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A COMPARATIVE STUDY OF ENERGY SECTOR'S VARIABILITY OF COUNTRIES IN THE ORGANIZATION OF TURKIC STATES

Türk Devletleri Teşkilatı Ülkelerinin Enerji Sektörü Değişkenliği Üzerine Karşılaştırmalı Bir Çalışma

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Abstract

The energy sector is critical to economic growth and development, and the ever-changing world order requires a new review of past and current trends in this area. This paper focuses on the members of the Organization of Turkic States (OTS) that share a common history, similar cultural and political perspectives, and similar national interests. While some OTS countries are net exporters of electricity energy (e.g., Azerbaijan, Kazakhstan, and Turkmenistan), others are net importers of it (e.g., Türkiye, and Hungary), and cooperation among member and observer states is growing rapidly. This paper documents the similarities and differences in energy sector variability among OTS members using a principal component analysis (PCA) of data between 1991 and 2021. Our study shows that all OTS countries are similar in terms of primary energy consumption per capita, but in terms of electricity consumption and renewable electricity per capita, Hungary and Kyrgyzstan differ from the rest of the sample. Additionally, carbon intensity varies to the same extent in Hungary, Kyrgyzstan, Turkmenistan, and Türkiye. Finally, Hungary and Kyrgyzstan have not changed their fossil fuel-based electricity generation, while Azerbaijan, Kazakhstan, and Turkmenistan show the same positive trend in electricity energy trade. The results of this study provide an integrated and methodological overview of the energy sector of the OTS countries and shed light on possible future cooperation between the member and observer countries.

Keywords: Dimension Reduction, Energy Sector, Energy Economics, Energy Transition, Organization of Turkic States (OTS), Principal Component Analysis (PCA).

1. Introduction

This study is of particular interest to energy economics, a branch of economics that deals with the production, distribution, and consumption of energy, both traditional forms of energy such as oil, coal, and natural gas, and newer forms of energy such as renewable energy sources like solar, wind, and hydropower. The number of academic papers in this field is growing exponentially, but regional foci such as the Organization of Turkic States (OTS) remain underexposed in academia. Meanwhile, OTS member and observer countries are increasing their cooperation, partnerships, and other economic interactions with the rest of the world, challenging their developments in the energy sector. On the one hand, countries such as Azerbaijan, Kazakhstan, and Turkmenistan need to supply more hydrocarbon resources to European markets after the Russo-Ukrainian war in 2022 (Abilov and Hajiyeu, 2022; Kuzmenko et al., 2022); on the other hand, as developing countries, they need to green their economies as soon as possible (Papathanasiou, 2022). New geopolitical, economic, and global processes require complex assessments of OTS countries (Mustofaev, 2022) to provide a holistic view of their energy production and consumption capacities based on integrated statistical data. Therefore, we found a visible research gap in this direction and were motivated to fill this contextual research gap.

The study of energy trends in developing countries is important for a number of reasons. First, energy is a critical factor in economic growth and development. Access to reliable and affordable energy is essential to support economic activities such as manufacturing, transportation, and agriculture. Second, developing countries often rely heavily on fossil fuels such as coal, oil, and natural gas to meet their energy needs, which can have negative environmental impacts, including air pollution and greenhouse gas emissions that contribute to climate change. Studying energy trends in developing countries can help identify opportunities to shift to cleaner, more sustainable energy sources that can reduce these negative impacts. Third, studying energy trends in developing countries can also help identify opportunities to improve energy efficiency and reduce excessive energy consumption. This can help countries save financial resources for energy costs, reduce their dependence on energy imports, and promote more sustainable economic growth. Similarly, the energy economies of OTS countries need to be analyzed and considered in future policy decisions. Therefore, studying energy trends in OTS countries is important to understand the energy needs and challenges these countries face and to identify opportunities to promote economic growth and development in a more sustainable and efficient manner.

The research question of this paper is as follows: What are the patterns of energy variability in OTS countries, and how do these patterns differ among member countries? This research question aims to identify the similarities and differences in energy variability among OTS countries and to understand how these patterns vary among members. The current research objective can be addressed through a variety of methods, such as statistical analysis of energy data or comparative case studies of individual countries within the organization. We use the principal component analysis (PCA) approach, which groups countries based on their variability in key energy indicators and reduces the number of countries to the most optimal and linearly constructed principal components.

PCA is a flexible and versatile tool that can be applied to a wide range of economic data, including financial data, macroeconomic data, and microeconomic data (Chang and McAleer, 2017). Indeed, PCA is increasingly used in economic studies (Noy et al., 2020), and OTS countries should receive more attention under this methodology. Our approach to the case study of OTS countries is novel and contributes to the literature on energy economics. Thanks to the PCA approach, we are able to show temporal and regional patterns as well as cross-country correlations in the evolution of the energy sector in OTS countries between 1991 and 2021. To the authors' knowledge, a PCA-based study of the energy sector of OTS countries has not been conducted before. In the wake of post-Covid 19 and the Russo-Ukrainian war, our findings are important and timely for state officials, think tanks, and other relevant decision makers.

This paper is organized as follows: Section 2 contains a literature review. Section 3 is devoted to the data and methodology of the study. Section 4 presents the results of the PCA of the energy sector in the OTS countries, and finally, Section 5 presents the conclusions.

2. Literature Review

There is limited research on the variability of the energy sector in the OTS countries. This section presents the main findings from these sources.

With regard to the energy sector, it is useful to divide the countries that joined the OTS into two groups: the energy-rich countries and the countries that depend on energy imports. The first group includes Azerbaijan, Kazakhstan, Uzbekistan, and Turkmenistan, which have rich hydrocarbon resources. The second group includes Hungary, Kyrgyzstan, and Türkiye, which are poor in hydrocarbon resources and obtain their energy mainly through imports.

Azerbaijan's energy mix is heavily concentrated in fossil fuels, with oil and gas accounting for more than 98% of total supply. Renewable energy, including hydropower,

contributed 2% to the total primary energy supply and 8% (2 TWh) to the electricity supply. In this context, it is necessary to diversify the domestic energy mix to gradually reduce the country's dependence on oil and gas. Azerbaijan has great potential for renewable energy development. The country has excellent solar and wind power resources and good prospects for biomass, geothermal, and hydropower. The country has committed to reducing its greenhouse gas emissions by 35% by 2030, measured against the 1990 baseline set in its national contribution under the Paris Agreement, which emphasizes the use of alternative and renewable energy sources to achieve this goal. However, practical implementation has been limited compared to the scale of available resources and the country's long-term goals (IEA, 2021a, 2021b). Also, according to Mustafayev et al. (2022), there is sufficient potential to increase the share of renewable energy in Azerbaijan. However, the potential is masked by a relatively unsound regulatory framework and a lack of expertise in the industry. Although renewable energy is a new policy area for Azerbaijan, significant progress has been made in the short time since the first laws established an early regulatory framework for renewable energy development in the country in the late 1990s. The State Program for the utilization of alternative and renewable energy sources can be considered a new step in Azerbaijan's energy policy toward the use of renewable energy sources. The establishment of the State Agency for Alternative and Renewable Energy Sources and the coordination of related activities under a central institution have shown positive effects in a short period of time (Aydın, 2019, p. 13).

Oil accounts for more than 50% of *Kazakhstan's* domestic energy production. The country's second-most important energy source is coal (28%), followed by natural gas (17%). Almost one-third of total final energy consumption was met by oil (31%), followed by coal (22%), while heat, natural gas, and electricity each accounted for about 15%. The 2013 Concept for the Transition to a Green Economy calls for the country to generate 50% of its electricity from "alternative or renewable" sources by 2050, which could include nuclear power. It also aims to reduce CO₂ emissions from electricity production by 15% by 2030 and 40% by 2050. The potential of renewable energy sources in Kazakhstan is significant, although the share of renewable energy sources in total energy supply is currently low, ranging between 1% and 2%. The country has set a target of generating 15% of its electricity from renewable energy sources by 2030, which does not include large hydropower (IEA, 2022c).

In Turkmenistan, oil and gas exports account for 85% of total exports, which is why this country is the most involved in the global energy market. Electricity is generated entirely from natural gas. The abundance of fossil fuels slows down the progress in renewable energy

investments, although they have significant potential (Pablo-Romero et al., 2020; Radanovic et al., 2021). Nonetheless, the National Socioeconomic Development Program for 2011–2030, supplemented by a shorter-term document (2019–2021), has been developed to address energy diversification; however, the documents lack actionable measures or assignment of responsibility for implementation (Laldjebaev et al, 2021).

Uzbekistan's energy production is concentrated in natural gas, but also includes oil and gas. Domestic gas production is more than sufficient to meet demand, but oil and coal are increasingly imported to meet consumption. Fossil fuels have traditionally covered almost all energy needs. Natural gas is the most important energy source, accounting for 83% of total energy supply, followed by oil (9%) and coal (6%). The contribution of renewable energy (almost exclusively hydropower) is currently modest at less than 1%. Uzbekistan has begun to rapidly build significant renewable energy capacity. The government plans to increase the share of renewables in the country's electricity supply to at least 25% by 2030. This would help ensure energy security and meet the country's climate change commitment to reduce its CO₂ emissions per GDP by 35% by 2030 (IEA, 2022d). According to Suyarov et al. (2022), Uzbekistan has a large potential for alternative energy sources, which, according to experts, is three times higher than the resources of organic non-renewable fuels, but the development process in this area is very slow.

Hungary is one of the countries with the lowest potential for energy resources in the region. Domestic energy production accounts for 45% of the total primary energy supply, which makes the country increasingly dependent on imports. Natural gas and oil are the main primary energy sources, while nuclear energy accounts for the largest share of electricity generation. Lignite (brown coal) is an important source of domestic primary energy that can be activated in the event of an energy crisis. In the early 1990s, coal production was gradually phased out as part of a system change, making Hungary dependent on imports of this raw material, mainly from the USA. Lignite mining currently amounts to 9.3 million tons per year, making the country self-sufficient in terms of energy production. It is worth mentioning that the continued use of coal is an important part of the national energy strategy until 2030. The share of renewable energy sources in the Hungarian energy sector has been slightly increasing for several years. Hungary's national energy strategy until 2030 states that 54% nuclear energy and 30% natural gas will be the country's main energy sources. After that, energy will come from renewable energy sources (16%) and coal (5%) (Kochanek, 2021). In addition, Hungary has set a 2030 target to reduce CO₂ emissions by 40% compared to 1990 and increase the share of

renewable energy in total final energy consumption to at least 21%. But today, Hungary's energy policy strategy focuses on strengthening the country's energy independence. Russia's invasion of Ukraine has created new challenges for energy security in Europe. In response, Hungary has declared an energy emergency. To address the emergency, the government plans to increase domestic gas and coal production, secure additional gas imports, and increase the output of the country's lignite-fired power plant. A possible extension of the operating life of the Paks nuclear power plant is also being discussed, while a possible ban on the export of energy sources and firewood is being considered (IEA, 2022a).

Because of its abundant water resources, hydropower is *Kyrgyzstan's* main source of energy. The country also has significant coal deposits, but oil and natural gas reserves are marginal. Hydropower accounts for two-thirds of the country's energy production. In fact, Kyrgyzstan relies on oil and gas imports to meet more than half its energy needs, especially during the winter months when hydropower production is low. The country's renewable energy is mainly hydropower (IEA, 2022b). According to Sabyrbekov and Ukueva (2019), income growth alone does not lead to a full energy transition in Kyrgyzstan. Kyrgyz households are not switching to modern fuels according to the predictions of the energy ladder hypothesis, suggesting that the Kyrgyz case is more consistent with the different fuels model. Indeed, the interviews showed that the poorest families rely on coal stoves, wealthier households use steam boilers (coal and electricity), and the wealthiest households install multi-fuel heating systems.

Türkiye's energy system is characterized by a high share of fossil fuels, which account for 83% of total primary energy supply and 73% of total final consumption. The rest comes from various renewable sources, most of which are geothermal energy and hydropower for electricity generation. While almost all of the oil and gas consumed is imported, about half of the coal and all types of renewable energy are produced domestically. Domestic energy production covers 31% of the total primary energy supply. Renewable energy production has more than doubled since 2009, while the use of traditional bioenergy for residential heating has declined. In particular, electricity production from renewable energy sources has almost tripled in the last decade, and its share in total electricity generation has reached 44%. However, Türkiye's economy continues to be driven by fossil fuels and is heavily dependent on imports, particularly oil and gas (93% and 99%, respectively). To reduce dependence on oil and gas imports, Türkiye has prioritized expanding domestic exploration and production. In addition, there is much room for Türkiye to grow even more ambitiously in renewable energy, not only in electricity but also in other sectors such as heating (IEAc, 2021). Regarding climate change,

Türkiye signed the Paris Agreement and committed to reduce greenhouse gas emissions by 21% by 2030. Although Türkiye has already achieved the 2023 targets in terms of renewable energy use, there is still a long way to go to reach the goal of reducing greenhouse gas emissions. Türkiye has officially announced that renewable energy will account for 32% of total energy consumption. However, considering the potential and success of the 2023 targets, it has been stated that the 2030 targets should be revised and increased from 32% to at least 50% (Erat et al., 2020).

Of the countries that have joined OTS, Azerbaijan, Kazakhstan, Uzbekistan, and Turkmenistan appear to have rich hydrocarbon resources and can not only meet their energy needs but also export energy. Hungary, Kyrgyzstan, and Türkiye are countries that rely on energy imports because they cannot meet their energy needs from domestic sources to any significant extent.

Research has shown that all of these countries, with the exception of Turkmenistan, have national strategies that include specific targets for renewable energy. However, in Azerbaijan, Kazakhstan, Uzbekistan, and Turkmenistan, which are rich in hydrocarbon resources, the share of renewable energy in total energy supply is negligible, and development processes in this area are relatively slow. While the development processes in the field of renewable energy are quite fast in Türkiye, which is one of the countries dependent on energy imports, the same cannot be said about Hungary and Kyrgyzstan. For various reasons, the latter two countries have not yet managed to initiate a serious turnaround in this area.

3. Data and Methodology

The data source for this study was Our World in Data, one of the largest open-source datasets. This platform integrates several trusted data sources, such as British Petroleum (BP), the International Energy Agency (IEA), etc., to present holistic indicators. For our purposes, seven indicators were collected for the energy sector between 1991 and 2021 based on seven OTS countries. Table 1 describes and defines the variables, their measures, and their specific sources.

While data on primary energy consumption per capita ranged from 1991 to 2018, data on carbon intensity of electricity, electricity from fossil fuels, and net electricity imports covered only the period between 2000 and 2021. The period for other variables was 1991–2021. The collected dataset contained some missing values, especially in the case of Kyrgyzstan, which were automatically replaced by the mean of the series for each country based on the PCA

algorithm used by the SPSS software. For example, in the case of primary energy consumption per GDP and per capita, the values for 1991, 2020, and 2021 were missing. Also, in the case of Kyrgyzstan, data on traditional electricity generation and renewable electricity generation per capita were missing for the period between 1991 and 1999. According to Kaiser (2014), the usual strategy for dealing with missing values was to replace them with series averages.

PCA is sensitive to the presence of outliers in the dataset (Jolliffe and Cadima, 2016). For this reason, the dataset was checked for the presence of outliers before applying the PCA algorithm (see Figure 1). The results showed that only two variables—primary energy consumption per capita and net electricity imports—had some outlier values, but overall, the dataset was free of overwhelming and recursive outlier values that could bias the PCA results. Therefore, no extensive preventive measures (e.g., winsorization) were taken to remove the outlier values from the dataset.

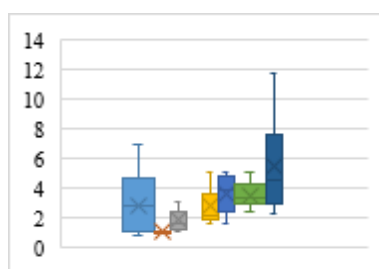
Table 1. The variables of interest used in the study.

N	Variable name	Definition	Measurement	Source
1.	Primary energy consumption per GDP	Commercially-traded fuels (coal, oil, gas), nuclear and modern renewables (excluding traditional biomass).	Terawatt-hours (TWh)	BP Statistical Review of World Energy; and EIA
2.	Primary energy consumption per capita		Kilowatt-hours per person (KWh/person)	BP Statistical Review of World Energy
3.	Electricity production	Total electricity production from fossil fuels, nuclear and renewables	Terawatt-hours (TWh).	BP Statistical Review of World Energy (2022); Ember's Global and European Electricity Reviews (2022)
4.	Carbon intensity of electricity	This indicator measures the equivalent grams of carbon dioxide released per kilowatt-hour of electricity.	Carbon dioxide-equivalents (gCO ₂ /KWh)	Ember Climate (from various sources including the European

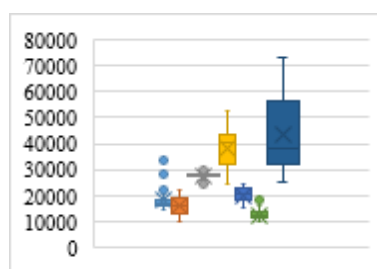
				Environment Agency and EIA)
5.	Renewable electricity per capita	This indicators consists of hydropower, solar, wind, geothermal, biomass, wave, and tidal energy.	Kilowatt-hours (KWh)	BP Statistical Review of World Energy & Ember
6.	Electricity from fossil fuels	Electricity production from coal, oil and gas sources altogether.	Terawatt-hours (TWh)	BP Statistical Review of World Energy (2022); Ember's Yearly Electricity Data (2022); European Electricity Review (2022)
7.	Net electricity imports	Net electricity imports indicator is electricity imports minus exports. Countries with positive values are net importers of electricity; negative values are net exporters.		

Source: Authors' own construction based on the analysis.

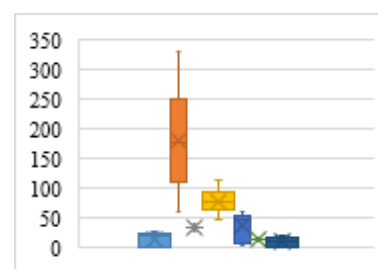
1. Primary energy consumption per GDP



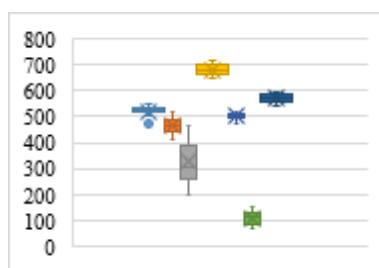
2. Primary energy consumption per capita



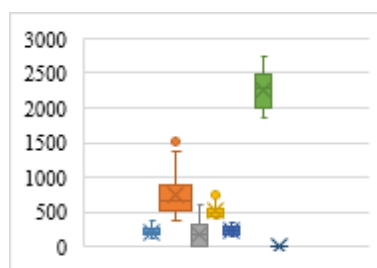
3. Electricity production from fossil fuels, nuclear and renewables



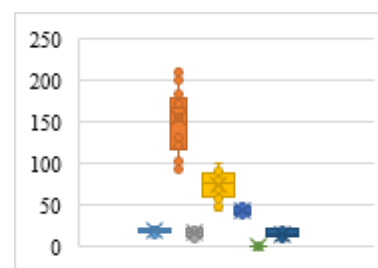
4. Carbon intensity of electricity



5. Renewable electricity per capita



6. Electricity from fossil fuels



7. Net electricity imports

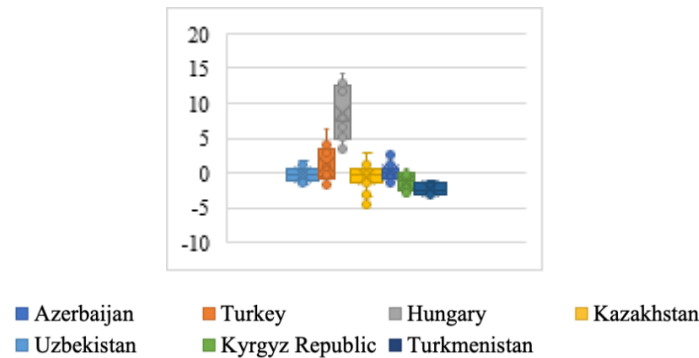


Figure 1. Boxplot Visualization of Variables for Outliers.

Source: Authors' own construction based on the analysis.

Because this dataset contained seven strongly related variables and countries, a dimensionality reduction technique was appropriate to create principal components that could reflect the similarities and differences in variation across countries. PCA is a statistical technique widely used in economics and other fields to analyze and understand complex datasets (Ringnér, 2008; Abdi and Williams, 2010). The main applications of PCA in economics include: data reduction, to identify and extract the most important variables in a dataset to reduce the complexity of the data and facilitate their analysis; dimensionality reduction, which is the process of reducing the number of variables in a dataset in order to make the relationships between variables easier to visualize and understand; selection of the most important variables in a dataset for predicting a particular outcome, such as stock price or economic growth; cluster analysis, grouping similar observations in a dataset, which allows researchers to identify patterns and trends in the data; and forecasting, which is basically identifying patterns in historical data that can be used to make predictions about future events, such as economic trends or stock prices (Abdi and Williams, 2010). Overall, PCA is a powerful tool widely used in economics to analyze and understand complex datasets and has a wide range of applications in areas such as finance, market analysis, and economic forecasting (Chang and McAleer, 2017).

To determine whether the collected dataset is suitable for PCA, the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO value) and Bartlett's test of sphericity should first be examined. Although there are no strict rules for the KMO value, researchers use 0.400 as a minimum threshold to determine whether the dataset is suitable for PCA (Tsiouni et al., 2021). Some researchers consider 0.500 as a threshold for KMO (Kalayci, 2005; Tastan and Yilmaz,

2008). This also depends on the variable types (e.g., continuous, categorical) and sample size. We mainly focused on the value of 0.500, which is quite acceptable given the nature of our study.

Then, the recommendation of the scree plot analysis was considered to establish the principal components as the standard protocol of PCA. That is, the scree plot suggests the number of principal components based on eigenvalues greater than 1. Next, we specify the average communalities. The reported average communality in this study is the average communality per OTS country. Instead of reporting each individual communality value for the countries, we averaged them to allow for compact reporting. In addition, the total variance explained shows how much of the information in the dataset is retained during the PCA process. Finally, we followed the recommendations of Corner (2009) to determine the rotation type of the PCA process. Typically, a rotation is either orthogonal (e.g., Varimax) or oblique (e.g., Direct Oblimin). However, it is usually challenging to accurately determine the rotation method. However, Corner (2009) suggests choosing Direct Oblimin first to see if the components created have a high correlation (e.g., 0.320). If the correlation is lower than the given benchmark value, then the rotational solution is orthogonal. If not, the oblique rotation should be applied. Also, in our dataset, some variables were reduced to only one principal component, so no rotation procedure is required for one-component solutions. However, if the scree plot indicates that there is more than one component, then, as mentioned above, a Direct Oblimin rotation was first performed to see if the rotation solution should be orthogonal or oblique.

Table 2 shows the KMO values and Bartlett's test of sphericity for each variable of interest, which includes all seven OTS countries. All variables exceed the threshold of 0.500 for the KMO value for sample adequacy and have statistically significant results on Bartlett's test of sphericity. The information from the scree plot shows that there are two principal components for primary energy consumption per capita, renewable electricity per capita and net electricity imports. Therefore, these variables were also rotated using the Varimax method (with Kaiser normalization). For the rest of the variables, only one principal component was created. As for the average communalities, two variables have low information retention, namely primary energy consumption per capita and carbon intensity of electricity. However, the other variables are in a relatively good position. The values for the total variance explained are high for all variables except primary energy consumption per capita.

Some other aspects of PCA as a whole should also be mentioned. First, in the Analysis section of the Extraction option of the PCA, the covariance matrix was used instead of the correlation matrix because the level of measurement of a particular variable of interest was the same for all countries. This means that all seven OTS countries were analyzed within one variable each, and all countries were included under the same variable during PCA (e.g., only “primary energy consumption per capita”). Second, the maximum iteration for convergence was left at 25, the default value normally provided by the SPSS software. Third, the principal component loadings were not stored as individual variables (a so-called new index), since our goal was not to create an index, as all counties were already grouped under a certain given variable and the main goal was to determine the similarities and differences in their variances. Therefore, we have already seen in the preliminary stages of PCA analysis that this dataset can be considered for PCA purposes, although some variables should be interpreted with caution.

Table 2. Pre-PCA assessment of the dataset.

Variable name	KMO value	Bartlett's test of sphericity	Scree plot	Average communality	Total variance explained	Rotation method
Primary energy consumption per GDP	0.620	0.000	1	0.798	89.83%	—
Primary energy consumption per capita	0.650	0.000	2	0.494	75.95%	Varimax with Kaiser normalization
Electricity production	0.624	0.000	1	0.700	96.47%	—
Carbon intensity of electricity	0.518	0.000	1	0.375	79.02%	—
Renewable electricity per capita	0.571	0.000	2	0.577	92.39%	Varimax with Kaiser normalization
Electricity from fossil fuels	0.681	0.000	1	0.739	97.37%	—
Net electricity imports	0.557	0.000	2	0.659	88.45%	Varimax with Kaiser normalization

Source: Authors' own construction based on the analysis.

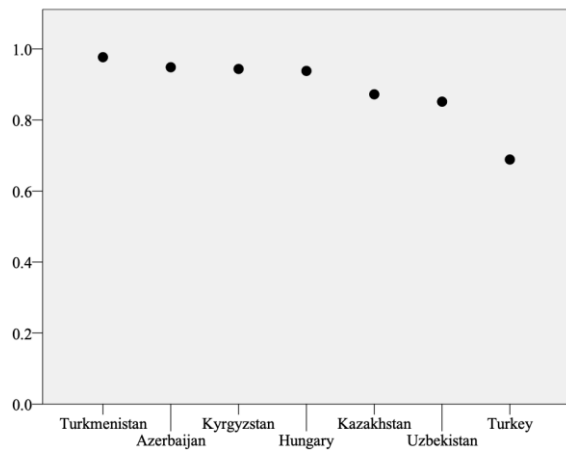
4. Results

Primary energy consumption per GDP varied similarly across the OTS countries, with the exception of Türkiye (see Figure 2, panel a). However, PCA explained primary energy consumption per capita by two principal components (see Figure 2, panel b). While Türkiye and Turkmenistan load significantly and positively on the first component, Azerbaijan and Kazakhstan load significantly and positively on the second component. Hungary and Turkmenistan, on the other hand, loaded negatively on the first component. Negative loadings for Uzbekistan and Hungary indicate a negative correlation with Turkmenistan and Türkiye. It should be noted that Kyrgyzstan and Kazakhstan behaved in a complex manner in the PCA algorithm, meaning that they had relatively high loadings on both components. This reduced the usefulness of PCA for these countries.

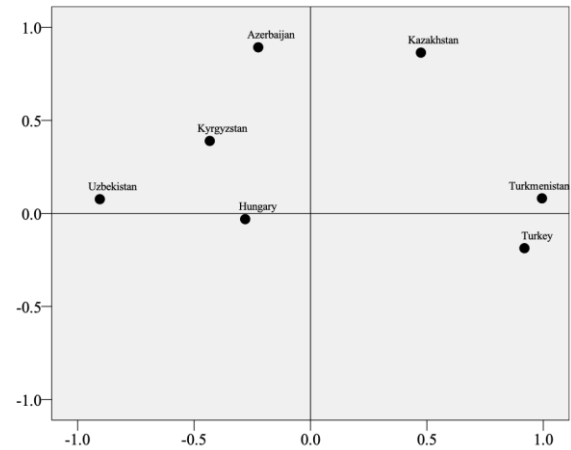
Electricity generation from fossil fuels, nuclear, and renewables showed the same variation in most OTS countries, but Hungary and Kyrgyzstan diverged noticeably from the main trend in the data (see Figure 2, panel c). Figure 2, panel d, shows that carbon intensity is similar in Hungary and Turkmenistan, Kyrgyzstan and Türkiye, and Azerbaijan and Kazakhstan. Uzbekistan loaded negatively on the only component of the PCA process related to carbon intensity of electricity.

Next, per capita renewable electricity in Kazakhstan, Türkiye, and Hungary was significantly and positively loaded on the first component, while Uzbekistan, Azerbaijan, and Turkmenistan were negatively loaded on the same component (see Figure 3, panel a). Thus, we can conclude that there is a negative correlation between the two groups of OTS countries in terms of renewable electricity generation. Kyrgyzstan, on the other hand, was an outlier country that loaded positively and significantly on the second component.

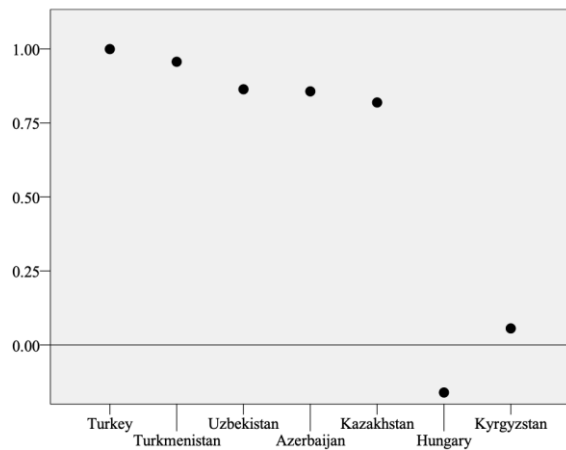
a. *Primary energy consumption per GDP.*



b. *Primary energy consumption per capita.*



c. *Electricity production from fossil fuels, nuclear and renewables*



d. *Carbon intensity of electricity*

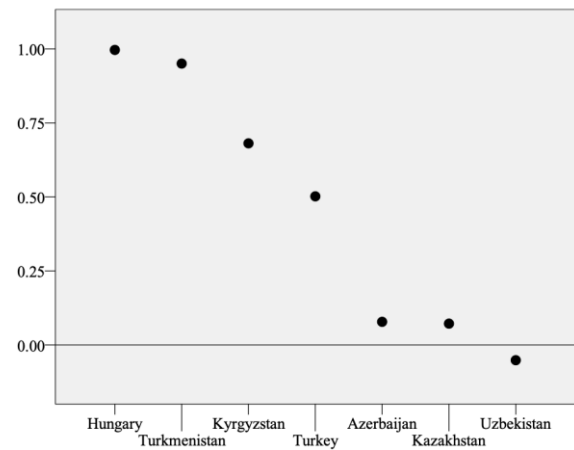


Figure 2. PCA Results of the Energy Sector in the Member Countries of the Organization of Turkic States.

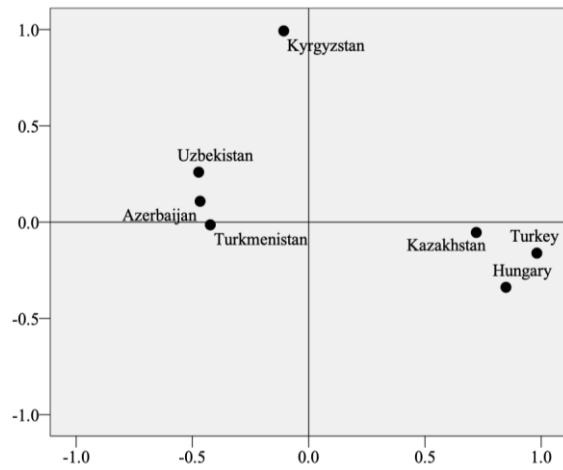
Source: Authors' own construction based on the analysis.

The OTS countries are similar in terms of electricity generation from fossil fuels, with the exception of Hungary and Kyrgyzstan, where nuclear and hydropower, respectively, account for a large share of total energy generation (see Figure 3, panel b). In Kyrgyzstan, electricity is mainly generated by hydropower plants. In Hungary, nuclear power plants play an important role, and in recent years, renewable energy sources have begun to contribute to production.

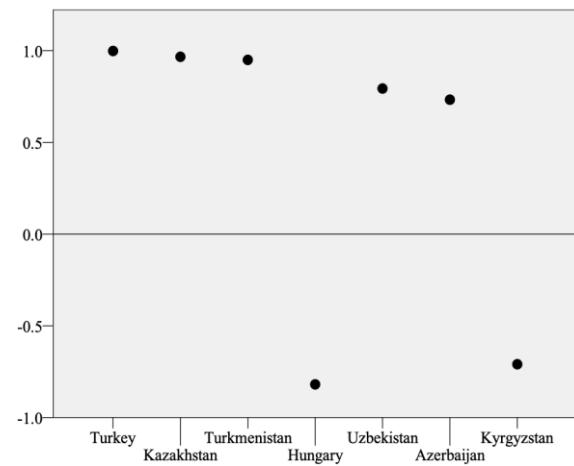
Figure 3, panel c shows that Azerbaijan, Turkmenistan, and Kazakhstan are the main exporters of electricity energy, and they also show the same trends in changes in their exports. Hungary and Kyrgyzstan were mainly net importers of electricity energy, and both countries

have increased their imports since 2011. Finally, the second principal component explains the energy trade of Türkiye and Uzbekistan, and these countries were negatively correlated in their exports and imports of electricity energy.

a. Renewable electricity per capita



b. Electricity from fossil fuels



c. Net electricity imports

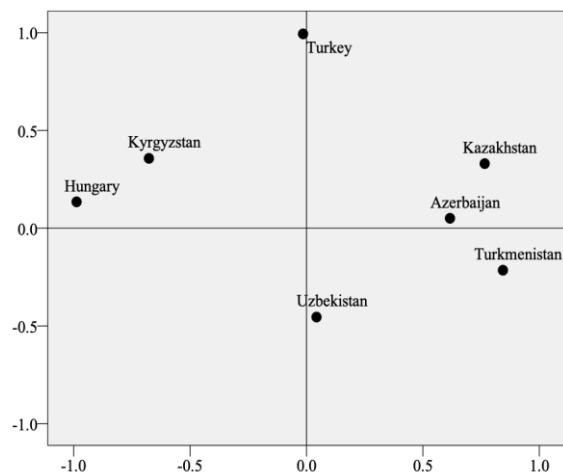


Figure 3. PCA Results of the Energy Sector in the Member Countries of the Organization of Turkic States.

Source: Authors' own construction based on the analysis.

Table 3 concludes our PCA approach for the energy sector of OTS countries. It shows that OTS countries are most similar in primary energy consumption per GDP, electricity generation, and fossil fuel electricity generation. The least similarity among OTS countries is in the primary energy consumption per capita variable. Also, Kyrgyzstan, Hungary, and Uzbekistan do not tend to enter the same clusters of variation with respect to the main

significant loadings. This makes them relative outliers in the energy sector among the OTS countries.

Table 3. Tabular representation of the similarities and differences among the the Organization of Turkic States.

Variable code	Azerbaijan	Hungary	Kazakhstan	Kyrgyzstan	Turkmenistan	Türkiye	Uzbekistan	T
1.	+	+	+	+	+	+	+	7
2.	+		+		+	+		2
3.	+		+		+	+	+	5
4.		+		+	+	+		4
5.		+	+			+		3
6.	+		+		+	+	+	5
7.	+		+		+			3
T	5	3	6	2	6	6	3	29 31

Source: Authors' own construction based on the analysis.

Notes: 1) The variable code denotes the corresponding number of the variable of interest given in the Data and Methodology section. 2) "T" denotes the total amount (frequency) of similarity between a given variable and a country. 3) The light green mark represents the first principal component. The light orange mark represents the second principal component. 4) Only significant loadings were considered.

5. Conclusion

Our study shows that primary energy consumption per GDP is quite similar in all OTS countries, with Türkiye differing slightly from the rest of the OTS countries. Primary energy consumption per capita shows three clusters, of which Turkmenistan and Türkiye form the first. The second cluster shows that Hungary, Uzbekistan, and Kyrgyzstan are similar to each other in the second group. Azerbaijan and Kazakhstan form the third group, which are similar in terms of primary energy consumption per capita. Moreover, Hungary, Kyrgyzstan, Turkmenistan, and Türkiye have the same variation in the carbon intensity of electricity in their energy sectors. In other words, compared to Azerbaijan, Kazakhstan, and Uzbekistan, the above countries show a significant downward trend in the carbon intensity of their energy sectors. Hungary and Kyrgyzstan do not show significant similarities with the other OTS countries in

terms of electricity generation from fossil fuels. In other words, Hungary and Kyrgyzstan rely mainly on nuclear and hydropower, respectively, for domestic electricity generation. Azerbaijan, Türkiye, Uzbekistan, and Turkmenistan, on the other hand, have increased their fossil fuel power generation over time and show similar variations. Ultimately, Azerbaijan, Kazakhstan, and Turkmenistan all show the same pattern of electricity energy trade (they are net exporters and are gradually increasing their export volumes), but countries such as Türkiye, Uzbekistan, Kyrgyzstan, and Hungary tend to be net importers of electricity energy.

The use of renewable energy sources is also becoming increasingly important for developing countries. Our analysis revealed two major groups in the per capita generation of electricity from renewable energy sources: the first group, which includes Kazakhstan, Türkiye, and Hungary, and the second group, which includes Uzbekistan, Azerbaijan, and Turkmenistan. While the first group loaded positively and significantly on the first principal component, the second group loaded negatively, indicating that there are two major groups in the OTS countries that are negatively correlated with each other when it comes to alternative energy production. One country, Kyrgyzstan, stands out among all OTS countries, primarily because it leads in per capita renewable electricity production. In the case of Turkmenistan, the per capita generation of electricity from renewable energy sources was zero between 2000 and 2021.

The PCA of primary energy consumption per GDP, electricity generation from fossil fuels, nuclear energy, and renewable energy, carbon intensity of electricity, and electricity from fossil fuels provided a one-component solution. The PCA of primary energy consumption per capita, renewable electricity per capita, and net imports of electricity energy provided a two-component solution. This shows that while most OTS countries have similarities in certain energy sector indicators, some indicators are more different from the others. In this case, PCA is useful to group the OTS countries according to the selected variables and can be used for further assessments.

Our results and applications are significant from a research gap perspective in several ways: first, PCA is a widely accepted and frequently used technique in many fields, including economics. It has a long history of successful applications and has been thoroughly tested and validated. Its application to organization-level economic studies is promising for a new conceptualization of organizations such as OTS, especially in the energy sector. Second, PCA can help identify and control multicollinearity. This is a common problem in economic research when there is a high correlation between different variables. This is of great importance for

energy economics research. This paper shows that PCA is a fruitful and reliable statistical tool and can improve the reliability and accuracy of economic analysis of the energy sector using OTS countries as an example. Third, this paper lays the foundation for future policy studies. The PCA has shown that the OTS countries are similar and different in terms of key energy economic indicators. Some of the countries are even very similar and have the same variation (development) in their energy sectors. They can share and exchange their energy sector development strategies, which could lead to harmonization of economic realities within the organization. Finally, the results of this study suggest that PCA is a reliable tool that OTS countries can use in a broader context.

Strategic partnerships and economic cooperation among OTS countries are becoming more intense. For example, Azerbaijan and Hungary signed several documents to strengthen the ongoing cross-country partnership in the fields of energy, culture and tourism, food security, migration, and space (Eruegur, 2023). Economic and diplomatic relations between Uzbekistan and Türkiye (Tanchum, 2022) and Kazakhstan and Kyrgyzstan (The Astana Times, 2023) are also increasing. In December 2022, possibilities for further trade relations and broader cooperation between Azerbaijan and Turkmenistan were also considered (Lmahamad, 2022). Similarly, the foreign ministers of Azerbaijan, Kazakhstan, and Türkiye met in Baku in June 2022 and decided to expand existing agreements and conclude new ones to further promote regional connectivity and cooperation among the three countries (Karimli, 2022). Southeast Asian countries and China are stepping up efforts to work with Kazakhstan, Azerbaijan, Georgia, and Türkiye to reach out to Europe. These countries are determined to fully exploit the potential of the Trans-Caspian East-West Middle Corridor. All this points to a new momentum among the OTS countries in integrating and developing their economies.

Some limitations in both the methodology we used and the study itself should also be noted. First, PCA is an unsupervised technique, which means that it does not account for known or flagged outcomes in the data. This can make it difficult to interpret the results of PCA, especially if the variables in the dataset are not well understood. Second, PCA is sensitive to the presence of outliers in the data. Outliers can have a disproportionate impact on PCA results, which can lead to misleading results. However, our dataset contained only a handful of outlier values, which cannot significantly bias the results. Third, PCA is not always the most appropriate technique for every dataset. There are other dimensionality reduction techniques that may be more appropriate for certain types of data or research questions and designs. For example, multidimensional correspondence analysis can also be used to assess the comparative

performance of OTS countries in their energy sector. In addition, future studies could focus on qualitative methods (e.g., qualitative comparative analysis, expert interviews, grounded theory) to shed light on the underexposed realities of the energy sector in OTS countries.

Ultimately, as Mustofaev (2022) puts it, “finding appropriate solutions to global problems based on the historical civilizational roots of the Turkish people and the persistence of the existing political will of the Turkish states will remain a key factor in determining the future fate of the OTS.” Energy and food security are the cornerstones of sustainable economic growth and the creation of progressively higher added value for the prosperity and well-being of the vast majority of societies. Differences can be reduced and commonalities leveraged for more intensive energy development cooperation to achieve remarkable economic growth. Studies such as the current one can improve our understanding of energy security and shed light on further policy collaborations.

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