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ENVIRONMENTAL PERFORMANCE DIVERGENCE IN CENTRAL ASIA UNDER SUSTAINABLE DEVELOPMENT

As an increasing number of countries engage in environmental protection efforts, it becomes important to assess how effectively these efforts are implemented. This study draws on country-level data and materials from Central Asia and employs a descriptive comparative approach to conduct a cross-country analysis of five countries: Kazakhstan, Uzbekistan, Turkmenistan, the Kyrgyz Republic, and Tajikistan. The five countries show modest but limited improvements in their levels of sustainable development. At the environmental level, this study constructs a CO_2 index based on CO_2 emission intensity. The results show that the emission intensity of Kazakhstan, Uzbekistan, and Turkmenistan has declined overall, indicating improvements in environmental performance, whereas the Kyrgyz Republic and Tajikistan have achieved relatively limited emission-reduction outcomes. At the same time, the annual standard deviation of the CO_2 Index indicates that environmental performance among Central Asian countries has exhibited a gradually diverging trend. Based on these findings, this study analyzes the drivers of differences in environmental performance from the perspectives of supply-side energy structure, demand-side heating patterns, and the level of economic development. Although all Central Asian countries have committed to reducing emissions, they continue to face substantial challenges. In

particular, the Kyrgyz Republic and Tajikistan may benefit from drawing on relevant experiences from Kazakhstan, Uzbekistan, and Turkmenistan.

Keywords: environmental performance, central Asia, energy supply, energy demand, economic development.

Introduction

In 2015, the United Nations adopted the Sustainable Development Goals, covering economic, social and environmental issues. The proposal of this framework was in line with the severe pollution situation of global environmental problems, and all countries need to assume corresponding environmental responsibilities. The 17 sustainable development goals proposed by the United Nations provide a comprehensive framework for achieving sustainable development for all countries. Among them, goals related to water resources, climate, and biodiversity are all included in the environmental goals of sustainable development.

In order to determine whether the environmental activities undertaken by countries are in line with their proclaimed environmental commitments, the analysis of the environmental performance is a valuable research objective. The assessment is also a significant aspect of environmental accounting discipline. In recent years, research has increasingly focused on examining the determinants of corporate environmental performance, including environmental ethics [1], digital technologies [2], governance structures [3], and green innovation [4], among others.These studies cover a wide range of countries and regions, including the G-6 nations [5], China [6], the United Arab Emirates [7], and others.

Most of this research concentrates on the firm level, representing a micro-level analysis of environmental performance. By contrast, studies assessing environmental performance at the national level remain relatively limited.

At the same time, for Central Asian countries, only a small number of studies have examined issues such as environmental auditing [8], and research specifically assessing national-level environmental performance remains largely absent.

As a geographically adjacent region with highly interconnected economic structures, the five Central Asian countries (Kazakhstan, Uzbekistan, Turkmenistan, the Kyrgyz Republic, and Tajikistan) exhibit the following characteristics: On the one hand, the energy systems of Central Asian countries rely heavily on fossil fuels; however, notable differences exist in their respective energy structures.

On the other hand, the Central Asian countries are generally undergoing a period of economic structural transition, exhibiting uneven development in terms of industrial structure, levels of urbanization, infrastructure, and governance capacity.

Although the Central Asian countries have all pledged to advance the Sustainable Development Goals, their actual progress in environmental dimensions

still requires further investigation. Therefore, evaluating and analyzing the environmental performance of the five Central Asian countries at the national level carries significant importance.

Based on this context, this study takes Kazakhstan (KAZ), Uzbekistan (UZB), Turkmenistan (TKM), the Kyrgyz Republic (KGZ), and Tajikistan (TJK) as its research objects and seeks to address the following questions.

RQ1: How did the environmental performance of the five Central Asian countries evolve during the period from 2000 to 2022?

RQ2: Do significant differences exist in environmental performance across these countries? Moreover, does their environmental performance exhibit a pattern of divergence or convergence over time?

RQ3: What are the potential factors that contribute to these differences in environmental performance?

By answering the above questions, this study aims to provide insights into environmental governance for Central Asia and to help promote each country's contribution to sustainable development.

Materials and methods

This study draws upon multiple sources of data and information. The data are primarily obtained from the World Bank, the Sustainable Development Solutions Network (SDSN), Our World in Data (OWID), and the International Energy Agency (IEA). They cover annual information for the five Central Asian countries (KAZ, UZB, TKM, KGZ, and TJK). The dataset includes indicators such as SDG Index, CO2 emission intensity, the structure of electricity generation (including the shares of coal, natural gas, and hydropower), the urbanization rate, GDP per capita, and total primary energy consumption, among others. All relevant data are drawn from the most recently released versions provided by each institution, thereby ensuring both the timeliness and the comparability of the study.

To supplement information that cannot be fully captured through statistical data alone, this study also draws upon official materials, including reports and documentation issued by major international organizations such as the Intergovernmental Panel on Climate Change (IPCC), the United Nations Framework Convention on Climate Change (UNFCCC), the International Energy Agency (IEA), the World Bank, and the United Nations Economic Commission for Europe (UNECE). In addition, this study incorporates academic articles published between in journals indexed by Scopus or the Web of Science, thereby providing further support from the existing literature.

This study employs a combination of quantitative and qualitative analytical methods. First, time-series plots are constructed to illustrate the SDG Index trends for each country. Next, a CO_2 Index is constructed, and the annual standard

deviation is calculated to identify whether environmental performance in Central Asia exhibits a trend of convergence or divergence over time. Finally, focusing on factors such as energy structure, heating patterns, and the level of economic development, the study calculates the mean values and standard deviations of the relevant indicators in order to analyze the potential drivers underlying these differences.

Results and discussion

To evaluate the performance of the five Central Asian countries in relation to the Sustainable Development Goals, this study employs the SDG Index published in the SDSN. The SDG Index is structured around the 17 Sustainable Development Goals and spans multiple dimensions, including the economic, social, and environmental domains. It develops a set of sub-indicators under each goal and subsequently computes an overall composite score. A higher score indicates a higher level of sustainable development for a country (with a maximum score of 100).

Table 1 shows that the scores of the five countries exhibit an overall upward trend during the study period. However, in the recent years, the variation in scores has been relatively small, indicating that there might be bottlenecks in the process of achieving the sustainable development goals.

From a cross-country perspective, UZB records the highest score among the five countries in most years. Meanwhile, KAZ, KGZ, and TJK display relatively small differences in their scores, reflecting a high degree of homogeneity among the three countries.

TKM exhibits relatively low overall scores throughout the study period; however, its rate of increase is comparatively substantial, indicating a gradual convergence toward the levels of the other countries.

Because the SDG Index is a composite measure that integrates economic, social, and environmental performance, it is difficult for it to directly capture the specific dynamics of environmental performance. Therefore, it is necessary to employ more direct and environmentally oriented indicators. This study therefore adopts CO2-related indicators to analyze the environmental performance of the Central Asian countries.

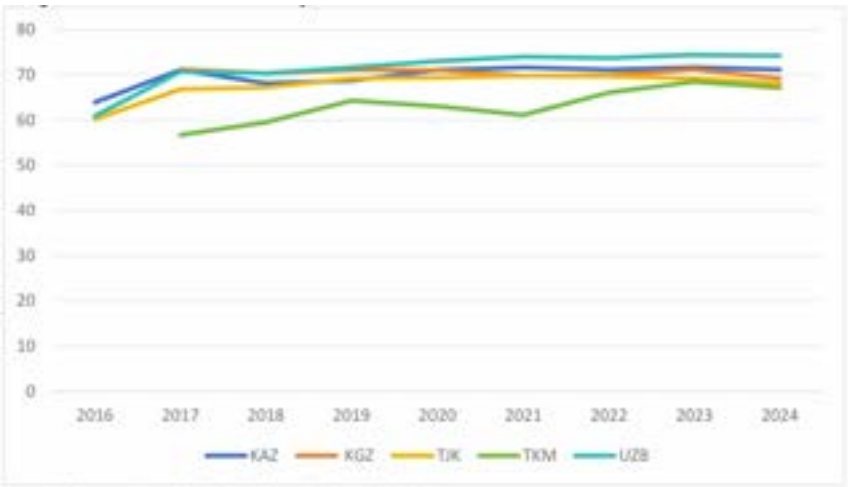

Figure 1 – SDG Index (2016–2024)
Note: complied by the author

Existing studies commonly employ CO_2-related indicators as the core proxy variables for measuring environmental quality [9,10]. The IPCC also points out that CO_2 is the principal greenhouse gas responsible for global warming induced by human activities [11]. At the same time, the global climate governance agreement known as the Paris Agreement explicitly designates CO_2 as a central target for emission reductions under the nationally determined contributions (NDCs) of all countries [12]. Reducing CO_2 emissions has already become a critical environmental issue that urgently requires attention at the global level. In summary, the governance of CO_2 emissions can effectively reflect a country's actual progress in environmental management, which constitutes the primary reason why this study selects CO_2-related indicators.

Among the many CO_2-related indicators, and in order to avoid interference from factors such as population size and total GDP, this study adopts the CO_2 emission intensity provided by Our World in Data as the baseline indicator. To ensure comparability across countries, the CO_2 emission intensity in the year 2000 is set as a common baseline, with the index normalized to 1. And the changes in each subsequent year relative to this baseline are calculated to derive the variable referred to as the CO_2 Index. This index reflects the CO_2 emission efficiency of each country over the period from 2000 to 2022. When the CO_2 Index is less than 1, it indicates that the country's CO_2 emission intensity has declined relative to the year 2000, meaning that carbon emission efficiency has improved and

environmental performance has been enhanced. Conversely, when the CO_2 Index is greater than 1, this indicates that CO_2 emission intensity has increased, carbon emission efficiency has declined, and environmental performance has not shown meaningful improvement.

Figure 2 shows the changes in the CO_2 index of various countries. From the perspective of the intervals where the CO_2 index is greater than 1, KGZ has been above 1 in most years and shows an inverted U-shaped trend. During the 22-year research period, the CO_2 emission intensity has no substantial improvement, and it has even increased in some years. Additionally, TJK's CO_2 index has remained around 1 since 2018, showing a positive U-shaped trend. Although TJK achieved certain emission reduction results in the early stage, they were not sustained over the long term, and a reversal occurred around 2013.

Within the intervals where the CO_2 index is less than 1, UZB's CO_2 index has continued to decline and has reached the lowest level among the five countries. TKM and KAZ have had minor fluctuations in some years, but the overall trend has been a decline, indicating that both countries have achieved certain emission reduction results.

Therefore, based on the results of the CO_2 index, the five countries can be classified into countries with environmental improvement (KAZ, UZB, TKM) and countries with limited environmental improvement (TJK, KGZ).

Figure 2 – CO_2 Index (2000–2022)

Note: complied by the author

The improvement in CO_2 emissions varies among the five countries. From the perspective of the entire Central Asia region, is the environmental performance converging or diverging? Therefore, this study further calculated the annual

standard deviation of the CO2 index. The smaller the standard deviation, the more convergent the regional environmental performance becomes; the larger the standard deviation, the more divergent it becomes.

Figure 3 shows that although the annual standard deviation of the five countries fluctuated slightly, it showed an upward trend over the 22-year study period. This indicates that the environmental performance in Central Asia is gradually diverging.

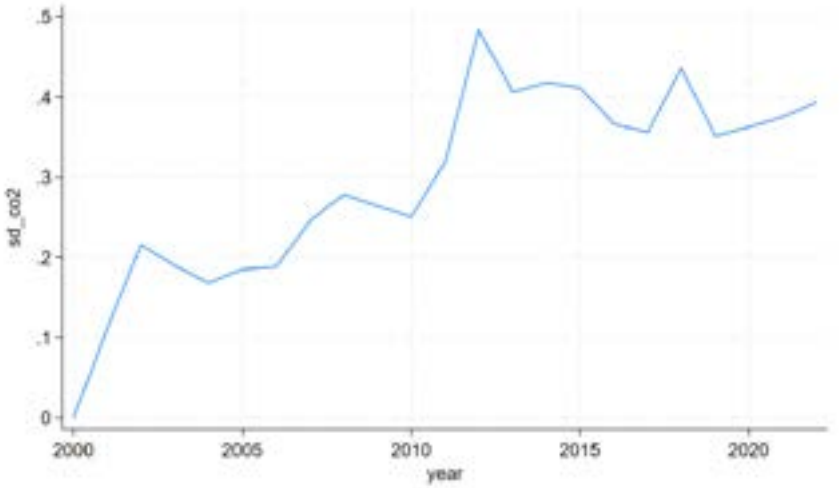

Figure 3 – Annual Standard Deviation of the CO_2 Index (2000–2022)
Note: complied by the author

One of the key factors contributing to these differences is the variation in energy structures across countries, which reflects the differing conditions on the energy supply side. The IEA points out that the energy sector accounts for approximately 85 % of global CO_2 emissions. There is a direct relationship between the energy structure and the trend of carbon dioxide emissions [13].

This is because the timeline for electricity generation structure data is complete, and the composition of power generation reflects a country's long-term choices regarding its energy pathway. Therefore, this study uses electricity supply data from the Central Asian region as a proxy indicator for energy structure. This mainly includes the shares of coal, natural gas, and hydropower in the electricity generation structure. Due to constraints on the length of the paper, the mean values and standard deviations of each indicator for the period from 2000 to 2023 were

calculated. The mean values reflect the central level of each country's long-term energy structure, while the standard deviations capture the degree of variation, as shown in Table 1.

Table 1 – Mean and Standard Deviation of Coal, Natural Gas, and Hydropower Shares in Electricity Generation (2000–2023)

Country	Statistic	Coal share (%)	Natural Gas share (%)	Hydropower share (%)
Kaz	Mean	69.42	16.62	10.44
	Sd	6.64	6.99	2.24
UZB	Mean	4.62	80.88	11.07
	Sd	1.38	4.42	2.93
TKM	Mean	0	100.00	0
	Sd	0	0.01	0.01
TJK	Mean	2.24	0.90	96.86
	Sd	3.17	0.72	3.31
KGZ	Mean	7.95	3.33	88.14
	Sd	3.42	4.07	3.57

Note: Mean refers to the sample mean; SD refers to standard deviation.

According to Table 1, the electricity generation systems of the Central Asia countries are highly differentiated, in the case of the countries with better environmental performance; UZB and TKM have had long-term electricity generation systems based on natural gas. In its turn, the natural gas share is on average about 81 %, and that of hydro-power stands at around 11 %, whereas the coal share is very minimal and thus on the profile of 2000–2023 the trend of CO_2 Index has continued to decrease. In 2022, the index had decreased to the significantly better point of 0.29, which proves a definite increase in the performance regarding the environment.

The electricity generation structure of TKM is rather extreme, and the portion of natural gas is near to 100 % in the long-term, whereas the portion of coal and hydro-electricity are almost 0. This represents a typical «single-source natural gas-based» energy structure. From the perspective of CO_2 reduction outcomes, an energy structure in which electricity generation is dominated by natural gas keeps CO_2 emissions at relatively low levels, thereby producing a clearly observable emission-reduction effect.

In contrast, KAZ has a more complex energy structure, with coal remaining the primary source of electricity supply. Over the long term, coal has accounted for an average of approximately 69 % of the electricity generation structure,

while natural gas has accounted for about 16 % and hydropower about 10 %. However, the standard deviations of coal and natural gas shares in KAZ are both higher than those of the other Central Asian countries, indicating that KAZ has undergone substantial adjustments in its energy structure. An examination of KAZ's electricity generation shares over time shows that, after 2011, the share of coal declined significantly (from 81 % in 2011 to 56 % in 2023). Over the same period, the share of natural gas rose rapidly (from 10 % in 2011 to 28 % in 2023).

The substitution of coal with natural gas as part of this energy structure adjustment has enabled KAZ to achieve a noticeable reduction in emissions, even though the share of coal remains relatively high. The IEA likewise points out that, for the power sector to achieve decarbonization, a key measure is the replacement of coal with renewable energy and other low-emission energy sources [13]. Natural gas, compared with coal, has a lower carbon emission factor and is commonly regarded as a low-carbon energy source. This characteristic represents an important advantage that has enabled UZB, TKM, and KAZ to achieve notable emission-reduction outcomes.

Unlike the three countries discussed above, the energy structures of TJK and KGZ appear relatively green, with hydropower accounting for nearly 90 % of electricity generation. However, despite this high share of hydropower, the CO_2 Index of both countries has not shown a clear improvement.

In TJK's electricity generation structure, hydropower accounts for an average share of 97 %, yet its CO_2 Index exhibits a U shape over time. During the period from 2000 to 2013, the CO_2 Index continued to decline, whereas after 2013 the index began to reverse and increase. The underlying reason is that, after 2013, TJK substantially increased its use of coal. From 2000 to 2013, the share of coal in electricity generation was 0 %. From 2013 to 2023, however, the coal share increased from 0.23% to 6 %, and at one point rose to over 8 %. At the same time, the share of hydropower declined from nearly 100 % to 93 %, and the increased use of coal altered TJK's electricity generation structure, thereby explaining why a reversal occurred in its CO_2 Index.

As for KGZ, its energy structure is likewise dominated by hydropower, with an average share of approximately 88 %. However, the share of coal in electricity generation has fluctuated within the range of 8 % to 13 % over the long term, while the share of natural gas has consistently remained below 1 %. This electricity generation structure has made it difficult for KGZ's CO_2 Index to decline, resulting in weak emission-reduction outcomes.

Therefore, countries with limited environmental improvement, although they possess seemingly «green» energy structures dominated by hydropower,

experience a situation in which the continued use of coal offsets the advantages associated with hydropower.

Although the absolute levels of CO_2 emission intensity in the two countries are significantly lower than those observed in KAZ, UZB, and TKM. However, this study employs the CO_2 Index as a relative indicator, which removes the influence of economic scale, and therefore the comparison of trends remains meaningful. This result is also consistent with the view of IEA, which emphasizes that coal use is the primary source of CO_2 emissions and that a key priority is to increase the share of low-carbon energy sources.

In addition to differences in energy structures on the supply side, energy consumption patterns on the demand side also exert a significant influence on environmental performance.

The World Bank noted in its 2023 report titled Toward a Framework for the Sustainable Heating Transition in Europe and Central Asia that the heating sector has a significant impact on environmental quality. Due to factors such as reliance on fossil fuels, aging infrastructure, and the widespread use of highly polluting fuels in remote areas, heating activities in Central Asia have adversely affected air quality [14]. In this section, we mainly discuss TJK and KGZ. Both countries have highly dependent energy structures on hydropower resources, but the CO_2 emissions intensity has not shown significant improvement over a long period of time. This is largely related to the heating patterns at the demand end.

The reason lies in the seasonal nature of the hydropower resources in both countries: in summer, due to the melting of snow, the water volume is abundant and the power supply is relatively stable. In winter, due to the cold weather, the water resources dry up, resulting in insufficient power generation. The rigid demand for residential heating cannot be continuously met by the hydropower resources. When electricity supply during the winter is insufficient to meet heating demand, as documented in a World Bank report which points out that the electricity grid capacity in the KGZ has long been operating close to saturation, leading to recurrent winter power shortages [15], residents in both countries are forced to rely on alternative energy sources for heating, most notably solid fossil fuels such as coal.

At the same time, households have adopted a decentralized coal-based heating mode. We calculate the average urbanization rate over the period from 2000 to 2024. Among the five Central Asian countries, KGZ and TJK exhibit the lowest levels of urbanization, with average urbanization rates of only 36 % and 27 %, respectively. By contrast, the average urbanization rates of the other three countries are generally close to 50 %, with KAZ reaching a level of 57 %. KAZ's high level of urbanization provides a solid foundation for the development of comprehensive centralized heating systems. By contrast, the lower levels of

urbanization in KGZ and TJK limit the conditions necessary for the development of large-scale centralized heating systems in the two countries.

For example, in KGZ, more than 80 % of households rely on individual heating solutions, and nearly half of these households use traditional coal-fired stoves, with heating efficiency below 40 %. At the same time, the types of fuels used by households are diverse and of unstable quality, including animal dung, firewood, rubber, and other materials, which further exacerbates air pollution and greenhouse gas emissions [16]. UNECE has also pointed out that the residential sector is the largest source of CO_2 emissions [17].

For TJK, due to historical factors, approximately 80 % of district heating facilities have been dismantled over the past several decades, leading to a sharp decline in centralized heating coverage from 35 % to less than 4% . At the same time, owing to the lack of natural gas and alternative electricity supply, as well as limited fuel options, more than one third of urban households rely on coal-fired or biomass stoves for heating [18]. Low heating efficiency, together with highly polluting decentralized heating practices, makes the advancement of emission reduction efforts particularly challenging.

Another contributing factor is the insufficient energy efficiency of public buildings in the two countries. A World Bank assessment report indicates that heating energy accounts for 70–88 % of total energy consumption in public buildings, reflecting a very high demand for winter heating. However, in KGZ, a large number of public buildings were constructed in earlier periods and exhibit poor thermal insulation, resulting in substantial heat losses during the winter season. Even where heating equipment is in place, overall heating efficiency remains low due to equipment aging. Under conditions of insufficient electricity supply and constrained budgets, public institutions are forced to shift toward lower-cost energy sources, such as coal [19]. TJK faces similar challenges: due to the very low coverage of district heating, public buildings likewise find themselves reliant on coal-based heating. Therefore, the actual conditions on the demand side in the two countries have profoundly influenced their realized levels of CO_2 emissions.

The level of economic development likewise influences national governance capacity and the ability to achieve emission reductions. We employs GDP per capita as an indicator to measure the level of economic development of the five Central Asian countries, as illustrated in Figure 4. KAZ has consistently maintained the highest GDP per capita in the Central Asian region over the long term, followed by TKM and UZB, whereas KGZ and TJK lag significantly behind, with their levels being relatively similar to each other. According to the World Bank's Atlas method classification, both KGZ and TJK are categorized as lower-middle-income

economies [20]. For both countries, the core policy priorities remain poverty reduction and the promotion of economic growth.

From an economic perspective, the level of economic development influences a country's fiscal capacity and its ability to invest in technology, thereby constraining the scale of national investment in energy infrastructure, low-carbon technologies, and heating systems. In general, the higher the level of economic development, the greater the capacity of a country to promote the upgrading of heating systems and the adoption of low-carbon technologies; by contrast, countries with weaker economic foundations tend to face constraints in their ability to invest in energy-related infrastructure and technologies. This conclusion is consistent with the basic proposition of the Environmental Kuznets Curve (EKC), which assumes an inverted U-shaped relationship between economic development and environmental pollution.

As discussed earlier, the hydropower resources of KGZ and TJK are characterized by strong seasonality, while both countries lack readily available alternative low-carbon energy options. Coupled with their relatively low levels of economic development, these constraints limit their capacity to improve heating systems and related infrastructure. For example, due to relatively high natural gas prices and insufficient alternative energy infrastructure, many low-income households are unable to afford modern heating technologies and therefore continue to rely on lower-cost but more polluting solid fuels, such as coal. In TJK, expenditure on solid fuels accounts for about 10 % of total household spending among urban poor households, and this share rises to approximately 15 % in rural areas [10].

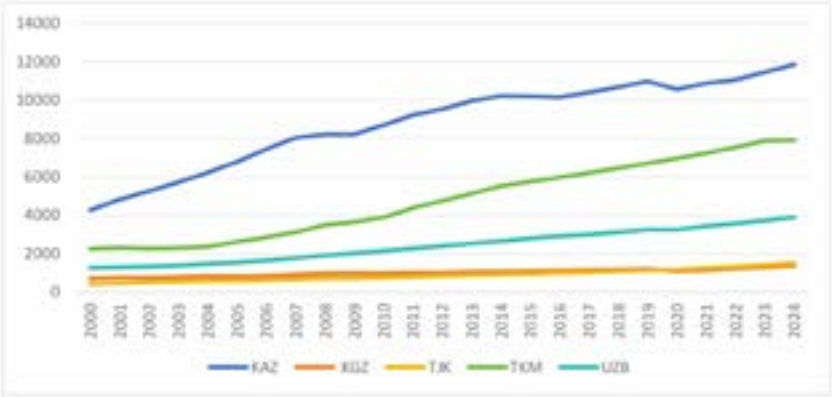

Figure 4–GDP per Capita (2000–2024)

Note: complied by the author

In addition to the level of economic development, this study also incorporates the indicator of primary energy consumption. This indicator refers to the total amount of natural energy directly used by a country prior to energy transformation, and it serves as a measure of the scale of the energy system as well as overall energy availability.

Figure 5 shows that the scale of primary energy consumption in KAZ, TKM, and UZB is significantly higher than that in KGZ and TJK. In general, countries with larger volumes of primary energy consumption tend to have more developed infrastructure, more diversified energy substitution pathways, and a greater capacity to shift toward alternative energy sources. By contrast, countries with smaller volumes of primary energy consumption typically face more limited energy options and have less room for emission reduction. The situations in KGZ and TJK indicate that both countries rely primarily on a single energy source and lack sufficient alternative energy options. Coupled with relatively weak fiscal capacity, they are unable to undertake large-scale structural adjustments, and these characteristics collectively constrain their ability to achieve emission reductions.

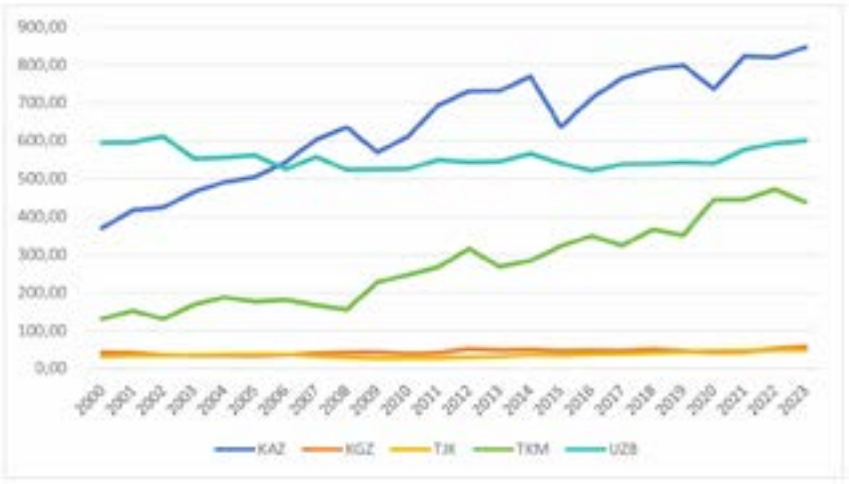

Figure 5 – Primary Energy Consumption (2000–2024)
Note: complied by the author

Conclusion

The SDG Index of the five Central Asian countries have generally shown an upward trend, but there are differences in the improvement of environmental performance. The CO_2 emission intensity in KAZ ,UZB, and TKM has generally

decreased, and their environmental performance has improved. However, KGZ and TJK have remained at high levels or even experienced a reversal, and the degree of environmental improvement is insufficient.

The reasons for these differences can be attributed to the energy structure on the supply side, the heating mode on the demand side, and the level of economic development. UZB and TKM rely mainly on natural gas, while KAZ is reducing coal usage and increasing the use of natural gas. These three countries have achieved emission reduction results. By contrast, KGZ and TJK, which are dominated by hydropower, face seasonal constraints on hydropower resources. Combined with rigid winter heating demand, these constraints have increased residents' reliance on decentralized coal-based heating during the winter, thereby undermining the effectiveness of emission reduction efforts in the two countries. In addition, differences in levels of economic development and primary energy consumption also constrain countries' capacities to pursue energy transitions and to seek feasible alternative energy options.

In this context, the experiences of the other three countries provide a reference for KGZ and TJK. Additionally, International experience shows that the Australian Bureau of Statistics has established several environmental economic accounts, such as the Energy Account, under the SEEA framework (System of Environmental Economic Accounting), thereby reflecting energy-related data and improving information transparency and international comparability. Central Asian countries can draw on the SEEA framework by incorporating environmental factors into national economic accounts and establishing country-specific accounts, such as the energy account.

In addition, Central Asian countries could implement energy audit programs. In its assessment of energy efficiency in public buildings in the KGZ, the World Bank pointed out that energy audits can be conducted for public buildings such as schools and hospitals to identify energy-saving potential, thereby providing evidence-based recommendations for building energy-efficiency retrofits [11].

The limitations of this study lie in the constrained availability of energy and environmental data for Central Asian countries. As a result, a descriptive comparative approach is adopted, with the data primarily drawn from international databases, and some indicators exhibiting a degree of time lag. Second, environmental performance is multidimensional. This study focuses on CO2 emission intensity and changes in the CO2 Index, and future research may adopt other, more comprehensive indicator approaches.

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ОРТАЛЫҚ АЗИЯ ЕЛДЕРІНДЕГІ ТҰРАҚТЫ ДАМУ ЖАҒДАЙЫНДАҒЫ ЭКОЛОГИЯЛЫҚ ТИІМДІЛІКТІҢ АЖЫРАУЫ

Қоршаған ортаны қорғау саласындағы іс-шараларға қатысатын елдердің саны артқан сайын, аталған шаралардың қаншалықты тиімді жүзеге асырылып жатқанын бағалау маңызды бола түсуде. Бұл зерттеуде Орталық Азия елдері бойынша елдік деңгейдегі деректер мен материалдар негізінде сипаттамалық салыстырмалы әдіс қолданылып, бес елге – Қазақстан, Өзбекстан, Түрікменстан, Қырғыз Республикасы және Тәжікстанға – мемлекетаралық талдау жүргізіледі. Зерттеу нәтижелері аталған бес елдің тұрақты даму деңгейінде біршама, алайда шектеулі ілгерілеу бар екенін көрсетеді. Экологиялық деңгейде зерттеу CO_2 шығарындыларының қарқындылығына негізделген CO_2 индексін қалыптастырады. Нәтижелер Қазақстан, Өзбекстан және Түрікменстанда шығарындылар қарқындылығының жалпы төмендегенін, яғни экологиялық тиімділіктің артқанын көрсетеді. Ал Қырғыз Республикасы мен Тәжікстанда шығарындыларды азайту нәтижелері салыстырмалы түрде шектеулі болып отыр. Сонымен қатар CO_2 индексінің жылдық стандартты ауытқуын талдау Орталық Азия елдеріндегі экологиялық тиімділіктің біртіндеп ажырау үрдісін көрсететінін айқындайды. Алынған нәтижелерге сүйене отырып, зерттеуде экологиялық тиімділіктегі айырмашылықтардың себептері энергиямен жабдықтаудың құрылымы, энергияға сұраныс (жылыту үлгілері) және экономикалық

даму деңгейі тұрғысынан талданады. Орталық Азия елдерінің барлығы шығарындыларды қысқарту бойынша міндеттемелер қабылдағанымен, олар әлі де елеулі қиындықтарға тап болып отыр. Атап айтқанда, Қырғыз Республикасы мен Тәжікстан Қазақстан, Өзбекстан және Түрікменстанның тиісті тәжірибесін пайдаланудан пайда көре алады.

Кілтті сөздер: экологиялық тиімділік, Орталық Азия;, энергиямен жабдықтау, энергияға сұраныс, экономикалық даму.

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ДИВЕРГЕНЦИЯ ЭКОЛОГИЧЕСКОЙ ЭФФЕКТИВНОСТИ В СТРАНАХ ЦЕНТРАЛЬНОЙ АЗИИ В УСЛОВИЯХ УСТОЙЧИВОГО РАЗВИТИЯ

По мере того как всё больше стран вовлекаются в деятельность по охране окружающей среды, становится важным оценить, насколько эффективно реализуются эти усилия. В данном исследовании на основе страновых данных и материалов по Центральной Азии используется описательный сравнительный подход для проведения межстранового анализа пяти государств: Казахстана, Узбекистана, Туркменистана, Кыргызской Республики и Таджикистана. Результаты показывают, что все пять стран демонстрируют умеренный, но ограниченный прогресс в достижении устойчивого развития. На экологическом уровне в исследовании построен индекс CO_2 на основе интенсивности выбросов CO_2. Полученные результаты свидетельствуют о том, что интенсивность выбросов в Казахстане, Узбекистане и Туркменистане в целом снизилась, что указывает на улучшение экологической эффективности, тогда как Кыргызская Республика и Таджикистан достигли относительно ограниченных результатов в сокращении выбросов. Одновременно анализ годового стандартного отклонения индекса CO_2 показывает, что экологическая

эффективность стран Центральной Азии характеризуется тенденцией к постепенной дивергенции. На основе полученных результатов в статье анализируются факторы, обусловливающие различия в экологической эффективности, с точки зрения структуры энергоснабжения, моделей энергопотребления в секторе отопления и уровня экономического развития. Несмотря на то что все страны Центральной Азии взяли на себя обязательства по сокращению выбросов, они по-прежнему сталкиваются с существенными трудностями. В частности, Кыргызская Республика и Таджикистан могут извлечь пользу из опыта Казахстана, Узбекистана и Туркменистана.

Ключевые слова: экологическая эффективность; Центральная Азия; энергоснабжение; спрос на энергию; экономическое развитие.

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