Energy use inefficiency and policy governance: the case of Central Asian countries

Taguchi, Hiroyuki

Saitama University

February 2022

Energy Use Inefficiency and Policy Governance: The Case of Central Asian Countries

Hiroyuki Taguchi
Aktamov Asomiddin
Graduate School of Humanities and Social Sciences, Saitama University

Abstract

This study aims to examine the energy-use inefficiency in the Central Asian (CA) countries by using the analytical framework of the energy-environmental Kuznets curve (EEKC). This study's contribution to the literature is to explicitly target the CA countries in the EEKC analysis in the first place. The empirical analyses identified the energy-use inefficiency of Turkmenistan, Uzbekistan, and Kazakhstan, and could show the contributions of the weak policy governance as well as the natural resource abundance to their energy-use inefficiency. This analytical result could also be endorsed by the Uzbekistan case. Thus, the policy implication is that there would be much room for these countries to improve their energy-use efficiency by enhancing their performances of energy policies.

Keywords: energy-use inefficiency, policy governance, Central Asia, energy-environmental Kuznets curve, and Uzbekistan
JEL Classification: Q4, O53

1. Introduction

The Central Asia (CA), which is composed of five countries: the Republic of Kazakhstan (hereafter Kazakhstan), the Kyrgyz Republic (Kyrgyzstan), the Republic of Tajikistan (Tajikistan), Uzbekistan, and Turkmenistan, was born after the disintegration of the Soviet Union in 1991. The CA countries have made significant progresses in their market-based economic transformations and in their linkages with the world economy, though they went through the severe hardships in their economic management in the early stages after their independence. All the CA countries now belong to the middle-income group (Kazakhstan and Turkmenistan are classified into the "upper" middle-income group and the others into "lower" middle income group), according to the World Bank income classification[1] (see the profile of the CA countries in Table 1).

Much of the existing literature has treated the CA countries as homogenous ones. In fact, the countries enjoy commonalities of history, geographical closeness, culture and language: all were historically colonized by Tsarist Russia and belonged to the Soviet Union for over 70 years, and were geographically landlocked. The CA countries vary, however, in terms of population and land sizes, neighboring countries and natural resource endowments as shown in Table 1 again: Kazakhstan has large sizes in population and territory, borders with Russia and China, and is endowed with oil and coal; Kyrgyzstan and Tajikistan have relatively smaller sizes in papulation and land, borders with China (and Afghanistan in Tajikistan), and is less-endowed with natural resources; Turkmenistan bordering with Afghanistan and Iran is less populated, but well-endowed with oil and natural gas; and Uzbekistan has large population and much endowment of natural gas.

One of the key issues in the economic development of the CA countries is the problem of energy use efficiency and power industry. Table 1 shows that the energy uses in terms of kilogram of oil equivalent per capita in Kazakhstan, Turkmenistan and Uzbekistan are far beyond the average in East Asia and Pacific excluding high income countries. There have also been several studies of pointing out the energy use inefficiency in the CA countries, though the published literature on energy in Central Asia focuses generally on the energy resources of the region as in Dorian et al. (1999) and Dorian (2006). Kaliakparova et al. (2020) argued that Central Asian region is one of the most energy-consuming regions in the world, and technical losses of energy resources reach 20% of the volume of electricity production. Mehta, et al. (2021) pointed out that the

[1] See the website: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519.

infrastructure in the Central Asian power sector is now outdated since it was set up by the Soviet Union in 1980s. Dyussembekova (2019), with a focus on the case of Kazakhstan, also pointed to the deterioration of its power system derived from the Soviet Union, and proposed its strategic adjustments to the global trends such as changes in the structure of demand, development of renewable energy sources, digitalization of the power industry, etc. Gomez et al. (2015), focusing on the case of Uzbekistan, picked up its energy efficiency problem in both supply and demand side: the obsolescence of power generation plants and facilities in the supply side and the intensity of natural gas usage particularly in the household sector in the demand side.

This article aims to examine the energy use inefficiency in the CA countries by using the analytical framework of the energy-environmental Kuznets curve (EEKC) with a focus on Asian countries. The study takes the following steps: first, to draw the EEKC for each Asian country for identifying the energy-use-efficiency positions of the CA countries; second, to estimate the EEKC econometrically with country-specific fixed effects on the energy use efficiency; third, to investigate the contributions of the factors of energy-abundance and institutional quality to the country-specific fixed effects for the CA countries; and finally, to conduct a case study in Uzbekistan on its energy use inefficiency problems.

The EEKC is a useful instrument for examining the nexus between energy consumption and economic growth. The hypothesis of the environmental Kuznets curve postulating the inverted-U-shaped path between environmental pollution and economic growth was initially proposed by Grossman and Krueger (1993), and it was Suri and Chapman (1998) that applied this hypothesis to energy consumption as the source of environmental pollution (this modified energy consumption-growth nexus has been called the energy-environmental Kuznets curve, EEKC, since then.). They argued, using this framework, that the imports of manufacturing good have contributed to the downward slope of the inverted-U curve. Since then, there have been a number of empirical studies to verify the existence of EEKC with their results being not necessarily conclusive: EEKC was confirmed in the world-wide sample countries (Shahbaz et al. 2019), in EU countries (Pablo-Romero and Sanchez-Braza 2017), in Middle East countries (Mahmood 2021), in Ethiopia (Hundie and Daksa 2019) and in Romania (Shahbaz et al. 2013), whereas the hypothesis was not identified in the world-wide samples (Chen et al. 2016, and Luzzati and Orsini 2009), and in Latin American and Caribbean countries (Pablo-Romero and De Jesus 2016).

When it comes to the Asian region that belongs to one of the fastest growing regions in terms of economy and energy consumption, Aruga (2019) dealt with EEKC for the 19

Asia-Pacific countries in the first place, and found that the EEKC hypothesis only holds for the high-income group in that region, while it is not apparent for the low- and middle-income groups. The analytical sample in Aruga (2019), however, does not contain the CA countries. This study thus contributes to the literature by explicitly targeting the CA countries in the EEKC analysis in the first place. Then, the research focus is to identify the locations of the CA countries' EEKCs among those of Asian countries, rather than the verification of the inverted-U-shaped hypothesis between energy consumption and economic growth.

The remainder of the paper is structured as follows. Section 2 conducts empirical analyses consisting of the simple EEKC description and its econometric estimation. Section 3 focuses on the case study in Uzbekistan on its energy use inefficiency issue. Section 4 summarizes and concludes the paper.

2. Empirical Studies

The empirical studies in this section are composed of a descriptive analysis of Asian countries' EEKC and their econometric analysis. This section starts with the EEKC descriptive analysis.

2.1 Descriptive Analysis

Figure 1 displays the EEKCs of selected Asian countries for 1970-2015[2]. The EEKC is drawn with the vertical axis being the energy use expressed as the kilogram of oil equivalent per capita, and with the horizontal axis being the gross domestic product (GDP) per capita in terms of US dollars at constant prices in 2015. The data of the energy use is retrieved from World Bank Open Data[3], and that of GDP per capita from UNCTAD Stat[4]. The sample countries are selected here into 12 ones: Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan in the CA countries, and China, Indonesia, Japan, Korea, Malaysia, Singapore, and Thailand in the other Asian countries.

The main findings from Figure 1 are summarized as follows. First, it is in Singapore and Japan that the inverted-U-shaped hypothesis of EEKC is identified among the sample countries. This finding is consistent with the outcome of Aruga (2019), who argued that the EEKC hypothesis only holds for the high-income group in that region. Second, what

[2] The sample period for the CA countries is 1992-2015.
[3] See the website: https://data.worldbank.org/.
[4] See the website: https://unctadstat.unctad.org/EN/.

is more important is that the locations of Kazakhstan, Turkmenistan and Uzbekistan among the CA countries reveal higher positions than the trends commonly described in the other Asian countries. This finding, together with the simple comparison in Table 1, suggests that the three CA countries have experienced extra-ordinary energy uses at their levels of GDP per capita, thereby implying energy use inefficiency problem.

The subsequent section expresses the country's position of energy use by the country-specific fixed effect through an econometric approach, and investigates the factors to contribute to the difference in the fixed effects.

2.2 Econometric Analysis: Methodology and Data

This section turns to the EEKC econometric analysis for Asian countries, and starts with the description of methodology and data. This study uses a standard model for the EEKC hypothesis as in Aruga (2019). Following this study's analytical concern, however, the estimation applies a fixed-effect model in order to explicitly show the country-specific effect on energy use, and also runs an alternative model to replace the fixed-effect with possible contributors (natural resource abundance and governance) to the fixed-effect. Then, the equations for the estimation are specified as follows.

$$\ln eng_{it} = \alpha_0 + \alpha_1 \ln ypc_{it} + \alpha_2 (\ln ypc_{it})^2 + f_i + f_t + \varepsilon_t \quad (1)$$

$$\ln eng_{it} = \beta_0 + \beta_1 \ln ypc_{it} + \beta_2 (\ln ypc_{it})^2 + \beta_3\, nrr_{it} + \beta_4\, gov_{it} + f_t + \varepsilon_t \quad (2)$$

where the subscripts i and t denote sample countries and years, respectively; *eng* represents the energy use expressed as the kilogram of oil equivalent per capita; *ypc* shows GDP per capita in terms of US dollars at constant prices in 2015; *nrr* denotes the natural resources rents (sum of oil, natural gas, and coal rents) expressed as a percentage of GDP; *gov* represents the governance indicators; f_i and f_t show a time-invariant country-specific fixed effect and a country-invariant time-specific fixed effect, respectively; ε denotes a residual error term; $\alpha_{0...2}$ and $\beta_{0...4}$ represent estimated coefficients, respectively; and ln shows a logarithm form, which is set to avoid scaling issues for the energy use (*eng*) and GDP per capita (*ypc*).

The details of the variables and the sample size for the estimation are shown as follows. The data sources for the energy use (*eng*) and GDP per capita (*ypc*) are the same as those in Section 2.1. The data of the natural resources rents (*nrr*) are retrieved from World Bank Open Data. The governance indicators (*gov*) are represented by World

Governance Indicators (WGI) of the World Bank[5]. This study, whose analytical concern is the energy policy performances, selects the following four indicators out of the total six ones: government effectiveness (*gve*), regulatory quality (*rgq*), rule of law (*rol*), and control of corruption (*cor*). Each index takes the number ranging from -2.5 (weak governance) to 2.5 (strong governance) with the world average being approximately zero. As for the sample size, the estimation targets 23 Asian countries: the 16 countries in Section 2.1 and the additional 11 countries (Bangladesh, Brunei Darussalam, Cambodia, India, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Sri Lanka, and Vietnam). The sample period is 1970-2015 for Equation (1), and 1996-2015 for Equation (2) due to the data constraint of WGI. The study then constructs a set of panel data of the sample countries and periods. The descriptive statistics for the data of all the variables are displayed in Table 2.

The notes on the specifications of the estimation models in (1) and (2) are needed to describe additionally as follows. Regarding Equation (1), it applies a fixed-effect model represented by f_i and f_t, respectively, for panel estimation. From the statistical perspective, the Hausman-test statistic is generally utilized for the choice between a fixed-effect model and a random effect one (Hausman 1978). This study, however, places a premium on presenting an country-specific effect on energy use explicitly, and also an time-specific factor such as economic fluctuations due to external shocks such as the Asian financial crises in 1997–1998 and the global financial crises in 2008–2009. The estimation sets China as a benchmark country for showing the country-specific effects, because China is located in the middle position in the EEKC descriptive analysis in Figure 1. The significantly positive coefficient of the country-specific effect would suggest that the energy use is more inefficient than that of China. The ordinary hypothesis of EEKC postulating the inverted-U-shaped path between energy use and GDP per capita would be verified if $\alpha_1 > 0$ and $\alpha_2 < 0$ are significant (in Equation 2, $\beta_1 > 0$ and $\beta_2 < 0$ are significant).

Equation (2) replaces the country-specific fixed effects above with possible contributors to the fixed-effects. For the possible contributors, this study adopts the natural resources rents (*nrr*) and the governance indicators (*gov*). It is because the lower performance of energy policies has affected the energy use inefficiency, in particular, in the CA countries as shown in Mehta, et al. (2021), Dyussembekova (2019), and Gomez et al. (2015) in the introduction, while natural resource abundance is supposed to be related to the energy use. The energy policy performance is represented by the four governance indicators: government effectiveness (*gve*), regulatory quality (*rgq*), rule of

[5] For the data acquisition and their definitions, see the website: https://info.worldbank.org/governance/wgi/.

law (*rol*), and control of corruption (*cor*). In the estimation of Equation (2), each governance indicator is separately inserted as an independent regressor, since there is a multicollinearity problem among the indicators. Table 3 reports the bivariate correlations and the variance inflation factors (VIF), a method of measuring the level of collinearity between the regressors. It shows a high bivariate correlation (around 0.9) in each combination, and high values of VIF that are beyond (or close to) the criteria of collinearity, namely, ten points. The natural resources rents (*nrr*) is supposed to have a positive effect on energy use, and each of the governance indicator is expected to equip a negative coefficient on energy use because the higher governance leads to more of energy use efficiency.

Regarding an estimation methodology, this study applies not only the ordinary least squares (OLS) estimator for Equation (1) and (2), but also the Poisson Pseudo Maximum Likelihood (PPML) estimator by the following equations.

$$eng_{it} = \exp\left[\alpha_0 + \alpha_1 \ln ypc_{it} + \alpha_2 (\ln ypc_{it})^2 + f_i + f_t\right] + \varepsilon_t \quad (3)$$

$$eng_{it} = \exp\left[\beta_0 + \beta_1 \ln ypc_{it} + \beta_2 (\ln ypc_{it})^2 + \beta_3\, nrr_{it} + \beta_4\, gov_{it} + f_t\right] + \varepsilon_t \quad (4)$$

The reason for the additional use of the PPML estimator is that the data of energy use might be plagued by "heteroskedasticity" problem, in which the OLS estimator leads to a bias and an inconsistency in its estimate. Thus, this study applies both of the estimators to ensure the robustness of their estimations, following the suggestions as in Santos Silva and Tenreyro (2006) and Head and Mayer (2014).

2.3 Econometric Analysis: Estimation Results

Table 4 reports the results of OLS estimation and PPML one in the form of log-link function. Column (i) displays the outcome of the fixed-effect model of each estimation, and Column (ii), (iii), (iv), and (v) presents the results of the alternative model containing the natural resources rents and the governance indicators instead of the fixed-effects. Both of OLS and PPML estimations show similar results in the sign and significance of each coefficient, and thus the subsequent description focuses on the result of PPML estimation that adjusts the heteroskedasticity. The findings from the estimation results are summarized as follows.

First, the EEKC hypothesis assuming the inverted-U-shaped relationship between energy use and GDP capita is confirmed in all the estimations from Column (i) to (v), because the coefficients of GDP per capita is significantly positive and those of its square is significantly negative. The turning points are, however, far beyond the reasonable range of GDP per capita. It might come from the observation in Section 2.1 that only Singapore and Japan show the inverted-U shape in their EEKC, while most of sample countries stay at the increasing trends of their EEKC. This finding leads the research focus to the locations of the EEKC trajectories rather than the EEKC shapes.

Second, focusing on the fixed effect model in Column (i), the coefficients of the country-specific dummies are significantly positive in Turkmenistan, Uzbekistan, and Kazakhstan in the CA countries (in common with the OLS estimation) and Brunei Darussalam; and insignificant or significantly negative in the other sample countries. It means that the energy uses of the three CA countries are inefficient due to their country-specific reasons compared to China, the benchmark country, and this result is consistent with the descriptive analysis in Section 2.1. The degree of the energy use inefficiency is shown by the magnitude of the coefficient of the country-specific dummy: exp.(0.936) = 2.550 in Turkmenistan, exp.(0.659) = 1.933 in Uzbekistan, and exp.(0.534) = 1.706 in Kazakhstan.

Third, turning to the alternative model containing the natural resources rents and the governance indicators in Column (ii) – (v), the coefficients of the natural resources rents (*nrr*) are significantly positive as expected in all the cases. As for the governance indicators, all the coefficients are significantly negative as supposed: the regulatory quality (*rgq*) and the rule of law (*rol*) show robust significance (the 99 percent level), while the government effectiveness (*gve*) and the control of corruption (*cor*) indicate weak one (the 90 percent level). This result suggests that the energy use is highly correlated with the natural resource abundance, and is more importantly affected by the policy governance such as the regulatory quality and the rule of law. The joint estimation outcomes of the country-specific fixed effect and the policy governance effect on the energy use lead to the question on the degree of contributions of the policy-governance factors to the country-specific energy use inefficiencies in the CA countries.

2.4 Econometric Analysis: Factor Compositions in Energy Use Inefficiencies

The final step is to examine the contributions of the natural resource abundance and the policy governance to the country-specific energy use efficiencies in the CA countries. Table 5 shows the fixed effects and the contributors in the four countries: Turkmenistan, Uzbekistan, Kazakhstan and Brunei Darussalam, focusing on the two governance indicators: the regulatory quality and the rule of law. Column (a) re-displays the coefficients of the country-specific fixed-effect dummies; Column (b) presents the period-average natural resources rents (*nrr*); Column (c) computes the *nrr* deviations from China (the benchmark country); Column (d) obtains the *nrr* contributions by multiplying the *nrr* deviations by the estimated *nrr* coefficient in Table 4; Column (e) presents the period-average governance indicators (the regulatory quality, *rgq* and the rule of law, *rol*); Column (f) computes the deviations of *rgq* and *rol* from China; Column (g) obtains the contributions of *rgq* and *rol* by multiplying their deviations by the estimated their coefficients in Table 4, respectively; and Column (h) finally shows the total contributions by summing up each of Column (d) and (g). Figure 2 displays the country-specific fixed-effects by the line and the contributions of the natural resources rents and the governance indicators by the bar graphs in the three CA countries.

The analytical results from Table 5 and Figure 2 are summarized as follows. First, the contributions of the natural resources rents account for 0.383 – 0.820 of the country fixed-effects in all the cases. Second, the regulatory quality has contribution rates to the country fixed-effects by 0.427 in Uzbekistan, 0.373 in Turkmenistan, and 0.038 in Kazakhstan. Third, the rule of law has contribution rates by 0.292 in Uzbekistan, 0.250 in Turkmenistan, and 0.159 in Kazakhstan. The results suggest that the lack of the policy governance as well as the natural resource abundance is an influential factor to explain the energy use inefficiency in Uzbekistan and Turkmenistan. This outcome is consistent with the argument of pointing out the lower performance of energy policies in Mehta, et al. (2021), Dyussembekova (2019), and Gomez et al. (2015). Thus, there would be much room for Uzbekistan and Turkmenistan to improve their energy use efficiencies by enhancing their performances of energy policies.

3. Case in Uzbekistan

The rise of population and the development of economy in Uzbekistan have induced increasing demands for energy. The population in Uzbekistan has risen from 20.8 million in 1991 to 33.7 million in 2020. In the economy, agricultural and industrial sectors are considered as dominant energy users. Thus, Uzbekistan's energy sector has played a significant role in that the value-added in the energy sector accounts for 7% of GDP and 72% of the government investment program. Moreover, primary energy demand in Uzbekistan is forecasted to increase with a annual growth rate of 1.7% by 2025 (Yuldasheva O., Goto N., 2016). Although there are a number of mines where gas-oil, coal, and uranium are extracted to produce energy, there is a shortage of energy generation and transmission. In fact, Uzbekistan has even resumed imports of electricity from neighboring Central Asian countries to meet the needs of the rising energy demands, especially during the peak load of the winter period: imports from Kazakhstan in 2019 and from Turkmenistan in February 2021.

What factors have caused the shortage of energy generation is a crucial question in Uzbekistan. First, the technologies and management in energy production are outdated and less efficient (e.g., Gomez et al. (2015). Although the energy-use intensity in Uzbekistan has decreased by approximately 45 percent for the last 15 years, it is still 35 percent higher than that of Kazakhstan and three times higher than that of Germany (World Bank Group). This is because most of the main energy generator, Thermal Power Station, which generates 56.5 million kilowatts of electricity, were built fifty years ago, and are still less productive under inefficient management system. The government is now on the way to modernize the energy generation system with the high-end technologies. Second, Uzbekistan has still depended highly on traditional energy resources such as natural gas (85 percent of energy products) (International Energy Agency). In Uzbekistan, sunny days are more than 300 days in during one year, and there are much room to develop renewable energy resources. According to statistics, the potential of the solar energy in Uzbekistan is enough to meet the rising energy demands and its production is expected to be cost-saving and sustainable, thereby contributing to energy-use intensity in the country.

4. Conclusion

This study examined the energy use inefficiency in the CA countries by using the analytical framework of EEKC. The EEKC analyses identified the energy-use inefficiency of Turkmenistan, Uzbekistan, and Kazakhstan, and could show the contributions of the weak policy governance as well as the natural resource abundance to their energy-use inefficiency. This analytical result could also be endorsed by the Uzbekistan case. Thus, the policy implication is that there would be much room for these countries to improve their energy-use efficiency by enhancing their performances of energy policies. The limitation of this study is the lack of the detailed researches on individual countries and thus of recommending the concrete policy prescriptions for their energy-use efficiency.

References

Aruga, K. 2019. Investigating the Energy-Environmental Kuznets Curve Hypothesis for the Asia-Pacific Region. *Sustainability*, 11: 2395.

Chen, P.Y., Chen, S.T., Hsu, C.S., and Chen, C.C. 2016. Modeling the global relationships among economic growth, energy consumption and CO2 emissions. *Renewable and Sustainable Energy Reviews*, 65: 420–431.

Gomez, A., Dopazo, C., and Fueyo, N. 2015. The future of energy in Uzbekistan. *Energy*, 85: 329-338.

Dorian, J.P. 2006. Central Asia: a major emerging energy player in the 21st century. *Energy Policy*, 34(5): 544-555.

Dorian, J.P., Tojiev, U., Tonkopy, M.S., Alaibek, O., and Daxiong, Q. 1999. Energy in central Asia and northwest China: major trends and opportunities for regional cooperation. *Energy Policy*, 27(5): 281-297.

Dyussembekova, G., Bayandina, G., Zakirova, D., Sartova, R., and Kalmenova, M. 2019. The Electric Energy Sector of Kazakhstan: State and Vision for the Country Taking into Account the International Trends. *International Journal of Energy Economics and Policy*, 9(3): 179-186.

Grossman, G., and Krueger, A. 1993. Environmental impacts of the North American Free Trade Agreement, in Garber, P. (ed.), *The U.S.-Mexico Free Trade Agreement*, Cambridge: MIT Press.

Hausman, J. 1978. Specification Tests in Econometrics. *Econometrica*, 46: 1251-1271.

Head, K., and Mayer, T. 2014. Gravity Equations: Workhorse, Toolkit, and Cookbook. In: Gopinath, G., Helpman, E., and Rogoff, K.S. (eds.), *Handbook of International Economics*, Oxford: Elsevier.

Hundie, S.K., and Daksa, M.D. 2019. Does energy-environmental Kuznets curve hold for Ethiopia? The relationship between energy intensity and economic growth. *Journal of Economic Structures*, 8: 1-21.

Kaliakparova, G.S., Gridneva, Y. E., Assanova, S.S., Sauranbay, S.B., and Saparbayev, A. D. 2020. International Economic Cooperation of Central Asian Countries on Energy Efficiency and Use of Renewable Energy Sources. *International Journal of Energy Economics and Policy*, 10(5): 539-545.

Luzzati, T. and Orsini, M. 2009. Investigating the energy-environmental Kuznets curve. *Energy*, 34: 291–300.

Mahmood, H., Maalel, N., and Hassan, M.S. 2021. Probing the Energy-Environmental Kuznets Curve Hypothesis in Oil and Natural Gas Consumption Models Considering Urbanization and Financial Development in Middle East Countries. *Energies*, 14: 3178.

Mehta, K., Ehrenwirth, M., Trinkl, C., Zörner, W., and Greenough, R. 2021. The Energy Situation in Central Asia: A Comprehensive Energy Review Focusing on Rural Areas. *Energies*, 14: 2805.

Pablo-Romero, M.P., and De Jesus, J. 2016. Economic growth and energy consumption: The Energy-Environmental Kuznets Curve for Latin America and the Caribbean. *Renewable and Sustainable Energy Reviews*, 60: 1343–1350.

Pablo-Romero, M.P., and Sanchez-Braza, A. 2017. Residential energy environmental Kuznets curve in the EU-28. *Energy*, 125: 44-54.

Santos Silva, J.M.C., and Tenreyro, S. 2006. The Log of Gravity. *Review of Economics and Statistics*, 88: 641-658.

Shahbaz, M., Mutascu, M., and Azim, P. 2013. Environmental Kuznets curve in Romania and the role of energy consumption. *Renewable and Sustainable Energy Reviews*, 18: 165–173.

Shahbaz, M., Mahalik, M.K., Shahzad, S.J.H., and Hammoudeh, S. 2019. Does the environmental Kuznets curve exist between globalization and energy consumption? Global evidence from the cross-correlation method. *International Journal of Finance & Economics*, 24(1): 540-557.

Suri, V., and Chapman, D. 1998. Economic growth, trade and energy: Implications for the environmental Kuznets curve. *Ecological Economics*, 25: 195–208.

Table 1 Profile of Central Asia Countries

Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan
Population (thousand, 2020)				
18,754	6,592	9,538	6,031	34,232
Surface Area (thousand sq. km)				
2,725	200	141	488	447
GDP per capita (current prices USD, 2020)				
8,733	1,146	844	7,967	1,702
Income Classification (2020)				
upper middle	lower middle	lower middle	upper middle	lower middle
Energy Use (kg of oil equivalent per capita, average for 1996-2014)				
3,511	552	336	3,925	1,843
East Asia & Pacific (excluding high income): 1,567				
Oil Rents (% of GDP, average for 1996-2019)				
14.796	0.372	0.130	15.267	4.055
East Asia & Pacific (excluding high income): 1.524				
Natural Gas Rents (% of GDP, average for 1996-2019)				
1.207	0.027	0.050	25.086	11.205
East Asia & Pacific (excluding high income): 0.281				
Coal Rents (% of GDP, average for 1996-2019)				
1.339	0.147	0.115	0.000	0.101
East Asia & Pacific (excluding high income): 1.035				

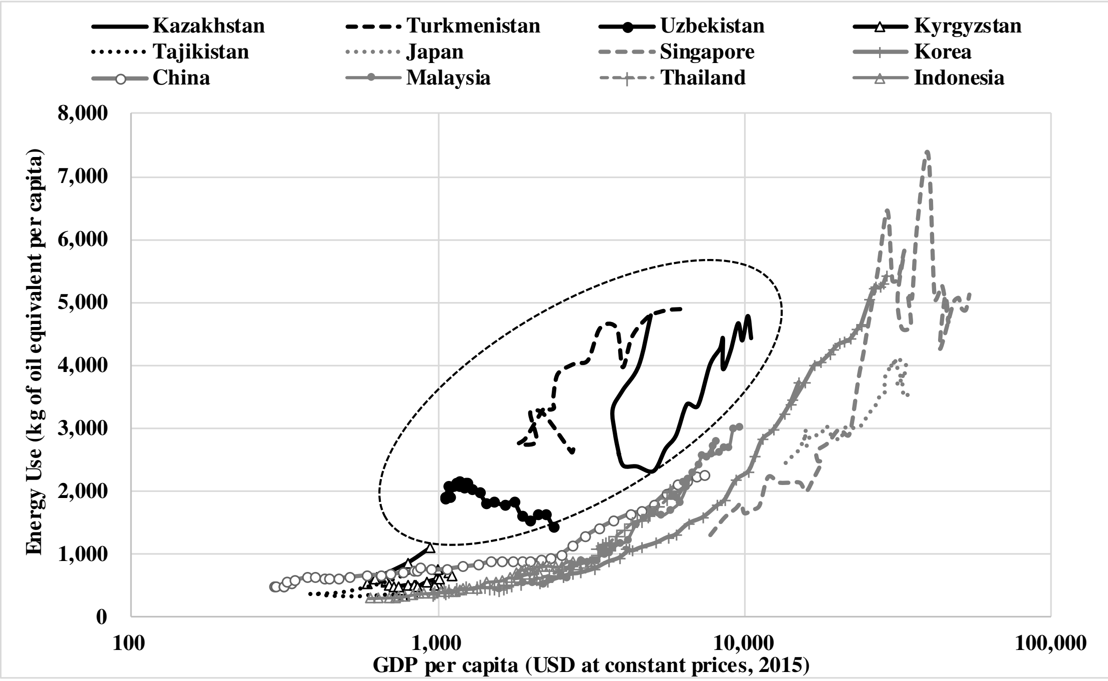
Sources:

Population, Surface Area, Energy Use, and Oil, Natural Gas and Coal Rents: World Bank Open Data, https://data.worldbank.org/

GDP per capita: World Economic Outlook Database, IMF, https://www.imf.org/en/Publications/WEO/weo-database/2021/April

Income Classification: World Bank, https://datahelpdesk.worldbank.org/knowledgebase/articles/906519

Figure 1 Trends in Energy Use in Selected Asian Countries



Sources: Author's calculation based on World Bank Open Data and UNCTAD Stat

Table 2 Descriptive Statistics

Variables	Obs.	Mean	Std. Dev.	Min.	Max
eng	879	1,538	1,856	87	9,837
ypc	930	6,582	11,728	151	68,694
gve	391	-0.158	0.906	-1.644	2.437
rgq	391	-0.278	0.940	-2.344	2.261
rol	391	-0.348	0.864	-1.740	1.825
cor	391	-0.442	0.885	-1.673	2.326

Sources: Author's calculation

Table 3 Correlation Matrix and Variance Inflation Factors

	gve	*rgq*	*rol*	*cor*
gve	1.000			
rgq	0.930	1.000		
rol	0.944	0.910	1.000	
cor	0.944	0.896	0.951	1.000
VIF	15.798	8.188	13.746	13.235

Sources: Author's estimation

Table 4 Estimation Outcomes

[OLS Estimation]

Variables	(i) ln *eng*	(ii) ln *eng*	(iii) ln *eng*	(iv) ln *eng*	(v) ln *eng*
ln *ypc*	1.118 ***	0.941 ***	0.932 ***	0.913 ***	0.921 ***
	(45.452)	(14.012)	(14.235)	(14.058)	(12.971)
$(\ln ypc)^2$	-0.027 ***	-0.011 **	-0.010 **	-0.007	-0.010 *
	(-9.002)	(-2.110)	(-2.133)	(-1.610)	(-1.808)
nrr		0.026 ***	0.026 ***	0.025 ***	0.027 ***
		(12.420)	(12.477)	(12.457)	(13.591)
gve		-0.107 **			
		(-2.048)			
rgq			-0.116 ***		
			(-2.727)		
rol				-0.165 ***	
				(-3.540)	
cor					-0.108 **
					(-2.148)
Country fix effects					
Turkmenistan	0.837 ***				
Uzbekistan	0.676 ***				
Kazakhstan	0.308 ***				
Mongolia	0.101 *				
Myanmar	0.002				
Kyrgyzstan	-0.094				
Nepal	-0.135 **				
Brunei	-0.216 *				
Tajikistan	-0.323 ***				
India	-0.331 ***				
Malaysia	-0.429 ***				
Korea	-0.444 ***				
Vietnam	-0.482 ***				
Singapore	-0.526 ***				
Cambodia	-0.541 ***				
Thailand	-0.555 ***				
Pakistan	-0.558 ***				
Japan	-0.580 ***				
Indonesia	-0.594 ***				
Philippines	-0.917 ***				
Sri Lanka	-0.985 ***				
Bangladesh	-1.314 ***				
Period fixed effects	Yes	Yes	Yes	Yes	Yes
Number of observation]	869	366	366	366	366

[PPML Estimation]

Variables	(i) ln *eng*	(ii) ln *eng*	(iii) ln *eng*	(iv) ln *eng*	(v) ln *eng*
ln *ypc*	1.087 ***	1.018 ***	0.961 ***	0.969 ***	1.006 ***
	(15.224)	(14.334)	(15.282)	(14.132)	(13.259)
$(\ln ypc)^2$	-0.035 ***	-0.017 **	-0.011 **	-0.011 *	-0.017 **
	(-5.067)	(-2.436)	(-2.007)	(-1.802)	(-2.338)
nrr		0.020 ***	0.018 ***	0.017 ***	0.021 ***
		(7.976)	(6.678)	(9.613)	(11.244)
gve		-0.149 *			
		(-1.769)			
rgq			-0.206 ***		
			(-3.108)		
rol				-0.240 ***	
				(-3.263)	
cor					-0.133 *
					(-1.785)
Country fix effects					
Turkmenistan	0.936 ***				
Uzbekistan	0.659 ***				
Brunei	0.546 **				
Kazakhstan	0.534 ***				
Mongolia	0.186				
Singapore	0.119				
Korea	0.114				
Japan	0.012				
Malaysia	-0.043				
Kyrgyzstan	-0.170				
Nepal	-0.219				
Myanmar	-0.231				
Thailand	-0.278 **				
India	-0.365 ***				
Tajikistan	-0.447 **				
Indonesia	-0.474 ***				
Vietnam	-0.504 ***				
Pakistan	-0.519 ***				
Cambodia	-0.686 ***				
Philippines	-0.768 ***				
Sri Lanka	-0.910 ***				
Bangladesh	-1.319 ***				
Period fixed effects	Yes	Yes	Yes	Yes	Yes
Number of observation]	869	366	366	366	366

Note: T-statistics are in parentheses. ***, **, and * denote statistical significance at 99, 95 and 90 percent level, respectively.
Source: Author’s estimation

Table 5 Fixed Effect Analysis in Selected Countries

[Regulatory Quality]

	Fixed Effects	*nrr*	(b) - China *nrr*	(c) × 0.018	*rgq*	(e) - China *rgq*	(f) × -0.206	(d) + (g)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Turkmenistan	0.937	43.787	40.919	0.769	-1.955	-1.689	0.350	1.118
Uzbekistan	0.660	16.941	14.074	0.264	-1.628	-1.362	0.282	0.546
Kazakhstan	0.535	18.066	15.199	0.285	-0.363	-0.097	0.020	0.306
Brunei	0.546	24.525	21.657	0.407	1.040	1.306	-0.270	0.137
China	0.000	2.868	-	-	-0.266	-	-	-

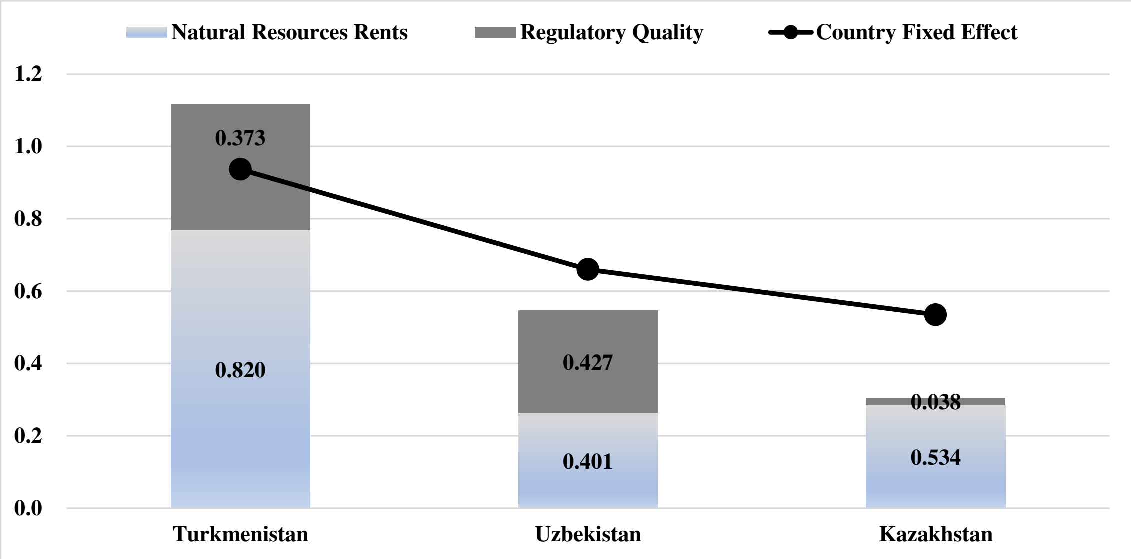
[Rule of Law]

	Fixed Effects	*nrr*	(b) - China *nrr*	(c) × 0.017	*rol*	(e) - China *rol*	(f) × -0.240	(d) + (g)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Turkmenistan	0.937	43.787	40.919	0.735	-1.470	-0.973	0.234	0.970
Uzbekistan	0.660	16.941	14.074	0.253	-1.299	-0.802	0.193	0.446
Kazakhstan	0.535	18.066	15.199	0.273	-0.850	-0.353	0.085	0.358
Brunei	0.546	24.525	21.657	0.389	0.548	1.045	-0.252	0.138
China	0.000	2.868	-	-	-0.497	-	-	-

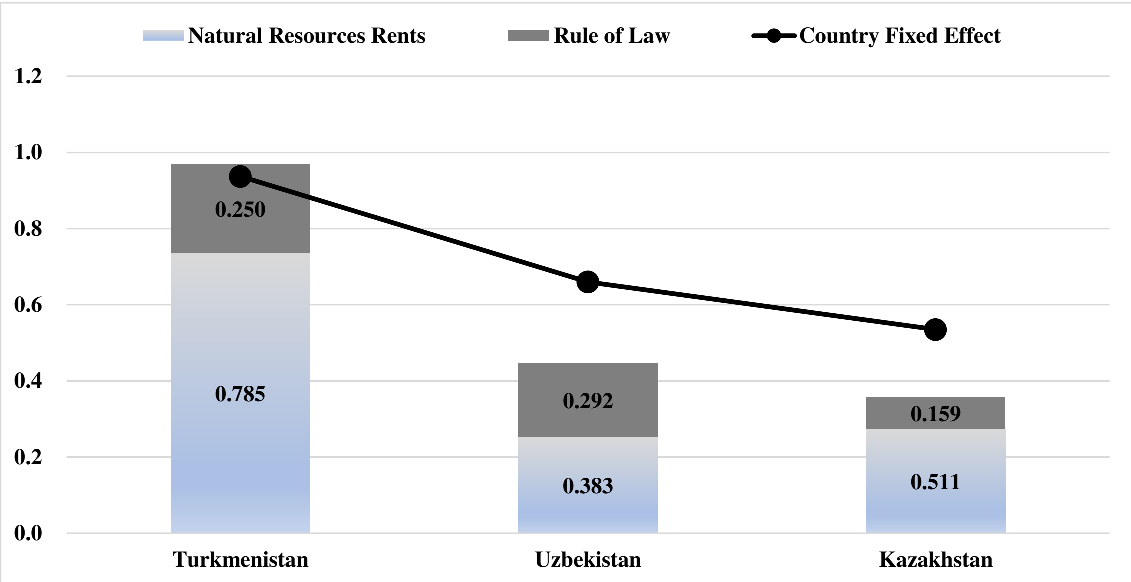
Source: Author's calculation

Figure 2 Decomposition of Fixed Effects in Selected Central Asian Countries

[Regulatory Quality]



[Rule of Law]



Note: The figure of the bar graph indicates the contribution rate of each factor (the natural resources rents and the governance indicators) to the country fixed-effect.

Source: Author's calculation