Republic of Korea on energy imports and in this context the growing concerns of the Republic of Korea in energy security. Kruyt *et al*. (2009) is provided an overview of available indicators for the long-term security of supply and, is claimed that there is no one ideal indicator for energy security. In these studies, empirical evidence for the economic effects of energy security is not presented, and countries in terms of energy security situations are evaluated with energy security indices or a few dimensions of energy security.

Besides these studies, some studies have investigated the economic effects of energy security by using variables that reflect a limited number of dimensions of energy security such as dependence on energy imports, energy prices, and energy supply. Accordingly, Balitskiy *et al*. (2014) investigate the issue of the European energy security and economic growth in the context of the EU's high dependence on Russian gas, and concluded that there is a negative relationship between natural gas consumption and economic growth in the EU. Nepal & Paija (2019) is investigated the inter-relationships between energy security captured through the channel of electricity availability based on electricity consumption and economic output for Nepal and suggested that there is no long-run relationship between electricity consumption and economic output. Varigonda (2013) was analyzed the relationship between state stability and energy insecurity taking into account a few limited features of energy security (energy insecurity in the form of fuel supply and electricity supply insecurities) in India and concluded that the combination of inadequate and unreasonably priced fuel supply gives rise to instability in the social and political spheres and, if the fuel supply is also unreliable, it could lead to chronic socio-political instability. A meta-analytic review has been conducted to identify the underlying concerns that can hinder energy security through China Pakistan Economic Corridor energy projects by Ahmed *et al*. (2019), and are concluded that there is a statistically significant strong negative correlation between energy security and economic burden and between energy security and project completion delays, and very strong positive correlation between project feasibility and project completion delays. Gasparatos & Gadda (2009) investigate the relationship between the amount of energy consumed and environmental stress in Japan and conclude a significant increase in the total amount of energy consumed by 66.9% and the environmental stress level by 93.7% between 1979 and 2003. Moreover, Alley *et al*. (2014) is claimed that oil price shocks negatively influenced economic growth in Nigeria, on the other hand, Berument *et al*. (2016) is claimed that oil price shocks positively influenced output in 16 MENA countries including Algeria, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Syria, and the United Arab Emirates.

As set forth also by Kruyt (2009), there is no single ideal variable for energy security, so energy security is a multidimensional concept. Therefore, to fully reveal the economic effects of energy security, data that consider all possible dimensions of energy security should utilize. However, only a few studies focus on energy security, which means the uninterrupted availability of energy sources at an affordable price and covering also entire elements of energy security such as access to energy, energy consumption, carbon emissions, renewable energy, energy prices. The first of these studies is the study by Kartal (2018) and Kartal and Öztürk (2020) that was examined the relationship among political instability, energy security, and growth by using data obtained from fifteen Middle Eastern countries between the years 1996–2014. As a result of econometric analysis, the author stated that a long-term relationship between the variables was determined. The results from the FMOLS estimator demonstrate that while a 1% increase in energy security risk level decreases GDP per capita by 0.41%, a 1% increase in political stability increased GDP per capita by 0.25%. In addition, according to the results obtained from the Panel Granger Causality Analysis in this study, there is a bi-directional association between energy security and GDP per capita and a one-way causality relationship from energy security to political stability and from GDP per capita to political stability. In a study by Le and Nguyen (2019), the relationship between energy security and growth was examined by using ten measures of energy security, which five aspects of energy security including availability, accessibility, affordability, and developability, with a data set covering 74 countries from 2002 to 2013. According to the authors, the results demonstrate that energy security increases economic growth for both all sample countries and sub-samples.

In addition, according to the authors, energy insecurity is measured by the variables of energy density and carbon density, and it negatively affects economic growth. The findings demonstrate that these three factors are interconnected in the economic development, energy security and climate change mitigation at the global level, so integrated policies should be followed. Another studies, which focuses on energy security, is by Stavytsk *et al*. (2018). In this study, an empirical analysis was performed for 29 European countries covering the years 1997–2016 with the assistance of an index (the New Energy Security Index) created by the authors. According to the findings obtained as a result of the study, it was stated by the authors that the increase in GDP positively correlated with NSI, and negatively with CPI. Fang *et al*. (2018) have proposed five dimensions of energy security, which are availability, accessibility, affordability, acceptability, and developability, to construct China's Sustainable Energy Security (CSES) evaluation index model. Moreover, in this study, an empirical study of China's energy security is carried out with data from 2005 to 2015 by using this proposed model, and dynamic changing trends are analyzed. Based on the results obtained, the authors argue that availability and developability are the most important weights in China's Sustainable Energy Security index system, where availability demonstrate a general downward trend; and developability presents an inverted U-type trend, with its lowest point in 2011. In addition, the authors state that from 2008 to 2012, China's sustainable energy security had been at risk.

The study performed by Kartal (2022b) has examined the causality relationship between energy security and growth in Turkey covering the years 1980 – to 2018, using the Asymmetric Causality Test proposed by Hatemi-J. (2012). According to the classical Granger causality analysis performed in this study, there is no causality between the variables. However, according to the asymmetric causality analysis, there is unidirectional causality from an increase in the energy security risk level (*i.e*., positive shocks) to a negative shock in GDP. Based on the results, the author argues that priority policies for energy security in Turkey should be to aim to prevent economic growth from being damaged rather than increasing economic growth. Similarly, Kartal (2022c) analyzed the asymmetric effects of energy security on economic growth in Turkey using the NARDL and ARDL methods. It has been determined in the study that the relationship between energy security and economic growth in Turkey is asymmetrical. According to the results obtained, a 1% increase in energy security risk level decreases economic growth by approximately 0.60%, while a 1% decrease in energy security risk level increases economic growth by approximately 1.72%. Another study by Kartal (2022a) has examined long-run the relationship between energy security and growth in the Turkic World countries including Turkey, Azerbaijan, Kazakhstan, Turkmenistan, and Uzbekistan the years 1992 to 2016. The study, in which the existence of a long-term relationship between the variables was determined using the Panel Durbin-Hausman Cointegration test, concluded that a 1% increase in energy security risk level in Turkic World countries reduces the economic growth by about 0.95%.

Considering the few studies focused on energy security as an entire, it is seen that the existing studies examine a narrow period, the countries/regions subject to the analysis include smaller samples such as Middle Eastern countries, Turkic World countries, Europe, China, and Turkey, and the income groups of the countries are not taken into the account in the analyzes. In this context, by considering the relevant literature, the main motivation of this study, which focus on the relationship between energy security and economic growth for a total of 74 countries including 64 countries between 1980–2016 and 10 countries between 1993–2018, is to contribute the relevant literature by examining the economic effects of global energy security over a wide period.

2. Data and Methodology

This study is investigated the relationship causality between energy security and economic growth by using data for 64 countries belonging to different income groups between 1980 and 2016 and data for 10 countries between 1993 and 2018 with the Kónya (2006) bootstrap panel causality test. Accordingly, the International Energy Security Risk Index published by the Global Energy Institute (2020) for 75 countries is used as the energy security variable. This index, which consists of eight main themes and twenty-nine sub-themes covering many aspects of energy security, was preferred for containing information on many aspects of energy security. The variables used in the index are given in Table 2. The majority of GDP data, which is another variable used in the study, was obtained from the World Bank database and missing data has been completed from UNCTAD. In empirical analysis has used natural log transformations of variables.

Although the Energy Security Risk Index (ESRI) is calculated for 75 countries, there are 64 countries where ESRI data are available for the entire 1980–2018 period. Accordingly, these 64 countries with full data have been classified according to three different income groups and have been conducted to empirical analysis. On the other hand, ESRI data for 10 countries out of the remaining 11 are entire for between 1993–2018 period. Accordingly, these 10 countries with full data between 1993 and 2018 have been conducted to empirical analysis as a mixed group. Serbia, which is one of the 75 countries for which ESRI data is calculated, has been excluded from the analysis due to the incompleteness of a large part of its data. Thus, the empirical analysis of this study, which investigates the causality relationship between energy security and economic growth has included 74 out of 75 countries for which the International Energy Security Risk Index was calculated by the Global Energy Institute (for the countries included in the analysis, see Table 3).

Table 2: Energy security risk index variables

Metric by classification (weight)	General description of metrics	Metrics (weight)
1. Global fuels (14)	Measure the reliability and diversity of global reserves and supplies of oil, natural gas and coal. Higher reliability and diversity mean a lower risk to energy security.	Security of world oil reserves (2) Security of world oil production (3) Security of world natural gas reserves (2) Security of world natural gas production (3) Security of world coal reserves (2) Security of world coal production (2)
2. Fuel imports (17)	Measure the exposure of the national economies to unreliable and concentrated supplies of oil, natural gas and coal. Higher supply reliability and diversity and lower import levels mean a lower risk to energy security.	Petroleum import exposure (3) Natural gas import exposure (3) Coal import exposure (2) Total energy import exposure (4) Fossil fuel import expenditures per GDP (5)
3. Energy expenditures (20)	Measure the magnitude of energy costs to national economies and the exposure of consumers to price shocks. Lower costs and exposure mean a lower risk to energy security.	Energy expenditure intensity (4) Energy expenditures per capita (3) Retail electricity prices (6) Crude oil prices (7)
4. Price and market volatility (15)	Measure the susceptibility of national economies to large swings in energy prices. Lower volatility means a lower risk to energy security.	Crude oil price volatility (5) Energy expenditure volatility (4) World oil utilization (2) GDP per capita (4)
5. Energy use intensity (14)	Measure energy use in relation to population and economic output. Lower use of energy by industry to produce goods and services means a lower risk to energy security.	Energy consumption per capita (4) Energy intensity (7) Petroleum intensity (3)
6. Electric power sector (7)	Measure indirectly the reliability of electricity generating capacity. Higher diversity means a lower risk to energy security.	Electricity diversity (5) Non-CO_2 emitting share of electricity generation (2)
7. Transportation sector (7)	Measure efficiency of energy use in the transport sector per unit of GDP and population. Greater efficiency means a lower risk to energy security.	Transportation energy per capita (3) Transportation energy intensity (4)
8. Environmental (6)	Measure the exposure of national economies to national and international greenhouse gas emission reduction mandates. Lower emissions of carbon dioxide from energy mean a lower risk to energy security.	CO_2 emissions trend (2) Energy-related carbon dioxide emissions per capita (2) Energy-related carbon dioxide emissions intensity (2)

Source: Global Energy Institute (2018: 71–75)

Table 3: List of countries subject to analysis

	Group A (1980–2018: 64 countries)	Group B (1993–2018: 10 countries)
High	Australia, Austria, Bahrain, Belgium, Canada, Chile, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Kuwait, Netherlands, New Zealand, Norway, Oman, Poland, Portugal, Qatar, Romania, Saudi Arabia, Singapore, South Korea, Spain, Sweden, Switzerland, Taiwan, Trinidad and Tobago, United Arab Emirates, United Kingdom, United States	Croatia, Czech Republic, Slovak Republic
Upper middle	Argentina, Brazil, Bulgaria, China, Colombia, Ecuador, Indonesia, Iran, Iraq, Libya, Malaysia, Mexico, Paraguay, Peru, South Africa, Thailand, Turkey, Venezuela	Azerbaijan, Belarus, Kazakhstan, Russian Federation, Turkmenistan
Lower middle	Algeria, Bangladesh, Egypt, India, Morocco, Nigeria, Pakistan, Philippines, Tunisia, Vietnam	Ukraine, Uzbekistan

Note: While the countries in the Group A have been subjected to the empirical analysis separately according to the income groups, the countries in the Group B have been subjected to the empirical analysis as an entire.

Source: Edited by the author

In this study, the causality relationship between the variables is investigated with the Kónya (2006) bootstrap panel causality test. The biggest advantage of the Kónya (2006) bootstrap panel causality approach, which is based on the seemingly unrelated regression (SUR) method and assumed country-specific heterogeneity, is that it does not require any pre-testing such as unit root and cointegration and, it does considering cross-section dependence. The bootstrap panel causality approach proposes by Kónya (2006)is based on the following systems of equations:

$$\begin{aligned}
\ln gdp_{1,t} &= \alpha_{1,1} + \sum_{i=1}^{k \ln gdp} \beta_{1,1,i} \ln gdp_{1,t-i} + \sum_{i=1}^{k \ln esri} \delta_{1,1,i} \ln esri_{1,t-1} + \varepsilon_{1,1,t} \\
\ln gdp_{2,t} &= \alpha_{1,2} + \sum_{i=1}^{k \ln gdp} \beta_{1,2,i} \ln gdp_{2,t-i} + \sum_{i=1}^{k \ln esri} \delta_{1,2,i} \ln esri_{2,t-1} + \varepsilon_{1,2,t} \\
&\vdots \\
\ln gdp_{N,t} &= \alpha_{1,N} + \sum_{i=1}^{k \ln gdp} \beta_{1,N,i} \ln gdp_{N,t-i} + \sum_{i=1}^{k \ln esri} \delta_{1,N,i} \ln esri_{N,t-1} + \varepsilon_{1,N,t}
\end{aligned} \tag{1}$$

and

$$\ln esri_{1,t} = \alpha_{2,1} + \sum_{i=1}^{k \ln gdp} \beta_{2,1,i} \ln gdp_{1,t-i} + \sum_{i=1}^{k \ln esri} \delta_{2,1,i} \ln esri_{1,t-i} + \varepsilon_{2,1,t}$$

$$\ln esri_{2,t} = \alpha_{2,2} + \sum_{i=1}^{k \ln gdp} \beta_{2,2,i} \ln gdp_{2,t-i} + \sum_{i=1}^{k \ln esri} \delta_{2,2,i} \ln esri_{2,t-i} + \varepsilon_{2,2,t} \tag{2}$$

$$\vdots$$

$$\ln esri_{N,t} = \alpha_{2,N} + \sum_{i=1}^{k \ln gdp} \beta_{2,N,i} \ln gdp_{N,t-i} + \sum_{i=1}^{k \ln esri} \delta_{2,N,i} \ln esri_{N,t-i} + \varepsilon_{2,N,t}$$

where the first one denotes the second one respectively: "ln*gdp*" – logarithmic form of gross national product; "ln*esri*" – logarithmic form of Energy Security Risk Index; "*N*" – number of countries; "*T*" – time period; "*k*" – lag length. Accordingly, it is defined that the causality from energy security risk level to gross domestic product in the Eq. (1), from gross domestic product to energy security risk level in the Eq. (2).

Since the most important assumptions of Kónya (2006) bootstrap panel causality approach are cross-sectional dependence and heterogeneity, pre-testing for this should be conducted first. In this study, slope homogeneity test is conducted with the delta test proposed by Pesaran and Yamagata (2008), which is derived from the $\hat{S}$ test of Swamy (1970). Accordingly, Pesaran and Yamagata (2008) propose the $\tilde{\Delta}$ test given in Equation (3) for large samples and the $\tilde{\Delta}_{adj}$ test given in Equation (4) for small samples:

$$\tilde{\Delta} = \sqrt{N}\left(\frac{N^{1}\tilde{S} - k}{\sqrt{2k}}\right) \tag{3}$$

$$\tilde{\Delta}_{adj} = \sqrt{N}\left(\frac{N^{1}\tilde{S} - E(\tilde{z}_{iT})}{\sqrt{Var(\tilde{z}_{iT})}}\right) \tag{4}$$

where, $E(z_{iT}) \quad k$, $Var(\tilde{z}_{iT}) = \frac{2k(T-k-1)}{T+1}$, and N is the number of cross-sections, $\hat{S}$ is Swamy statistics, k is the number of descriptive variables. While the null hypothesis of delta tests is that the parameters are homogeneous, the alternative hypothesis is that the parameters are heterogeneous.

Whether the data sets used in this study contain cross-sectional dependence was investigated using by LM_{BP} Test (Breusch & Pagan, 1980), CD_{LM} Test (Pesaran, 2004), CD Test (Pesaran, 2004), and LM_{adj} (Pesaran *et al.*, 2008a).

$$y_{it} = \alpha_i + \beta_i^{'} X_{it} + \varepsilon_{it} \tag{5}$$

for $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$.

The test is based on the following Berusch-Pagan (1980) LM statistic, which is asymptotically distributed as chi-squared with $(N-1)/2$ degrees of freedom:

$$\mathrm{LM}_{\mathrm{BP}} = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{p}_{ij}^{2}. \tag{6}$$

Pesaran (2004) proposes the test statistics given in Equation (7) for testing the cross-sectional dependency. This test is based on bidirectional correlation coefficients instead of the squares used in the LM test and it can be used in cases where there is both T > N and N > T.

$$\mathrm{CD}_{\mathrm{LM}} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{p}_{ij}\right). \tag{7}$$

Due to occur of deviations as N grows in the $\mathrm{CD}_{\mathrm{LM}}$ test, Pesaran (2004) proposed the test statistic given in Equation (8), which can be used in the case of N > T.

$$\mathrm{CD} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\sqrt{T_{ij}}\,\hat{p}_{ij}\right). \tag{8}$$

It has been determined that the $\mathrm{CD}_{\mathrm{LM}}$ test gives erroneous results in some cases. While the population correlation coefficient is zero, it is actually different, which causes Type-2 error. To solve this situation in the $\mathrm{CD}_{\mathrm{LM}}$ test, Pesaran *et al*. (2008a) has proposed a bias-adjusted LM test (LM_{adj}) given in equation (9).

$$\mathrm{LM}_{\mathrm{adj}} = \sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{(T-k)\hat{p}_{ij}^{2}-\mu_{Tij}}{v_{Tij}}. \tag{9}$$

While the null hypothesis of delta tests is that there is no cross-sectional dependence, the alternative hypothesis is that there is cross-sectional dependence.

3. Empirical Results

In this study, the relationship causality between energy security and economic growth for high, upper-middle, and lower-middle-income countries have been examined by using the Kónya (2006) bootstrap panel causality approach[1]. In Kónya (2006) bootstrap panel causality analysis must firstly be viewed whether there is cross-section dependence and whether the slope coefficient is homogeneous. The results of cross-section dependence and homogeneity tests performed in this direction are given in Table 4.

1 Econometric analyses are carried out by using gauss21 econometrics package program and Nazlıoğlu (2021) Gauss library.

Table 4: Cross-section dependence and homogeneity tests results

	Group A (1980–2018: 64 countries)			Group B (1993–2018: 10 countries)
Test	**High-income**	**Upper middle-income**	**Lower middle-income**	**Mixed group**
LM	12896.788 0.000	2171.934 0.000	632.783 0.000	176.876 0.000
CD_{LM}	345.578 0.000	115.415 0.000	61.958 0.000	13.901 0.000
CD	101.204 0.000	40.181 0.000	22.926 0.000	6.422 0.000
LM_{adj}	368.215 0.000	116.290 0.000	65.919 0.000	78.54 0.000
Delta	31.968 0.000	29.684 0.000	17.565 0.000	15.002 0.000
$Delta_{adj}$	33.238 0.000	30.864 0.000	18.263 0.000	15.912 0.000

Note: Data in parentheses demonstrate probability values. k is selected as 1 in all panels.
Source: Edited by the author

The results obtained indicate that there is cross-section dependence and heterogeneity in all panels. These results allow the Kónya (2006) bootstrap panel causality analysis can be performed. Accordingly, the Kónya (2006) bootstrap panel causality results performed are given in Table 5.

Table 5: Panel causality test results

Country	H_0: ESRI does not cause GDP				H_0: GDP does not cause ESRI			
	Statistic	Critical values			Statistic	Critical values		
		1%	5%	10%		1%	5%	10%
High-income countries								
Australia	124.92***	110.59	38.10	21.77	2.67	51.51	24.47	14.91
Austria	4.10	21.72	10.33	7.18	7.20*	15.06	8.97	6.86
Bahrain	3.97	1,258.08	569.08	362.79	2.28	83.44	34.52	23.56
Belgium	72.21***	33.87	11.68	7.74	8.41**	18.44	7.93	5.70
Canada	2.76	384.88	190.79	120.28	3.10	131.63	47.63	27.70
Chile	227.61***	50.83	27.80	16.23	16.30***	15.24	6.72	4.76
Croatia	6,58***	4,56	3,20	2,54	24,65***	6,98	4,61	3,52
Czech Republic	0,06	24,12	16,63	13,39	1,36	35,03	25,88	21,90
Denmark	474.58***	230.58	114.81	79.25	14.58	79.34	32.26	21.58
Finland	8.67	31.25	15.76	11.33	32.47***	3.20	1.21	0.76
France	11.42	99.24	52.95	33.01	26.46**	67.89	23.53	17.74
Germany	78.42**	87.80	30.42	17.98	10.96***	2.61	1.19	0.77
Greece	43.30	558.12	273.27	166.52	39.60	162.20	72.86	40.01
Hungary	55.60***	17.21	9.33	6.75	13.11***	5.65	2.79	1.94
Ireland	44.58	210.60	103.11	62.71	6.70	140.67	54.96	34.24
Israel	3.66	35.57	12.42	7.27	3.33	10.42	5.18	3.47
Italy	5.90	137.49	62.25	35.53	13.54	71.77	31.98	22.44
Japan	2.98	36.68	14.73	9.98	43.89**	49.62	23.42	15.34
Kuwait	227.59*	610.32	261.28	169.35	60.39*	187.16	82.58	57.09
Netherlands	3,632.78***	357.35	140.85	82.40	3.11	22.41	14.80	11.20
New Zealand	24.60***	5.35	2.60	1.81	1.75	44.54	22.82	13.39
Norway	193.46	1,062.69	464.15	288.19	0.09	81.86	36.36	23.74
Oman	339.48***	133.18	59.93	42.00	111.81***	35.57	17.86	13.60
Poland	25.96	274.33	153.57	107.97	26.29	120.79	50.49	32.38
Portugal	18.55***	17.75	8.63	5.85	0.01	17.30	9.18	7.24
Qatar	2.21	1,203.59	559.46	369.03	0.51	122.38	61.46	39.57
Romania	344.09***	30.17	12.04	8.01	0.17	3.32	1.88	1.25
Saudi Arabia	515.06**	689.80	335.97	235.10	11.84	163.34	84.45	51.48
Singapore	8.50	103.07	37.49	20.29	14.80***	2.27	1.19	0.80
Slovak Republic	0,00	36,82	27,89	22,59	12,54***	7,41	4,78	3,67
South Korea	0.03	291.19	130.20	83.28	18.20	173.42	67.56	38.34
Spain	0.36	117.54	53.81	33.47	8.65***	2.23	1.07	0.62
Sweden	4.64	217.76	101.08	64.30	5.86	134.87	50.35	31.71
Switzerland	4.25	29.11	15.50	11.00	4.34***	3.21	1.59	1.06
Taiwan	18.29	387.43	194.53	136.89	38.32*	107.88	46.12	32.81
Trinidad and Tobago	833.19***	86.17	36.79	21.29	11.05	31.72	19.52	14.09
United Arab Emirates	0.00	1,069.74	427.94	270.22	3.95	81.11	37.34	24.79
United Kingdom	11.54	56.78	31.22	19.44	7.64	58.69	30.40	19.46
United States	34.29	702.15	291.20	182.56	2.51	100.80	39.35	25.07

Table 5 (Continuation)

Upper middle-income countries									
Argentina	4.14	6.46	6.40	6.36		1.88***	0.04	0.03	0.02
Azerbaijan	0,75	9,89	5,35	3,65		14,66***	5,34	3,75	2,97
Belarus	2,85	18,68	13,70	11,70		10,55***	10,40	6,64	5,17
Brazil	2.91***	0.21	0.20	0.19		2.82	4.77	4.55	4.46
Bulgaria	0.69	3.51	3.42	3.36		1.36	6.01	5.42	4.96
China	0.11	1.45	1.34	1.29		0.14	2.64	2.33	2.19
Colombia	3.01***	1.98	1.91	1.88		0.02	2.20	2.02	1.92
Ecuador	26.26***	0.69	0.64	0.61		8.75***	0.79	0.67	0.62
Indonesia	16.94***	0.16	0.14	0.12		0.56***	0.14	0.12	0.11
Iran	0.00	2.05	1.97	1.92		2.52***	0.62	0.55	0.51
Iraq	5.29***	3.81	3.68	3.61		0.42	7.24	6.95	6.74
Kazakhstan	9,37***	8,78	4,28	2,97		0,64	12,09	8,40	7,03
Libya	6.06***	1.54	1.51	1.48		19.33***	1.94	1.76	1.64
Malaysia	5.53**	5.56	5.26	5.10		9.82***	0.98	0.61	0.43
Mexico	2.40	4.85	4.71	4.66		4.15***	0.19	0.12	0.09
Paraguay	1.33	2.02	1.90	1.84		0.15	0.40	0.36	0.34
Peru	4.32***	0.14	0.11	0.10		0.93	1.49	1.43	1.39
Russian Federation	18,61**	19,83	13,23	11,13		16,89***	11,37	6,69	5,11
South Africa	2.27***	2.07	1.97	1.91		6.99***	1.55	1.41	1.36
Thailand	1.33	1.79	1.70	1.67		20.11***	3.98	3.53	3.34
Turkey	0.03	4.39	4.29	4.25		8.71***	4.12	3.89	3.78
Turkmenistan	39,21***	5,78	3,67	3,07		20,29	32,15	24,07	20,60
Venezuela	38.79***	0.63	0.58	0.54		10.78***	0.90	0.79	0.74
Lower middle-income countries									
Algeria	4.25	10.71	10.62	10.58		1.91***	1.16	1.11	1.08
Bangladesh	9.01***	4.40	4.34	4.29		5.08***	0.33	0.29	0.28
Egypt	2.07	4.69	4.64	4.61		0.53**	0.56	0.49	0.47
India	8.97***	4.30	4.25	4.22		11.33***	0.40	0.37	0.35
Morocco	6.19***	5.68	5.64	5.61		0.24	1.63	1.47	1.40
Nigeria	5.40***	1.24	1.20	1.18		5.70***	0.57	0.54	0.53
Pakistan	9.16***	0.14	0.13	0.13		0.72***	0.52	0.45	0.41
Philippines	5.52***	1.15	1.11	1.09		5.71***	0.10	0.08	0.07
Tunisia	8.13***	1.38	1.35	1.34		0.58***	0.10	0.08	0.06
Ukraine	0,19	10,68	8,14	7,06		14,01*	24,72	16,87	13,92
Uzbekistan	13,26***	2,17	1,19	0,77		9,30***	4,98	2,82	2,00
Vietnam	11.47***	0.27	0.25	0.24		9.71***	2.62	2.52	2.46

Note: *, **, *** indicate significance at the 0.01, 0.05, 0.1 levels, respectively. While the countries in Group A were subjected to the empirical analysis separately according to the income groups, the countries in Group B were subjected to the empirical analysis as a whole. The results have been combined in a single table.

Source: Edited by the author

Table 6: Summary of direction of causality by country

	Countries		ESRI vs GDP		Countries		ESRI vs GDP
High-income countries	1	Australia	→	Upper-middle-income countries	40	Argentina	←
	2	Austria	←		41	Azerbaijan	←
	3	Bahrain	–		42	Belarus	←
	4	Belgium	⇄		43	Brazil	→
	5	Canada	–		44	Bulgaria	–
	6	Chile	⇄		45	China	–
	7	Croatia	⇄		46	Colombia	→
	8	Czech Republic	–		47	Ecuador	⇄
	9	Denmark	→		48	Indonesia	⇄
	10	Finland	←		49	Iran	←
	11	France	←		50	Iraq	→
	12	Germany	⇄		51	Kazakhstan	→
	13	Greece	–		52	Libya	⇄
	14	Hungary	⇄		53	Malaysia	⇄
	15	Ireland	–		54	Mexico	←
	16	Israel	–		55	Paraguay	–
	17	Italy	–		56	Peru	→
	18	Japan	←		57	Russian Federation	⇄
	19	Kuwait	⇄		58	South Africa	⇄
	20	Netherlands	→		59	Thailand	←
	21	New Zealand	→		60	Turkey	←
	22	Norway	–		61	Turkmenistan	→
	23	Oman	⇄		62	Venezuela	⇄
	24	Poland	–	Lower-middle-income countries	63	Algeria	←
	25	Portugal	→		64	Bangladesh	⇄
	26	Qatar	–		65	Egypt	←
	27	Romania	→		66	India	⇄
	28	Saudi Arabia	→		67	Morocco	←
	29	Singapore	←		68	Nigeria	⇄
	30	Slovak Republic	←		69	Pakistan	⇄
	31	South Korea	–		70	Philippines	⇄
	32	Spain	←		71	Tunisia	⇄
	33	Sweden	–		72	Ukraine	←
	34	Switzerland	←		73	Uzbekistan	⇄
	35	Taiwan	←		74	Vietnam	⇄
	36	Trinidad and Tobago	→				
	37	United Arab Emirates	–				
	38	United Kingdom	–				
	39	United States	–				

Note: "→" "←", and "⇄" represents the causality direction.
Source: Edited by the author

When the results obtained are examined, it has been determined that there is unidirectional causality from energy security risk level to GDP for 14 countries (22% of countries). When the results are evaluated by income groups, it can be stated that there is unidirectional causality from energy security risk level to GDP for 8 of 39 high-income countries and 6 of 23 upper-middle-income countries. Accordingly, the growth hypothesis for these countries is valid. That is, these results state that economic growth is dependent on the energy security risk level in these countries. Moreover, there is unidirectional causality from GDP to energy security risk level for 20 countries (30% of countries). When the results are evaluated by income groups, it can be argued that there is unidirectional causality from GDP to energy security risk level for 9 of 39 high-income countries, 7 of 23 upper-middle-income countries and 4 of 12 lower-middle-income countries. According to this result, the conservation hypothesis for these countries is valid. This result means that economic growth has an active role in ensuring energy security in these countries. Additionally, it has been determined that there is bidirectional causality relationship between energy security risk level and GDP for 22 countries (34% of countries). When countries are considered according to income groups, there is a bidirectional causality relationship between energy security risk level and GDP for the 7 of 39 high-income countries, 7 of 23 upper-middle-income countries, and 8 of 12 lower-middle-income countries. This result proves the validity of the feedback hypothesis in these countries. This hypothesis states that means both economic growth and energy consumption influence each other in these countries. Finally, there is no causal relationship between energy security and GDP in 18 countries (28% of countries), 15 of which are high-income countries and 3 are upper-middle-income countries. For the countries where the neutrality hypothesis is accepted, this result implies that energy security has no effect on ensuring economic growth, as well as economic growth has no effect on ensuring energy security. The direction of the causality relationship between energy security and GDP by country is summarized in Table 6, and which hypothesis is valid for which countries can be easily obtained from the table.

Conclusion

This study has examined the relationship causality between energy security and growth for a total of 74 countries including 39 high-income countries, 23 upper-middle-income countries, and 12 lower-middle-income countries by using the bootstrap panel causality approach proposed by Kónya (2006). According to the causality analysis results, it was determined that there is unidirectional causality from energy security risk level to GDP for 14 countries, from GDP to energy security risk level for 20 countries. Moreover, there is a bidirectional causality relationship between energy security risk level and GDP for 22 countries, on the other hand; there is no causality relationship between energy security risk level and GDP for 18 countries.

The results demonstrate that the causality relationship between energy security and economic growth cannot be generalized across countries. However, it may be argued that the direction of causality between energy security and GDP is predominantly bi-directional (valid for 34% of the sample). When the results are evaluated by income groups, the results predominantly suggest that there is no causality in high-income countries (15 out of 39 countries, in other words 38% of countries), while there is bidirectional causality in upper-middle-income (7 out of 23 countries, in other words 30% of countries) and lower-middle-income countries (8 out of 12 countries, in other words 70% of countries). However, there is at least one causality relationship between energy security and economic growth in 56 of 74 countries (in other words 76% of countries). Moreover, there is at least one causality relationship between energy security and economic growth in 24 of 39 high-income countries (in 62% of countries), 20 of 23 upper-middle-income countries (in 87% of countries), and all 12 lower-middle-income countries (in 100% of countries).

In this direction, the most remarkable result obtained from this study is that the ratio of the causality relationship determined in the country group increases as one moves from high-income group countries to lower-middle-income group countries. The strongest case here is that the bidirectional causality relationship has been detected in almost all lower-middle-income countries. This situation can be explained by the fact that the emergence of the following situations in countries as the income level rises:

- They relatively easier can access to energy resources in terms of money.
- They relatively easier can solve the problems that occur faster thanks to their more advanced and more alternative physical/technical and transportation infrastructure in energy.
- They relatively easier can turn to more alternative suppliers in a negative situation that arises at a supplier thanks to their access to more suppliers.
- They relatively easier can affect the energy market in the negativities that arise in the energy market since they are in a strong buyer/seller position.

While cutting off access to energy in high-income countries is likely to have more negative economic consequences, they can cope with the problem in some way, as these countries have a much greater capacity to produce solutions. Accordingly, the fact that there is no causality relationship between energy security and economic growth in the world's three largest economies, the USA, China, and Japan, makes this situation even more meaningful. Although energy has an important place in the economies of these countries, thanks to their strong economic structures, they allow them to easily accessible the world's important energy resources. Moreover, it can be argued that the most important risk in terms of energy security in these countries is environmental pollution rather than access to energy.

On the other hand, for relatively low-income countries, it may be argued that they also have to face more factors that make it difficult to access energy, which is also an important input in production. Since economic growth may make their access to energy relatively easier, it can be argued that an increase in economic growth has a positive impact on the energy security risk level of these countries. Likewise, it can be argued that the fact that energy resources become relatively more easily uninterrupted availability of energy sources at an affordable price in these countries may increase their economic output. This causes by reveals a bidirectional causality between energy security risk level and economic growth.

The fact that the results obtained in this study provide evidence for the existence of a relationship between energy security risk level and economic growth in most countries reveals the importance of the policies to be implemented in this direction. Accordingly, energy security can also be used as a policy tool in accelerating economic growth, as policies to ensure energy security in 14 countries where the growth hypothesis is valid may also positively affect economic output. For 20 countries where the conservation hypothesis is valid, increasing economic growth is an important policy tool in ensuring energy security. In a sense, the increase in purchasing power in these countries positively affects the access to energy, which is an important input for production, as well as social welfare, thus may contribute to social welfare. On the other hand, according to the result obtained predominantly in the causality analysis, in the 22 countries where the feedback hypothesis is valid, this result implies that both economic growth may be stimulated by energy security policies and economic growth may be stimulated energy security. Accordingly, policies aimed at ensuring energy security should be implemented within the framework of the 4A of energy security. The following elements come to the fore in the policy recommendations on ensuring energy security:

- Country and crossing-route diversification (for reducing risks in energy imports and exports);
- Increasing the share of renewable energy use in total energy consumption and implementing the policies on energy saving and the energy efficiency (for reducing both the dependency on imports and the environmental adverse effects of fossil fuel consumption as well as providing resource diversification);
- Identifying new energy sources (for reducing import dependency on energy sources).
- Ensuring stability in the exchange rate and, trading with local currencies (for accessibility to energy at affordable prices);
- Looking as an issue of national security to energy security (for raising awareness of energy efficiency).

When this study examining the causality relationship between energy security and GDP in 74 countries with the highest energy consumption worldwide is compared with other studies in the related literature, it could be argued that it differs significantly in terms of including a larger sample and data period, providing results for cross-sections (countries) rather than generalized results for a particular panel (group of countries) and including an index covering many aspects of energy security in the empirical analysis. Thus, it may be expected that the results obtained will create an important added value for the relevant literature. In terms of the results obtained, when this study is compared to other studies examining the causality relationship between energy security and GDP by Kartal (2018) and Kartal and Öztürk (2020), it is seen that other studies have determined a bidirectional causality relationship for the Middle East country group (15 countries). On the other hand, although the results obtained in this study including 74 countries cannot be generalized for entire countries, the dominant result in this study indicates a bidirectional relationship as in two other studies. Therefore, it can be argued that the results from this study are partially compatible with the results obtained from the other two studies. However, it should especially be noted that this study differs from the other two studies in the following aspects: includes cross-section-specific results instead of panels (thus, allowing for country-specific policy implications) and covers more countries and time periods (thus, enabling assessment of the subject in a wider range of data for more countries). Future studies on the subject can focus on the following: the effects of energy security on different economic variables can be examined, empirical analyzes can be created on the asymmetric effects of energy security, time series analysis methods can be used instead of panel data analysis, and the role of energy security on economic variables for certain countries can be focused.

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