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Analysis of the Contribution of Energy, Industry, Agriculture and Food Production to Improving the Quality of Life of Citizens in Turkic States with Efficiency and Super Efficiency Analysis Methods

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ABSTRACT

One of the main goals of countries is to increase the welfare and quality of life of their citizens by using their existing wealth and production. This study aims to analyze the contribution of energy, industry, agriculture, and food production towards improving the quality of life for citizens in the Turkic States. Specifically, the study will use the efficiency and super efficiency analysis methods, known as data envelopment analysis, to analyze the years between 2017 and 2022. According to the findings, Turkic States showed successful management in terms of GDP and health quality in 2019 and 2020. In 2021, only Kazakhstan and Turkmenistan remained below the effective limit. The efficiency analysis model for input showed that the efficiency in the energy production input variable for Kazakhstan is very low (83.9% idle capacity). The findings revealed a point of criticism since efficiency analysis assigns higher efficiency score values to countries that produce output with less input. Thus, testing the findings obtained by comparing efficiency analysis with different input-output models and analysis methods is considered an important methodological approach.

Keywords: Data Envelopment Analysis, Super Efficiency, Energy Production, Industrial Production, Agricultural Production
JEL Classifications: C13, C20, C22

1. INTRODUCTION

Azerbaijan, Kazakhstan, Uzbekistan, Kyrgyzstan, and Turkmenistan, countries that gained independence after the dissolution of the Union of Soviet Socialist Republics in 1991 after a long Cold War period, stepped into a completely new era both politically and economically. After giving up on the planned economic structure before their independence, the Turkic States underwent significant political and economic changes to transition to a free market economy, driven by their internal dynamics. The primary purpose of these radical changes was to increase the people's welfare and living standards by integrating into world markets. This restructuring process in the economy of the newly independent states from the Soviet Union is known as the "transition economy/period" (Niyetalina et al., 2023). During the transition period, each country adopted different strategies based on its natural resources and industrial infrastructure. However, except for Kyrgyzstan, most countries relied primarily on exporting raw materials and natural resources for economic development. In Azerbaijan and Kazakhstan, oil and gas drive economic growth and trade while Uzbekistan relies on oil, gas, and gold, and Turkmenistan depends on natural gas. Although

Kyrgyzstan lacks natural resources such as gas, oil, and gold, it has shown impressive economic growth, thanks in part to remittances from its citizens working abroad. Since independence, Turkic States faced internal and external economic difficulties, including the 1998 Asian Crisis, the 2007-2008 Global Economic Crisis, and the Covid-19 pandemic, which negatively impacted their economies. Despite the difficulties, the Turkic States have made significant progress in terms of foreign trade, development, welfare, economic growth, and living standards over the past 30 years. The countries have been able to overcome the economic difficulties faced during the early years of independence. And since the 2000s, there has been an increase in GDP and living standards (Jie et al., 2024). However these economies are heavily reliant on natural gas and oil exports, and that makes them vulnerable to price fluctuations in natural resources.

1.1. Azerbaijan

Azerbaijan declared its independence on October 18, 1991, after the dissolution of the USSR. The country then underwent significant structural reforms to transition into a free-market economy (Aydin and Uste, 2022). In addition to the problems caused by the ongoing transition period, the occupation of Nagorno-Karabakh by Armenia has led to new social and economic challenges in Azerbaijan. Azerbaijan, which is the second-largest oil and natural gas producer among the Turkic States after Kazakhstan, has 7 billion barrels of oil and approximately 2.5 trillion cubic meters of natural gas reserves. These reserves correspond to approximately 0.6% of the world's oil reserves. These natural gas and oil resources were key to Azerbaijan's economic development and improved living standards (Zulfigarov and Neuenkirch, 2020).

1.2. Kazakhstan

Kazakhstan declared its independence on December 16, 1991, after the collapse of the USSR. Like other ex-Soviet countries, Kazakhstan underwent significant structural reforms to ensure economic development by transitioning to a free market economy (Taibek et al., 2023; Bekzhanova et al., 2023; Kelesbayev et al., 2020). Kazakhstan is a country that has abundant natural resources. It possesses around 3% of the world's total oil reserves, approximately 1.1% of natural gas reserves, and roughly 3.3% of coal reserves (Baimaganbetov et al., 2019; Syzdykova et al., 2019). Moreover, it is the second-largest country in the world in terms of uranium reserves. Thanks to its abundant natural resources, Kazakhstan was able to transition to a free market economy with relative ease (Mudarissov and Lee, 2014; Xiong et al., 2015; Bolganbayev et al., 2021; Kelesbayev et al., 2022a; Mashirova et al., 2023). Since gaining independence, Kazakhstan has implemented structural reforms and investments that have contributed to significant economic growth. As a result, the country has become a major player among other developing nations. Kazakhstan's GDP now ranks second within the CIS, after Russia (Sabenova et al., 2023; Sartbayeva et al., 2023; Mukhtarov et al., 2020; Kelesbayev et al., 2022b). This is also apparent in the remarkable rise in living standards in Kazakhstan.

1.3. Turkmenistan

Turkmenistan declared independence on October 27, 1991, and implemented radical reforms for economic growth during the transition to a free market economy (Atai and Azizi, 2012). The government eliminated price controls on certain goods, incentivized the creation of private farms, and implemented regulations that aligned with the principles of a free market economy in the financial system. New regulations have been introduced in Turkmenistan's monetary policy and privatization sectors to attract foreign investments (Jie et al., 2024). Its rich oil and natural gas reserves, which rank fourth in the world for natural gas production, have played a significant role in its economic success (Wang et al., 2024).

1.4. Uzbekistan

After the dissolution of the USSR, Uzbekistan declared its independence on August 31, 1991. Like other Turkic States, it implemented structural changes to stabilize and expand its economy. Uzbekistan has implemented slightly different regulations compared to other Turkic States. Despite being poor in natural gas and oil reserves compared to Kazakhstan, Azerbaijan, and Turkmenistan, Uzbekistan is still in a much better situation than Kyrgyzstan (Putz, 2017). In addition to significant natural gas, oil, and coal reserves, Uzbekistan is also a major producer of gold and uranium (Wang et al., 2024). As in other Turkic States, Uzbekistan started to see the positive results of economic reforms in the 2000s. In recent years, Uzbekistan has received financial relief through cooperation with international financial institutions such as the World Bank, IMF, and European Bank for Reconstruction (Jie et al., 2024). The transition to a free market economy after independence resulted in Uzbekistan's economic development and increased GDP, which in turn improved living standards.

1.5. Kyrgyzstan

Kyrgyzstan declared its independence on August 31, 1991, after the dissolution of the USSR, and is the smallest country in Central Asia. Unlike other Turkic States, Kyrgyzstan doesn't have abundant natural resources such as natural gas and oil. Kyrgyzstan has implemented structural reforms necessary for the transition to a free market economy. It was the first country among the states that gained independence to print national currency and the first to become a member of the World Trade Organization. Kyrgyzstan's economy is comparatively in a worse situation due to its lack of natural resources such as natural gas and oil. Kyrgyzstan produces 90% of its energy from hydroelectric power plants and has the lowest GDP rate among the Turkic States (Wang et al., 2024). Lack of natural resources and weak industrial infrastructure have led to worker migration from Kyrgyzstan to other countries, especially Russia. Therefore remittances sent by these workers have a crucial place in the Kyrgyzstan economy.

The concept of quality of life has become a crucial universal goal for modern societies. It is closely linked to Maslow's (1970) hierarchy of needs, which highlights the importance of meeting basic needs before moving on to higher ones. It is concerned with an individual's subjective sense of satisfaction with their life and takes into account both the quantity and the quality of the needs. However, the concept was first mentioned in Long's article "On the Quantity and Quality of Life" published in 1960. Quality of life, along with human rights, has become an important indicator in making all political decisions and has become a universal goal that societies aim to achieve in some way (Verdugo and Schalock, 2024). For this study, the selected output variables were income (GDP) and health (per capita health expenditure), as these are considered the most significant indicators of quality of life. The input variables of the research, namely energy, industry, agriculture, and food production, play an indisputable role in the economic development and welfare level of countries. They also contribute significantly to the increase in countries' GDP and per capita health expenditures, which are important indicators of the quality of life.

This study analyzes the contribution of energy, industry, agriculture, and food production to the citizens' quality of life in the five ex-Soviet Turkic States i.e., Azerbaijan, Kazakhstan, Turkmenistan, Uzbekistan, and Kyrgyzstan. The study uses the Data Envelopment Analysis method and examines the 2017-2022 period. Electricity production data is used as a proxy for energy production data. The research data is obtained from the websites https://www.imf.org/, https://ourworldindata.org/, and https://datacatalog.worldbank.

2. LITERATURE REVIEW

In their 2016 article titled "Measuring Economic Growth Using Data Envelopment Analysis," Škare and Rabar (2016) summarize the extensive literature that applies data envelopment analysis as a non-parametric approach to measuring macroeconomic efficiency. The authors also identify the key factors that most affect macroeconomic efficiency, along with the magnitude of their effects. They also emphasized the importance of the non-parametric approach in macroeconomic efficiency analysis and offered a more comprehensive perspective on the subject.

In Lábaj et al. (2014) and his colleagues conducted a study titled "Data Envelopment Analysis for Measuring Economic Growth in Terms of Welfare Beyond GDP." The study aimed to demonstrate the benefits of using non-parametric approaches and extended DEA models in situations involving multiple inputs and outputs. After evaluating efficiency measurement methods, they expanded their RIA models to include social performance, known as eco-efficiency. They used the developed model to evaluate the policy scenarios for thirty European countries in 2010 and concluded that the proposed models could be used for intertemporal analysis.

In their study titled "Economic Complexity and Human Development: Comparing Standard and Slack-Based Data Envelopment Analysis Models," Ferraz et al. (2023) sought to compare the effectiveness of standard models with SBM DEA models in measuring countries' ability to transform economic complexity into human development. For this, they developed the Composite Index of Human Development and Economic Complexity (CIHD-EC) and analyzed 50 countries with 2013 data. They found that standard models overestimate the effectiveness of developed and prosperous countries, but the SBM model provides a better ranking. They also found that CIHD-EC is the only model that effectively transforms Singapore's economic complexity into human development.

Without changing the secondary conditions for the use of DEA on direct observational data, Banker et al. (1984) made a distinction between technical efficiency and scale efficiency with the new model they developed in their study titled "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis." Technical inefficiencies are characterized by the failure to achieve the best possible output levels and/or the use of excessive input. This study provides information about methods to determine the magnitude of these inefficiencies and correct them. They defined a new discrete variable to determine whether operations are conducted in regions with increasing, constant, or decreasing returns (in multiple input and multiple output situations). While evaluating the results, they related them not only to classical (single-output) economic theories but also to more modern "controversial market theories."

In 2020 Matsumoto et al. (2020) published a study titled "Evaluating environmental performance using data envelopment analysis: The case of European countries." This research assessed the environmental performance of European Union (EU) nations through the data envelopment analysis (DEA) method and the global Malmquist-Luenberger index. A key contribution of this study was the inclusion of various undesirable outputs and the utilization of long-term panel data from EU countries. Specifically, the DEA window analysis technique was employed to analyze the environmental performance of 27 EU countries using both cross-sectional and time-varying data from 2000 to 2017. Three DEA models were investigated, employing labor, capital, and energy as common inputs, alongside a range of outputs such as gross domestic product, carbon dioxide emissions, particulate matter emissions, and waste. The findings indicated that the trends in environmental performance for both the EU as a whole and its individual member states were consistent across all models examined. Additionally, the analysis with the global Malmquist-Luenberger index demonstrated that, overall, EU countries saw an improvement in efficiency during the study period, despite some observed fluctuations.

Verdugo and Schalock (2024) classified quality of life indicators under various headings i.e., gender, age, marital status, social support, housing and its features, health, education, income, work life, leisure activities. They also provided information about the literature on these indicators. Research has found that certain factors can significantly reduce the quality of life. These include being a woman, being elderly, being a widow or divorced, having a low level of education, having a low income, having weak social support, inadequate housing, chronic and/or chronic illness, low job satisfaction, lack of leisure time activities, and inadequate health.

Charnes et al. (1978) in their study "Measuring the efficiency of decision-making units," focused on a "nonlinear (nonconvex) programming model" that provides a framework for evaluating the participation of non-profit organizations in public programs. They also provided a measure to evaluate the effectiveness of each participating unit. This measure includes methods to determine multiple outputs and multiple inputs objectively. This nonlinear model is introduced by establishing equivalences to ordinary linear programming models to perform calculations. Furthermore, the secondaries of these linear programming models have offered a new method for estimating extreme relationships from observation data. In these studies, the connections between engineering and economic approaches were highlighted. New interpretations and methods for evaluating effectiveness and controlling managerial behavior were presented.

In a study titled "Developing a sustainable development goals index for OECD countries: An effectiveness-based hierarchical data envelopment analysis" Guo et al. (2024) used effectiveness-based hierarchical data envelopment analysis method for developing a sustainable development goals index for OECD countries. The primary goal of this paper is to develop an SDG index for organisation for economic co-operation and development (OECD) countries using an effectiveness-based hierarchical data envelopment analysis (H-DEA) model, which will be applied to evaluate SDG effectiveness across these nations. The findings of this study offer countries valuable insights derived from the weights of the goals (indicators) that are inherent to the dataset, helping them pinpoint priorities and strategies to enhance their future SDG performance.

In a study titled "A data envelopment analysis game theory approach for constructing composite indicator: An application to find out development degree of cities in West Azarbaijan province of Iran" Omrani et al. (2020) used data envelopment analysis game theory approach to find out development degree of cities in West Azarbaijan province of Iran and for constructing composite indicator. This paper employs a game theory approach to enhance the distinguishing capability of the DEA model and identify fair weights within the context of cross-efficiency DEA. The DEA-Game theory method is utilized to rank cities in the West Azarbaijan province of Iran. Initially, 68 relevant indicators are identified and subsequently organized into 10 categories. Actual data from 2013 is then collected, and the DEA-game theory model is implemented. To validate the DEA-game theory approach, the results are compared with those obtained from the simple additive weighting (SAW) and TOPSIS methods. The Spearman correlation analysis among the DEA-game, SAW, and TOPSIS models indicates that the DEA-game theory model is effective for constructing composite indicators.

In a research study titled "Super-efficiency and Stability Intervals in Additive DEA" Gouveia et al. (2013) approached the problem of determining the efficiency range of each decision making unit (DMU) using uncertain data. The study used a two-stage additive data envelopment analysis (DEA) model for performance evaluation, which incorporated the concept of super-efficiency to enable robustness analysis of DMUs in the face of uncertain information. To capture the uncertainty in the DMU coefficients on each factor (input or output), the study used range coefficients. The authors classified each DMU as definitely efficient, potentially efficient, or definitely inefficient for specified uncertainty ranges. Additionally, the study presented how to calculate the maximum stability hyper-polygon for each DMU, thereby contributing to the academic literature.

In their 2018 study titled "Examining the Environmental Performance of OECD Countries through Data Envelopment Analysis," Aksu and Gencer (2018) analyzed the environmental performance of OECD countries using the current environmental performance index data. They specifically evaluated Turkey's situation among these countries. Since multiple output variables were included in the analysis, they used data envelopment analysis to calculate performance activities and used the EMS 1.03 package program for the efficiency analysis of the data. To control the output variables, they used the output-oriented CCR model. Based on their research findings, they conducted analyses and made recommendations for effective and ineffective countries.

In their 2023 study entitled "Examining the impact of the COVID-19 pandemic on container carrier performance" Hwang and Joo (2023) analyzed the impact of COVİD-19 pandemic on on container carrier performance. This study aims to analyze the effects of the pandemic on the performance of 26 major container shipping companies. To assess performance variations before and during the pandemic, we gathered data from the years 2019 to 2020. We categorized the carriers' business processes into two phases: Asset acquisitions and transportation operations. Relevant data envelopment analysis (DEA) models were utilized for this analysis. The average efficiency score in 2020 surpassed that of 2019, indicating that container carriers generally enhanced their performance during the COVID-19 pandemic. However, seven companies experienced a decline in efficiency in 2020. Likewise, eight companies operated efficiently but struggled with their asset acquisition strategies. The findings highlight the significance of firm strategy in responding to external disruptions.

3. METHODS

The concept of effectiveness is a performance criterion that determines the degree to which an institution or business achieves its defined goals as a direct result of its activities and investments (Youcef and Nils, 2017). Efficiency, in the most general terms, can be defined as producing the most output using available inputs or using the least amount of inputs to produce a particular output. The efficiency analysis method was introduced with an article called data envelopment analysis (DEA) by Charnes, Cooper, and Rhodes published in EJOR in 1978. The method was developed based on Farrell's concept of frontier production functions.

EA is a non-parametric technique based on linear programming principles, designed to measure the relative effectiveness of "Decision Making Units" (DMUs) that produce the same outputs using the same inputs. The method has guiding comments about the actions that need to be taken to bring ineffective decision units to an effective position. And this has further increased the importance of the method.

The effectiveness analysis is widely used to examine the effectiveness of countries, health institutions, educational institutions, and similar public institutions within a country. It is used to analyze the economic activities of countries (Matsumoto et al., 2020), to evaluate the environmental and waste management performance (Amirteimoori et al., 2023), to compare medical tourism activities of countries (George and George, 2023), and to conduct a comparative analysis of resource use activities of EU countries and candidate countries (Matsumoto et al., 2020).

EA consists of two stages. The first is to identify effective and ineffective decision units, and the second is to identify actions that can be taken to turn ineffective decision units into effective ones (improvements). In input analysis, "improvement" refers to the reduction in input variables that can be achieved while keeping the output constant. In contrast, output analysis defines "improvement" as the increase in output that can be obtained with the same input variables.

The super-efficiency model was developed by Andersen and Petersen (1993) and is based on the CCR model (Yang and Zhao, 2010). In this model, efficiency scores do not change for ineffective decision units. Only the scores of the active decision units change (Ren et al., 2024). The mathematical structure of the activity models used in this study is given below.

Input-oriented CCR model:

$$\min_{\theta,\lambda,s^+,^-} \quad z_0 = \theta - \varepsilon \vec{1} s^+ - \varepsilon \vec{1} s^-$$
$$s.t. \quad Y\lambda - s^+ = Y_0$$
$$\theta X_0 - X\lambda - s^- = 0$$
$$\lambda, s^+, s^- \geq 0$$

Output-oriented CCR model:

$$\max_{\varphi,\lambda,s^+,s^-} \quad z_0 = \varphi + \varepsilon \vec{1} s^+ + \varepsilon \vec{1} s^-$$
$$s.t. \quad X\lambda + s^- = X_0$$
$$\varphi Y_0 - Y\lambda + s^+ = 0$$
$$\lambda, s^+, s^- \geq 0$$

Input-oriented CCR super-efficiency model:

$$\min_{\theta,\lambda,s^+,^-} \quad z_0 = \theta - \varepsilon \vec{1} s^+ - \varepsilon \vec{1} s^-$$
$$s.t. \quad Y\lambda - s^+ = Y_0$$
$$\theta X_0 - X\lambda - s^- = 0$$
$$\lambda, s^+, s^- \geq 0;\ j \neq j_0$$

Output-oriented CCR super-efficiency model:

$$\max_{\varphi,\lambda,s^+,s^-} \quad z_0 = \varphi + \varepsilon \vec{1} s^+ + \varepsilon \vec{1} s^-$$
$$s.t. \quad X\lambda + s^- = X_0$$
$$\varphi Y_0 - Y\lambda + s^+ = 0$$
$$\lambda, s^+, s^- \geq 0 \quad j \neq j_0$$

While the φ variable gives the efficiency value of the DMU in the input-oriented model, the θ variable gives the efficiency value of the KVB in the output-oriented model. While the θ variable shows how much the inputs should be reduced proportionally, the φ variable shows how much the outputs should be increased proportionally. In the input-oriented model, the theoretical unit for the inactive decision is obtained with the equation below.

$$\hat{X} = \theta X - s^-$$
$$\hat{Y} = Y + s^+$$

Whereas in the output-oriented model, the theoretical unit for the inactive decision is obtained with the equation below.

$$\hat{X} = X - s^-$$
$$\hat{Y} = \varphi Y + s^+$$

This study analyzed the effectiveness of countries with the CCR model, a total efficiency scale analysis model for decision units (Amani et al., 2018).

4. FINDINGS

This study conducted efficiency analysis for the Turkic States using energy production, industrial production, and agricultural production as input variables, and per capita national income and health expenditures as output variables. Annual electricity production was used as a proxy for national energy production, and industrial and agricultural production as a proxy for the industrial production index. Variables and country codes are given in Table 1. The research data is obtained from the websites https://ourworldindata.org, https://w3.unece.org, https://www.imf.org, and https://data.worldbank.org (Date of access: March 10, 2024). Data for 2017-2022 were analyzed to determine differences in country activities by year.

Table 2 presents the results of four different models that were used to analyze the effectiveness of countries in 2017. In the first stage, an efficiency analysis was conducted to calculate the efficiency scores of the countries. In the second stage, the super efficiency scores were calculated, and the countries were ranked based on their efficiency. According to the analysis, Kyrgyzstan and Turkmenistan were found to be effective in both input-oriented and output-oriented analysis, while Azerbaijan, Kazakhstan, and Uzbekistan were found to be ineffective. In the input-oriented model, Azerbaijan's efficiency score was calculated to be 0.975, Kazakhstan's efficiency score was 0.955, and Uzbekistan's efficiency score was 0.933. This means that 97.5% of Azerbaijan's current inputs, 95.5% of Kazakhstan's, and 93.3% of Uzbekistan's inputs are sufficient to produce the current output. In other words, Azerbaijan, Kazakhstan, and Uzbekistan have idle capacities of 2.5%, 4.5%, and 6.7%, respectively. When the output-oriented is evaluated, Azerbaijan received a score of 1.026, Kazakhstan received a score of 1.047, and Uzbekistan received a score of 1.072. This means that Azerbaijan, Kazakhstan, and Uzbekistan should increase their output by 2.6%, 7.7%, and 7.2%, respectively. Furthermore, according to the super efficiency analysis conducted in the second stage to determine the success rankings of the countries, Kyrgyzstan was found to be the most successful, followed by Turkmenistan, Azerbaijan, Kazakhstan, and Uzbekistan, respectively.

Table 3 presents the results of four separate models that were used to determine the effectiveness of countries in 2018. The first stage involved an efficiency analysis where the efficiency scores of the countries were calculated. In the second stage, super efficiency scores were calculated, and the countries were ranked according to their efficiency. The efficiency analysis found that all five countries

Table 1: Research variables and descriptions

Code	Country	Variable	Description
AZE	Azerbaijan	ENGEN	Electricity generation
KAZ	Kazakhstan	INDPRO	Industrial production index 2010=100
KGZ	Kyrgyzstan	GDP	Gross domestic product; constant prices - percent change
TKM	Turkmenistan	HLEX	Current health expenditure per capita (current US$)
UZB	Uzbekistan	CRPRO	Crop production index (2014-2016=100)

were effective in both input-oriented and output-oriented analysis. This means that the countries were successful in producing output using input resources in 2018. In the second stage, the super efficiency analysis was conducted to determine the success rankings of the countries. According to the results, Kyrgyzstan was the most successful country, followed by Uzbekistan, Turkmenistan, Kazakhstan, and Azerbaijan, respectively.

Table 4 presents four different models that were used to assess the effectiveness of various countries in 2019. The first stage involved conducting an efficiency analysis to calculate the efficiency scores of each country. In the second stage, the super efficiency scores were calculated and the countries were ranked according to their efficiency. Based on the efficiency analysis conducted, all five countries were found to be effective in both input-oriented and output-oriented analysis in 2019. This implies that these countries were successful in producing output with the given input resources. In the second stage, a super-efficiency analysis was conducted to determine the success rankings of the countries. Following the analysis, Kyrgyzstan was found to be the most successful country, followed by Uzbekistan in second place, Azerbaijan in third place, Kazakhstan in fourth place, and Turkmenistan in fifth place.

Table 5 presents the results of analyzing four different models to determine the effectiveness of countries in 2020. The analysis involved two stages. In the first stage, efficiency analysis was conducted to calculate efficiency scores for each country. In the second stage, super-efficiency scores were determined, and a ranking was created based on the countries' efficiency levels. The analysis revealed that all five countries in question were found to be effective in both input-oriented and output-oriented analysis. Therefore, countries were able to effectively utilize their resources to produce output in 2020. A super-efficiency analysis was conducted in the second stage to determine the success rankings of the countries. As per the analysis, Kyrgyzstan was the most successful country, followed by Azerbaijan in second place, Turkmenistan in third place, Kazakhstan in fourth place, and Kyrgyzstan again in fifth place.

Table 6 presents the analysis of four different models that measure the effectiveness of countries in 2021. In the first stage, an efficiency analysis was conducted to calculate the efficiency scores of each country. In the second stage, super efficiency scores were calculated and the countries were ranked based on their efficiency. Azerbaijan, Kyrgyzstan, and Uzbekistan were found to be effective

Table 2: Efficiency analysis findings of countries for 2017

Country	Efficiency score for the input	Super efficiency score and ranking for the input	Efficiency score for the output	Super efficiency score and ranking for the output
AZE	0.975	0.975 (3)	1.026	1.026 (3)
KAZ	0.955	0.955 (4)	1.047	1.047 (4)
KGZ	1	1.444 (1)	1	0.693 (1)
TKM	1	1.106 (2)	1	0.905 (2)
UZB	0.933	0.933 (5)	1.072	1.072 (5)

Table 3: Efficiency analysis findings of countries for 2018

Country	Efficiency score for the input	Super efficiency score and ranking for the input	Efficiency score for the output	Super efficiency score and ranking for the output
AZE	1	1.148 (5)	1	0.871 (5)
KAZ	1	1.247 (4)	1	0.802 (4)
KGZ	1	2.614 (1)	1	0.383 (1)
TKM	1	1.274 (3)	1	0.785 (3)
UZB	1	1.939 (2)	1	0.516 (2)

Table 4: Efficiency analysis findings of countries for 2019

Country	Efficiency score for the input	Super efficiency score and ranking for the input	Efficiency score for the output	Super efficiency score and ranking for the output
AZE	1	1.464 (3)	1	0.683 (3)
KAZ	1	1.294 (4)	1	0.773 (4)
KGZ	1	3.075 (1)	1	0.325 (1)
TKM	1	1.049 (5)	1	0.953 (5)
UZB	1	1.492 (2)	1	0.670 (2)

Table 5: Efficiency analysis findings of countries for 2020

Country	Efficiency score for the input	Super efficiency score and ranking for the input	Efficiency score for the output	Super efficiency score and ranking for the output
AZE	1	1.836 (2)	1	0.545 (2)
KAZ	1	1.070 (5)	1	0.934 (5)
KGZ	1	1.196 (4)	1	0.836 (4)
TKM	1	1.476 (3)	1	0.677 (3)
UZB	1	2.106 (1)	1	0.475 (1)

in both input-oriented and output-oriented analyses. On the other hand, Kazakhstan and Turkmenistan were considered ineffective. According to the input-oriented model, Kazakhstan's efficiency score is 0.814, while Turkmenistan's efficiency score is 0.907. This result indicates that 81.4% of Kazakhstan's current inputs and 90.7% of Turkmenistan's inputs are sufficient to produce the current output. In simpler terms, it means that Kazakhstan has 18.6% idle capacity, while Turkmenistan has 9.3%. When we evaluate the output-oriented efficiency analysis model, we see that Kazakhstan's efficiency score is 1.229, while Turkmenistan's efficiency score is 1.103. It has been determined that with the current input values, Kazakhstan needs to increase its output by 22.9%, and Turkmenistan needs to increase its output by 10.3%. The success rankings of the countries were obtained through a super-efficiency analysis conducted in the second stage. According to this analysis, the top five countries in terms of success ranking are Uzbekistan, Azerbaijan, Kyrgyzstan, Turkmenistan, and Kazakhstan.

Table 7 presents the analysis of four different models that measure the effectiveness of countries in 2022. In the first stage, an efficiency analysis was conducted to calculate the efficiency scores of each country. In the second stage, super efficiency scores were calculated and the countries were ranked based on their efficiency. Azerbaijan, Kyrgyzstan, and Uzbekistan were found to be effective in both input-oriented and output-oriented analyses. On the other hand, Kazakhstan and Turkmenistan were considered ineffective. According to the input-oriented model, Kazakhstan's efficiency score is 0.721, while Turkmenistan's efficiency score is 0.936. This result indicates that 72.1% of Kazakhstan's current inputs and 93.6% of Turkmenistan's inputs are sufficient to produce the current output. In simpler terms, it means that Kazakhstan has 27.9% idle capacity, while Turkmenistan has 6.4%. When we evaluate the output-oriented efficiency analysis model, we see that Kazakhstan's efficiency score is 1.387, while Turkmenistan's efficiency score is 1.068. It has been determined that with the current input values, Kazakhstan needs to increase its output by 22.9%, and Turkmenistan needs to increase its output by 6.8%. The success rankings of the countries were obtained through a super-efficiency analysis conducted in the second stage. According to this analysis, the top five countries in terms of success ranking are Kyrgyzstan, Azerbaijan, Uzbekistan, Turkmenistan, and Kazakhstan.

Table 8 presents the results of the input analysis of inefficient countries according to the input efficiency analysis for 2017. To become effective among the five countries, Azerbaijan needs to improve its energy production by 56.2%, industrial production by 2.5%, and agricultural production by 39.2%. Whereas Kazakhstan needs to improve its energy production by 87.8%, industrial production by 4.5%, and agricultural production by 22.82%. Yet again, Uzbekistan needs to improve its energy production by 66.0%, industrial production by 6.7%, and agricultural production by 6.7%.

According to the efficiency analysis for input for 2021, the input analysis of ineffective countries is given in Table 9. Kazakhstan needs to improve by 77.6% in energy production, 18.6% in industrial production, and 18.6% in agricultural production to become effective among the five countries. Turkmenistan, on the other hand, needs to enhance its energy production by 9.3%, its industrial production by 17.8%, and its agricultural production by 9.3%.

Table 10 presents the results of the input analysis of inefficient countries according to the input efficiency analysis for 2022. To become effective when compared to the other five countries, Kazakhstan needs to improve its energy production by 86.1%, industrial production by 27.9%, and agricultural production by 27.9%. Similarly, Turkmenistan needs to improve its energy production by 6.4%, industrial production by 17.5%, and agricultural production by 6.7%.

Table 11 presents the results of the input analysis of inefficient countries according to the output efficiency analysis for 2017. For Azerbaijan to be among the five effective countries, it needs to improve its per capita income by 97.2% and health expenditures by 2.5%. Kazakhstan needs to improve its per capita income by 4.84% and health expenditures by 75.1%. Similarly, Uzbekistan

Table 6: Efficiency analysis findings of countries for 2021

Country	Efficiency score for the input	Super efficiency score and ranking for the input	Efficiency score for the output	Super efficiency score and ranking for the output
AZE	1	1.778 (2)	1	0.562 (2)
KAZ	0.814	0.814 (5)	1.229	1.229 (5)
KGZ	1	1.445 (3)	1	0.692 (3)
TKM	0.907	0.907 (4)	1.103	1.103 (4)
UZB	1	1.855 (1)	1	0.539 (1)

Table 7: Efficiency analysis findings of countries for 2022

Country	Efficiency score for the input	Super efficiency score and ranking for the input	Efficiency score for the output	Super efficiency score and ranking for the output
AZE	1	1.548 (2)	1	0.646 (2)
KAZ	0.721	0.721 (5)	1.387	1.387 (5)
KGZ	1	2.876 (1)	1	0.348 (1)
TKM	0.936	0.936 (4)	1.068	1.068 (4)
UZB	1	1.249 (3)	1	0.801 (3)

Table 8: Improvement recommendation for input according to 2017 effectiveness analysis (in percentage)

Country	ENGEN	INDPRO	CRPRO
AZE	56.23	2.51	39.23
KAZ	87.81	4.53	22.82
KGZ	---	---	---
TKM	---	---	---
UZB	65.97	6.68	6.68

---: Since the relevant country is active, the improvement recommendation has not been calculated

Table 9: Improvement recommendation for input according to 2021 effectiveness analysis (in percentage)

Country	ENGEN	INDPRO	CRPRO
AZE	---	---	---
KAZ	77.63	18.64	18.64
KGZ	---	---	---
TKM	9.31	17.78	9.31
UZB	---	---	---

---: Since the relevant country is active, the improvement recommendation has not been calculated

Table 10: Improvement recommendation for input according to 2022 effectiveness analysis (in percentage)

Country	ENGEN	INDPRO	CRPRO
AZE	---	---	---
KAZ	86.13	27.88	27.89
KGZ	---	---	---
TKM	6.36	17.47	6.36
UZB	---	---	---

---: Since the relevant country is active, the improvement recommendation has not been calculated

Table 11: Improvement recommendation for output according to 2017 effectiveness analysis (in percentage)

Country	GDP	HLEX
AZE	97.22	2.46
KAZ	4.84	75.08
KGZ	---	---
TKM	---	---
UZB	7.17	22.73

---: Since the relevant country is active, the improvement recommendation has not been calculated

needs to improve its per capita income by 7.2% and health expenditures by 22.7%.

According to the efficiency analysis for output for 2021, the output analysis of ineffective countries is given in Table 12. Kazakhstan needs to improve its per capita income by 27.5% and health expenditures by 22.9%. On the other hand, Turkmenistan needs to increase its per capita income by 10.3% and health expenditures by 29.9%.

Table 13 presents the results of the input analysis of inefficient countries according to the output efficiency analysis for 2017. To become effective among the five countries, Kazakhstan needs to improve its per capita income by 64.0% and health expenditures by 38.7%. Meanwhile, Turkmenistan needs to improve its per capita income by 91.2% and health expenditures by 6.8%.

Table 12: Improvement recommendation for output according to 2021 effectiveness analysis (in percentage)

Country	GDP	HLEX
AZE	---	---
KAZ	27.5	22.91
KGZ	---	---
TKM	10.27	29.93
UZB	---	---

---: Since the relevant country is active, the improvement recommendation has not been calculated

Table 13: Improvement recommendation for output according to 2022 effectiveness analysis (in percentage)

Country	GDP	HLEX
AZE	---	---
KAZ	63.97	38.71
KGZ	---	---
TKM	91.23	6.79
UZB	---	---

---: Since the relevant country is active, the improvement recommendation has not been calculated

5. CONCLUSION AND RECOMMENDATIONS

Many countries aim to enhance the well-being and standard of living of their citizens by utilizing their available resources and production. In this study, an efficiency analysis model was employed to evaluate the effectiveness of the efforts made by the Central Asian Turkic States toward achieving this objective, based on the selected variables. The findings reveal that the Turkic States exhibited successful management in terms of GDP and health quality in 2018, 2019, and 2020. Only two countries remained below the effective limit in 2021 and 2022. In particular, when we analyze the efficiency model for input, it becomes evident that the energy production input variable for Kazakhstan has a very low efficiency (83.9% idle capacity).

The findings of the analysis have revealed that there is a criticism regarding efficiency analysis, which assigns higher efficiency scores to countries that produce more output with less input. Therefore, it is important to test the obtained findings by comparing efficiency analysis with different input-output models and analysis methods, as it is considered a crucial methodological approach.

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