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Coal Energy in Energy Consumption: An Empirical Analysis in the Case of Russia and Türkiye

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ABSTRACT

Coal, the fundamental element of the industrial revolution, is widely used for energy production in many countries. The use of coal in energy production continues in countries that have coal reserves, as well as in countries that are rapidly transitioning to renewable energy production. The aim of this study is to investigate the causal relationship between coal production and general energy consumption in Russia and Türkiye, which are among the countries that consume heavy coal. In the article, the relationship between the variables in these countries was tested with Granger causality analysis. According to the results of the analysis, it was determined that there was a one-sided causality relationship from coal production to energy consumption in Russia. When the findings of the study were examined from the perspective of Türkiye, no causality relationship was found between the variables.

Keywords: Coal Energy, Energy Use, Granger Casuality, Russia, Türkiye
JEL Classifications: O13, Q43, O11

1. INTRODUCTION

Coal, which is the most important energy source, is the fundamental element of the industrial revolution in the world. Coal is produced in more than 50 countries and has a lifespan of more than 200 years (Wang, 2011). Coal, which maintains its importance today, also remains as an energy source. Traditional energy is the most preferred method historically and is still used today. However, the scarcity of resources and the decrease in world reserves have led countries to find alternative energy (Huseynli, 2022). For many years, conventional energy has been the most extensively used. However, resource scarcity and dwindling global stocks have prompted governments to seek for new energy sources (Huseynli and Huseynli, 2022).

Coal is a fossil fuel and a non-renewable energy source used to produce electricity by burning. Coal consists mostly of carbon and hydrocarbons with high energy density released through combustion (combustion) (Gasparotto and Martinello, 2021). Coal is widely used for energy production in many countries (Zou et al., 2016). Coal, the second most important energy source worldwide, contributes to 40% of global primary energy consumption (World Energy Research World Energy Council, 2016). Many developing countries use coal as an energy source.

During the First Industrial Revolution, coal burning became a movement. From an economic perspective, this energy source was revolutionary. However, from an environmental perspective, ambient air pollution is a threat (Lozano et al., 2018; Oliveira et al., 2018b; Oberschelp et al., 2019). A coal-fired power plant is a tremendous generator of environmental pollution, releasing large amounts of particles into the atmosphere in the form of aerosols. Inhalation of hazardous substances such as coal microparticles, nanoparticles and their byproducts pose an invisible risk to human health. Although coal consists predominantly of carbon, there are many other components including sulfur, nitrogen, organometallic compounds, and minerals that contribute to the formation of highly toxic

secondary compounds that come into contact with the atmosphere (Gasparotto and Martinello, 2021).

The dynamics of the development of the electric power industry is one of the main indicators of economic developments in the country. The main factor that determines the dynamics of energy use is the economic growth rate (Sadikova et al., 2017). Energy use has become a major concern in recent years due to the rapid increase in energy demand. The most common applications of solar thermal energy used in industry are SWHs, solar dryers, space heating and cooling systems, and water desalination (Mekhilef et al., 2011). Coal is also widely used in power plants and homes. Due to the inevitable decrease in world oil reserves and the increase in demand for energy, coal, in addition to nuclear energy, is an important alternative in meeting these needs (Uslu, 2002; Yılmaz and Uslu, 2006).

In times of the crisis of national economy it is impossible to reach a stable economic growth without implementing and using a complex of innovation techniques of using renewable and alternative energy sources; it makes it possible to reduce dependence of national economy on the world prices for energy resources, to avoid irretrievable loss of money for purchasing the imported energy sources, to provide with the reduction of energy intensity of output of industrial products and to increase competitiveness of national industrial products (Nitsenko et al., 2018).

A significant increase in world resource consumption is predicted over the next few decades. In this context, the importance of solving the current problem of efficient energy use is increasing, as the results of the solution affect not only the present but also the future generations of humanity (Sadikova et al., 2017). The increase in coal production and use predetermines the need for technological innovations to ensure the transition of the coal industry to sustainable economic and ecological development (Palyanova et al., 2017).

Coal seems to maintain its indispensable position among other energy sources for many years, as it is produced in more than 50 countries, is least affected by price fluctuations, and has a lifespan of over 200 years. Countries that are aware of this are investing in mining areas in countries rich in coal reserves and continue to invest in significant amounts (Yılmaz and Uslu, 2007). Despite the increasing demand for renewable energy due to its environmental friendliness compared to fossil fuels, many countries continue to rely on fossil fuel consumption (Achuo et al., 2022).

While natural gas ranks first in primary energy consumption, oil follows it with a share of 19%. Coal also plays a dominant role in the energy production mix in Russia (Grammelis et al., 2006). Coal use, and therefore investment, is expected to increase significantly in the Russian Federation in the next few decades. Projections suggest that at least $200 billion in investment will be needed to modernize existing coal-fired power plants by 2030, but most of this financing will come from the private sector or foreign ventures (Gorbacheva and Sovacool, 2015). Despite the drive towards environmental sustainability and achieving the sustainable development goals (SDGs), coal, oil and natural gas energy use remains Türkiye's largest energy mix (Alola and Donve, 2021). The assessment of short/long-term resilience in the coal industry is an important theoretical and applied problem, with the factors of growth potential revealed and studied (Goosen et al., 2022). Based on this, the aim of this study is to investigate the causal relationship between coal production and general energy consumption in Russia and Türkiye.

2. LITERATURE REVIEW

2.1. Coal Energy

The importance of coal to the Russian economy means that the sector is a strong local actor and producers have close relations with regional and federal governments. The coal sector employed 138,000 people in Russia in 2021 (Petrenko, 2022). Russia ranks second in the world in terms of coal reserves (19% of world reserves), fifth in terms of annual production (5% of world production), and also accounts for approximately 12% of world thermal coal trade (Ministry of Energy of the Russian Federation, 2010). The sustainable economic and ecological development of the coal industry in Russia may be hampered by the lack of some documents at the national level (Palyanova et al., 2017).

Erdem et al. (2009), the performance of nine thermal power plants under the control of public institutions in Türkiye was comparatively analyzed in terms of energy and exergetics. In a study conducted by Erdem (2010), the structure of coal consumption in Türkiye in the last 30 years was analyzed. In a study conducted by Ocal et al. (2013), the relationship between coal consumption and Gross Domestic Product (GDP) in Türkiye was examined based on data for the period 1980-2006. In the study conducted by Capik et al. (2013), Türkiye's energy demand based on hard coal, lignite and natural gas was evaluated. In the study conducted by Ören and Şensöğüt (2019), information on coal potential, which plays a key role in Türkiye's electricity generation, is compared with renewable energy sources in terms of future energy policies, considering this potential. In the study conducted by Alola and Donve (2021), the role of energy use from coal and oil in Türkiye's environmental sustainability move within the framework of sustainable development was examined in terms of income.

In a study by Sasana and Ghozali (2017), the impact of fossil fuels (coal, oil, and natural gas) and renewable energy consumption on economic growth in Brazil, Russia, India, China and South Africa (BRICS) countries was analyzed. Panel data for time series from 1995 to 2014 were tested with multiple linear regression. Downie (2017) demonstrated evidence that coal companies in the United States have demonstrated strong resistance to government attempts to impose regulations limiting coal emissions. Blondeel and Van de Graaf (2018) compare coal mining policies in four major coal-producing states (Australia, China, the USA and India) and found that, in general, climate change considerations are not taken into account in coal extraction. Spencer et al. (2018) reach similar conclusions in their survey of Australia, South Africa, India, and China, and suggest that all four states are not actively preparing for a large-scale coal transition.

Brauers et al. (2020) note that framing techniques used by the coal industry in Britain and Germany, focusing on issues such as electricity prices and employment, were useful in obtaining economic support from the government for the industry. In the study by Ahmad and Zhang (2020), a comprehensive analysis of historical energy consumption (from 1990 to 2017) and future energy requirements (from 2020 to 2040) is presented based on geographical coverage.

2.2. Energy Use

The amount of energy consumption is one of the most important indicators showing the development stages of countries and the living standards of societies. Population growth, urbanization, industrialization, and technological development directly lead to an increase in energy consumption. In parallel, this rapid growth trend brings with it important environmental problems such as pollution and greenhouse effect (Erdem et al., 2009). A study conducted by Sarkhanov and Huseynli (2022) found that there was a positive relationship between economic growth and renewable energy consumption of Kazakhstan and Kyrgyzstan in the period 1996-2018. In the study conducted by Sadikova et al. (2017), the relationship between unemployment, energy use, population growth and foreign direct investment on unemployment for Russia was examined using quarterly data for the period 1992-2015.

Energy use can also vary significantly across different sectors. Erdal et al. (2007), the energy consumption of inputs and outputs used in sugar beet production in Türkiye was examined and a cost analysis was made. The construction industry and its associated industries dominate world energy consumption as the second largest energy users (Mekhilef et al., 2011). García-Martín et al. (2019) examined basic approaches to estimating energy consumption in the field of computer architecture, paired with machine learning applications.

In a study by Yilmaz et al. (2005), direct input energy and indirect energy per hectare in cotton production in Türkiye were examined and compared with input costs. In the study conducted by Madlool et al. (2011), energy use in the cement sector was examined. In the study conducted by Akcaoz (2011), the energy inputs in banana production in Türkiye were evaluated, the most energy-consuming operations were determined, and the energy equivalents of inputs and outputs in banana production were examined.

In the study conducted by Brounen et al. (2012), it was examined to what extent gas and electricity usage depends on the technical characteristics of the house compared to the demographic characteristics of the residents. The study by Achuo et al. (2022) examines the effects of renewable and non-renewable energy consumption on environmental sustainability with a global panel data of 173 countries in the period 1996-2020.

2.3. 2.3.Coal and energy in Russia and Türkiye

It has been noted that little attention is paid to the institutional framework of the coal energy industry in Russia. The role and scope of coal has not been defined in the short or medium term, and its economic preconditions have not been correctly formulated by policymakers. Russia has large coal deposits with favorable mining conditions. In turn, the regions where these deposits are located need electrical power and heat for their development (Lisin et al., 2016).

The strategic goals of the development of the coal industry in Russia are (Ministry of Energy of the Russian Federation, 2010):

- Reliably and effectively meeting the domestic and foreign demand for first-class solid fuel and products obtained from its processing
- Ensuring the marketability of coal products in conditions of saturation of domestic and foreign markets with alternative energy sources
- Increase in the level of operational safety of coal mining and reduction in its harmful impact on the environment.

According to the Russian Energy Strategy, the maximum inclusion of coal in the fuel balance of power plants is ensured for the period until 2030. In this case, despite the serious need to diversify the consumption of fuel and energy resources and reduce the dependence of the energy sector on natural gas, the transition to the primary use of coal-fired technologies does not occur. Additionally, coal-fired electricity generation continues to be displaced from natural gas-based generation (Lisin et al., 2016). According to the Energy Strategy of Russia for the period until 2030 (Ministry of Energy of the Russian Federation, 2010), the consumption of electricity-generating coal in the energy industry will increase, which will increase its production.

Electricity production in Türkiye is mainly based on hydroelectricity and fossil fuels. Türkiye's total coal reserves are around 12 Gt; it consists mostly of lignite with low calorific value. Mining of low-grade coal (lignite and sub-bituminous) is higher than bituminous coal, which only comes out of a coal bed and goes to thermal power plants. Low-grade coals are of great importance and their exploration and exploitation are more advanced than other domestic energy sources. Türkiye has large coal reserves that can be mined at low cost (Oskay et al., 2013).

Türkiye's energy consumption has increased along with its economy and will continue to grow. The country's energy demand is growing by 8% every year, one of the highest rates in the world. Türkiye's oil, natural gas and hard coal reserves are quite limited. Türkiye is currently largely dependent on imports to meet its energy demand due to limited domestic energy resources (Erdem, 2010). Türkiye's energy consumption is increasing faster than its production. The largest source of energy consumption is natural gas with a share of 32%. Lignite coal is Türkiye's largest domestic energy source, and its reserves are 12.4 billion tons. Since most of the lignite reserves are of poor quality, they are mostly used in electricity production (Capik et al., 2013).

3. RESEARCH METHODOLOGY

3.1. Purpose of the Study and Data Set

The data set required for this study on Russia and Türkiye, which have a significant share in coal consumption, was obtained from the World Bank database. The data in the analysis is divided into two: coal production and general energy consumption in these

countries. The data set consists of annual data between 1998 and 2015. The limitation of the article is that we cannot access data after 2015 for both countries.

The overview of Russia's and Türkiye's electricity production from oil, gas, and coal resources (percentage of total) by years is given in Figure 1. Figure 2 shows the electricity generated from coal resources in Russia and Türkiye (percentage of total) data. Energy use (kg of oil equivalent per capita) in Russia and Türkiye over the years is given in Figure 3.

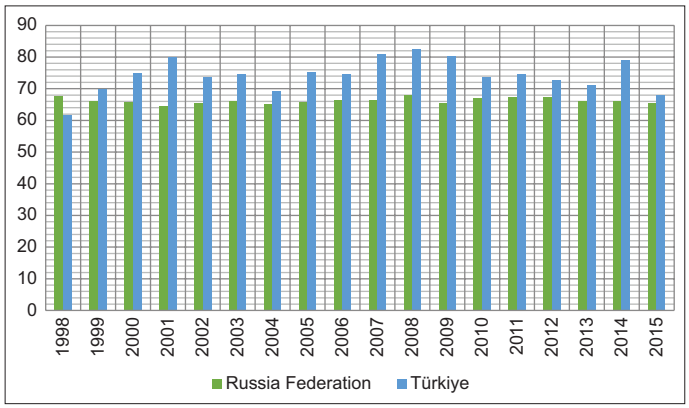
3.2. Analysis Method

In this study, the data were analyzed with the Granger causality test. Among the methods that measure whether the relationship between variables is effective, the Granger causality test is important. In the study, first of all, unit root tests were carried out to determine the time series properties of the variables and whether they were stationary in this context. Whether the series are stationary or not is important in determining the maximum degree of integration in causality analyses. There are many unit root tests in the literature. In this study, ADF (Augmented Dickey-Fuller) root tests are included.

The cointegration test developed by Engle and Granger (1987) is based on the residuals of the long-run regression model. Various cointegration tests were developed in the following years. For example, Johansen (1991) cointegration test is a system-based test. Boswijk (1994) introduced a new cointegration test based on the error correction model and applied with F statistics. Banerjee et al. (1998) test is based on error correction model and t statistics. None of the mentioned cointegration tests are perfect or completely strong. For this reason, Bayer and Hanck (2012) developed a new test to increase the power of cointegration tests (Govindaraju and Tang, 2013).

In order to test the existence of a causal relationship between variables, the causality test developed by Hacker and Hatemi (2006) and based on the boostrap technique was used. Hacker and Hatemi (2006)'s causality test is based on the causality test developed by Toda and Yamamoto (1995). For this reason, the lag length of the VAR model and the degree to which the series are stationary are important. However, there is no condition for the series to be stationary at level. However, while Toda and Yamamoto (1995) consider the asymptotic chi-square distribution in the causality test, Hacker and Hatemi (2006) use the bootstrap distribution. Using bootstrap simulation techniques to obtain critical values can obtain more accurate critical values and therefore reduce deviations. Another advantage of this method is that, unlike the causality test of Toda and Yamamoto (1995), it is not sensitive to the assumption of normality and time-varying volatility (Hacker and Hatemi, 2006).

Figure 1: Electricity production from oil, gas, and coal sources in Russia and Türkiye (% of total)



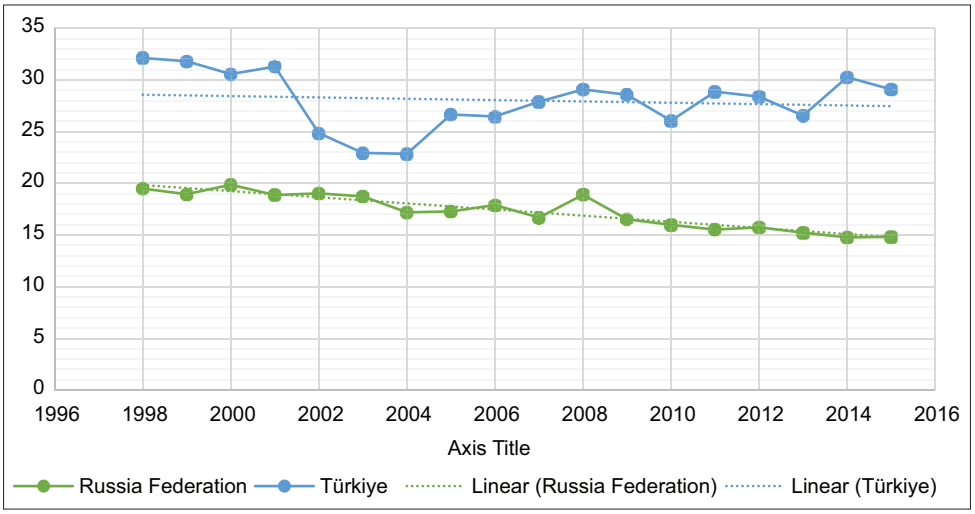
4. ANALYSES AND RESULTS

Before applying analysis methods in the research, the model required for analysis was established. The function used to mathematically determine the relationship between coal production and energy consumption is as stated in Equation 1.

$$Y = f(CP, Eu) \quad (1)$$

CP is the amount of coal production; *Eu* represents the energy use in the countries. When the function is revised, the following equation is finally obtained (Equation 2).

Figure 2: Electricity production from coal sources in Russia and Türkiye (% of total)



$$Y = \beta 0 + \beta 1 CP + \beta 2 Eu \quad (2)$$

Stationarity test was performed for the data sets of both countries included in the research. Augmented Dickey-Fuller (ADF) unit root test was applied to examine stationarity in this data set. As can be seen from Table 1, it is observed that the data set is not stationary at the basic level. In this case, analysis stationarity tests were continued to measure the stationarity level.

As can be seen from Table 2, the data set became stationary after first order differences were taken. After taking the first order differences, the series became stationary. Thus, it was seen that

Figure 3: Energy use in Russia and Türkiye (kg of oil equivalent per capita)

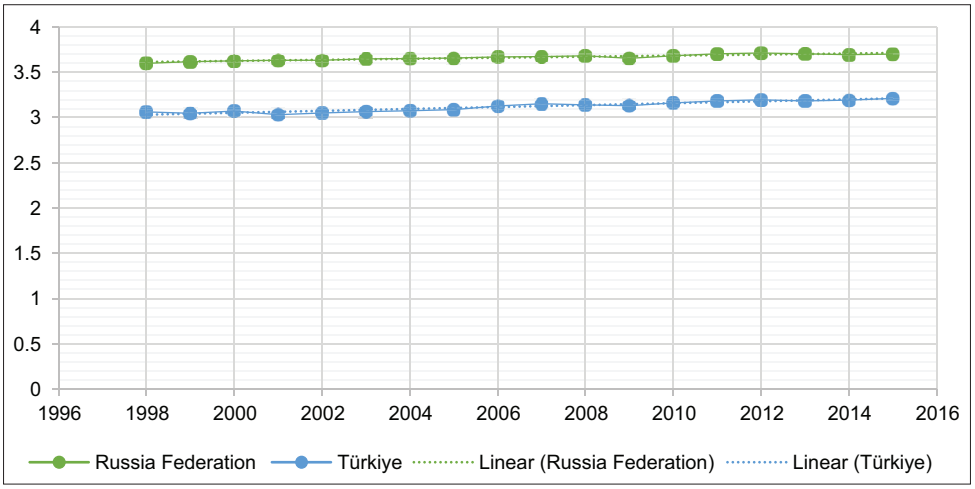


Table 1: Level values of series

	Russia			
ADF test resault	**Electricity production from coal sources**		**Energy use**	
	t-statistics	**Possibility**	**t-statistics**	**Possibility**
ADF testing statistics	−0.249754	0.9129	−1.731456	0.3989
Test critical values				
%1	−3.920350		−3.886751	
%5	−3.065585		−3.052169	
%10	−2.673459		−2.666593	
	Türkiye			
ADF test resault	**Electricity production from coal sources**		**Energy use**	
	t-statistics	**Possibility**	**t-statistics**	**Possibility**
ADF testing statistics	−2.305112	0.1814	−0.167154	0.9260
Test critical values				
%1	−3.886751		−3.886751	
%5	−3.052169		−3.052169	
%10	−2.666593		−2.666593	

ADF: Augmented Dickey-Fuller

Table 2: Stationarity level of first order series

	Russia			
ADF test resault	**Electricity production from coal sources**		**Energy use**	
	t-statistics	**Possibility**	**t-statistics**	**Possibility**
ADF testing statistics	−7.212071	0.0000	−4.302667	0.0367
Test critical values				
%1	−3.920350		−4.057910	
%5	−3.065585		−3.119910	
%10	−2.673459		−2.701103	
	Türkiye			
ADF test resault	**Electricity production from coal sources**		**Energy use**	
	t-statistics	**Possibility**	**t-statistics**	**Possibility**
ADF testing statistics	−4.161504	0.0063	−3.928256	0.0460
Test critical values				
%1	−3.920350		−3.159148	
%5	−3.065585		−3.081002	
%10	−2.673459		−2.681330	

ADF: Augmented Dickey-Fuller

Table 3: Appropriate delay length

Russia						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	13.68797	NA	0.000568	−1.798149	−1.711234	−1.816014
1	29.41979	24.20280*	9.50e-05*	−3.603045*	−3.342299*	−3.656640*
2	31.29787	2.311483	0.000141	−3.276596	−2.842019	−3.365921
3	33.62907	2.151879	0.000216	−3.019858	−2.411451	−3.144913
4	37.89155	2.623064	0.000305	−3.060239	−2.278001	−3.221024
5	42.27864	1.349872	0.000739	−3.119790	−2.163722	−3.316305
Türkiye						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	−1.207441	NA	0.005618	0.493452	0.580368	0.475587
1	14.54613	24.23626*	0.000936	−1.314789	−1.054043	−1.368384
2	15.82781	1.577460	0.001520	−0.896586	−0.462010	−0.985911
3	22.60440	6.255311	0.001176	−1.323754	−0.715347	−1.448809
4	33.42854	6.661011	0.000606	−2.373622	−1.591384	−2.534407
5	54.44727	6.467300	0.000114*	−4.991887*	−4.035819*	−5.188402*

*Indicates the appropriate lag length for the relevant test

Table 4: Granger causality test

Russia			
Hypotheses	**F-value**	**Probability value (p)**	**Decision at 1% significance level**
Electricity production from coal sources is the cause of energy use	13.43314	0.0012	
Energy use are the cause of electricity production from coal sources	2.865485	0.2387	
Türkiye			
Hypotheses	**F-value**	**Probability value (p)**	**Decision at 1% significance level**
Electricity production from coal sources is the cause of energy use	1.848123	0.3969	
Energy use are the cause of electricity production from coal sources	3.774316	0.1515	

the autocorrelation problem was eliminated in this data set. It was determined that the data used in the research were first order integrated.

The fact that the series is stationary means that it allows the application of Engle and Granger and Johansen cointegration tests, which are widely used in this field. Cointegration tests developed by Engel-Granger and Johansen were applied to examine the long-term relationship between variables.

In the test to determine the appropriate lag length for the data set, the appropriate lag length for this data set was determined as 5. Results regarding the appropriate lag length are included in Table 3.

Granger causality analysis test results on Russia and Türkiye are shown in Table 4. As can be seen from Table 4, there is a one-sided relationship from coal production to energy consumption in Russia. In other words, coal production is the cause of energy consumption in this country. When we consider the analysis for Türkiye, there is a different situation. In this country, there is no causal relationship between variables.

5. DISCUSSION AND CONCLUSION

As a result of the study conducted by Ocal et al. (2013), no causality was found in terms of the relationship between coal consumption and GDP in Türkiye. As a result of the study conducted by Sasana and Ghozali (2017), it was determined that fossil energy consumption, especially coal energy, positively and significantly affects economic growth in BRICS countries. As a result of the study conducted by Sadikova et al. (2017), it was determined that energy consumption and population growth have a positive and statistically significant effect on unemployment.

The Russian electric power industry lags behind developed countries in terms of per capita production, electric power, and household energy consumption level (Sadikova et al., 2017). It is of great importance that approximately 41 percent of Türkiye's electricity comes from coal and that renewable alternative energy sources are efficiently deployed in Türkiye's sustainable energy corridor (Ören and Şensöğüt, 2019).

In order to establish sustainable production systems without damaging natural resources, there is a need to follow a new policy that will force producers to use energy efficient practices (Erdal et al., 2007). Comparison between different forms of commercial energy production shows that the health burden is higher in coal, lignite, and oil-fired power plants, which pollute the outdoor air the most (Markandya and Wilkinson, 2007). As a result of the study conducted by Alola and Donve (2021), it was revealed that both energy mixes (coal and oil) have a harmful effect on the environment in both the short and long term, but oil consumption has a less serious impact compared to coal energy.

This study includes two countries where coal has a significant share in energy consumption. The causality between coal production and general energy consumption was measured in the countries considered as Russia and Türkiye. According to the findings

obtained as a result of the analysis, it has been determined that there is a unilateral causality relationship from coal production to energy consumption in Russia. In other words, the level of coal production in this country is also the reason for energy consumption in this country. However, when the results were examined for Türkiye, no causality relationship was found between the variables. In other words, coal production is not a cause of energy consumption in Türkiye.

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