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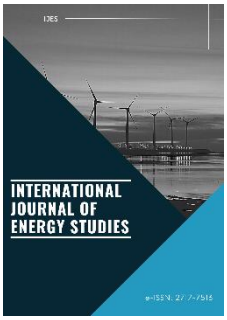

Research Article
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Do financial development, trade openness, and institutional quality matter for energy consumption in Central Asia?

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Highlights

- The study examines the effects of financial development, trade openness, and institutional quality on energy consumption in Central Asian countries.
- The purpose of the study is to assess the factors influencing energy consumption in Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan between 1996 and 2014.
- Institutional quality was proxied by "political stability and absence of violence" from World Bank.
- The analysis of static panel data reveals that financial development and trade openness positively influence energy consumption. Furthermore, it has been found that political stability has a major and positive impact on energy consumption.
- Policymakers are mainly recommended 1) to invest in renewable energy sources necessary for sustainable growth, addressing the increasing energy demands and 2) to ensure that energy policy stringency is provided, leading to increasing institutional quality.

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ABSTRACT

This study aims to provide valuable information on which factors are determinant for energy consumption in the long term. In this respect, the study investigates the impact of financial development, trade openness, and institutional quality on energy consumption for Central Asia which comprises Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The analysis covers 1996–2014 period and political stability and absence of violence is included as institutional quality indicator as described by the World Bank. To test this relationship, the method employed is static panel data analysis. Empirical results show that financial development and trade openness positively affect energy consumption in these countries. In addition, institutional quality also has positive and significant effect on energy consumption. Based on this finding, policymakers are advised to invest in renewable energy sources given the energy needs and recommended to ensure that energy policy stringency is provided, leading to increasing institutional quality.

Keywords: Energy consumption, Trade openness, Political stability, Panel data analysis, Central Asia

1. INTRODUCTION

Energy is an imperative element that is not only used directly for various purposes in daily life but also a key component in the production of many goods and services. In other words, direct or indirect use of energy is common in transportation, industry, manufacturing, and food sectors but not only these. This, each passing day, enhances energy requirements and makes energy valuable and crucial. Accordingly, energy consumption is known to rise recently based on different factors. In the light of literature and theories, we think that financial development, trade openness, institutional quality, and urbanization play a decisive role in energy consumption.

Nexus between financial development and energy consumption is complicated a little and emanates from several channels. Prior to these channels, it is crucial to specify that a lot of energy is key to the production of almost all goods and services (Mahalik et al., 2017). In this way, the first channel that financial development affects the demand for energy is the consumer effect which makes borrowing money for consumers to buy their wants and needs. The second one is business effect which makes access easier for businesses to financial capital, so a well-developed financial system enables the businesses to grow. Accordingly, stock market development that signs economic growth and prosperity is also increased and consumer and business confidence support each other, increasing the demand for energy intensive goods. This effect which consumers and businesses create together can be called wealth effect and emerges from increasing the financial activity in the market (Sadorsky, 2010, 2529; Sadorsky, 2011).

From a different viewpoint, according to Mahalik et al., financial development attracts inflows of foreign direct investment enhancing economic efficiency, thus, affecting economic activity and demand for energy (Mahalik et al., 2017). In this direction, Sadorsky, Shahbaz and Lean and Mahalik et al. indicate a positive relationship between financial development and energy consumption (Sadorsky, 2011; Shahbaz and Lean, 2012; Mahalik et al., 2017). On the other hand, it can be said that using efficient technologies on the grounds of financial development can reduce energy consumption. Chiu and Lee found that the impacts of different types of financial development and country risk environments on energy consumption are different in 79 countries (Chiu and Lee, 2020). As a result, the nexus between financial development and energy consumption can be in different directions on the grounds of the economic structure of a country.

The relationship between trade openness and energy demand emerges from three channels: energy demand via scale effect, technique effect and composite effect. Trade openness encourages economic activities and therefore domestic production, so this situation tends to increase energy demand. We call this process as a scale effect. Technique effect emanates from adoption of advanced technology for developing economies. Trade openness helps lower energy intensity and produces more outputs thanks to this adoption of advanced technology. Lastly, composite effect depends on stages of economic development. Shifting from agriculture to industry requires energy consumption more and in maturity stage of economic development energy intensity is lowered because of composite effect (Shahbaz et al., 2014). On the other hand, since energy is necessary for production and transportation of exporting or importing goods, energy affects trade openness and, in this respect, Nasreen and Anwar, in their study for 15 Asian countries, show that there is a bidirectional causality between trade openness and energy consumption and positive impact of trade openness on energy consumption (Nasreen and Anwar, 2014). Shahbaz et al. (2014) investigates this relationship for 91 countries and the results of pooled mean group estimation show that it has differed in middle-low-income countries and high-income countries.

Political stability and absence of violence, which is one of the institutional quality indicators, measures perceptions of the likelihood of political instability and/or politically-motivated violence (World Bank, 2024). Considering that political stability signifies political efficiency, it can be expected that it affects energy consumption behavior. Accordingly, the energy-efficient policies implemented by the government might regulate the energy utilization attitude of residents (Chang et al., 2018; Godil et al., 2021). The relationship between institutional quality and energy consumption can be observed by means of corruption (Al-Tal and Al-Tarawneh, 2021). In this direction, Fredriksson et al. (2004) evidence that corruption reduces energy policy stringency. Thus, while trying to make efficient policies regarding energy consumption, it is proven that institutional quality or political stability should be taken into consideration.

Other variables considered to affect energy consumption, which are used as control variables in our model, are urbanization and GDP per capita. Rapid growth in population, which is the most important trigger of urbanization, is considered to boost energy consumption (Shahbaz and Lean, 2012). Moreover, urbanization promotes the development of the economy and contributes to the living standard of households, thus rises energy consumption (Liu et al., 2017). Shahbaz and Lean (2012) for Tunisia, Mahalik et al. (2017) for Saudi Arabia, and Sheng et al. (2017) for 78 countries

confirm that the process of urbanization increases energy demand and so energy consumption. Disparately, Liu et al. (2017) claim that urbanization promotes energy efficiency thanks to advancements in urbanization-based industry, technology, and products and thus urbanization can lead to a decrease in energy consumption, as is the case with China. The relationship between GDP per capita and energy consumption proceeds from that energy is a pivotal input for economic growth. That is, it appears as the driving force of GDP. Another channel creating the relationship between GDP and energy consumption depends on people's energy consumption habits. These habits are affected by the administration's energy policy results, bringing structural change in the relationship between energy consumption and GDP (Lee and Chang, 2007).

It is readily apparent that factors influencing energy consumption do not have to be same for every country or do not have to have an effect in the same direction. The effects can vary depending on the distinctive characteristics of the economic structure, energy sector, political system, consumption patterns, etc. In this respect, firstly, distribution of energy consumption in Central Asia is set out in Figure 1.

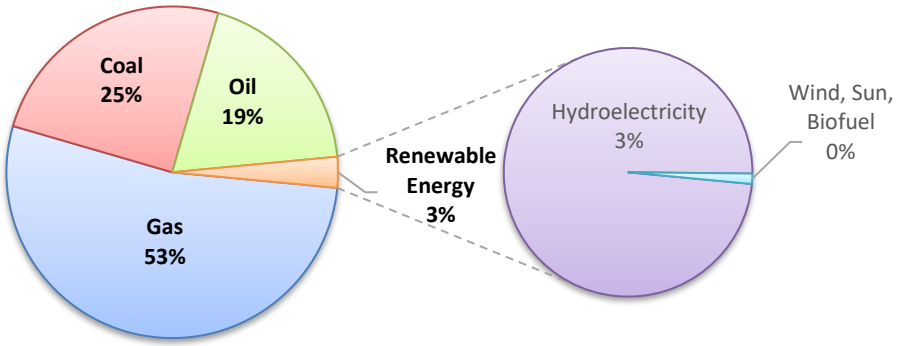

Figure 1. Percentage Distribution of Energy Consumption in Central Asia (ORASAM, 2022)

The most consumed energy source is natural gas, which meets more than half of the energy requirement. Coal and oil follow natural gas, meeting 25 percent and 19 percent of energy requirement, respectively. Kyrgyz Republic and Tajikistan have an important hydroelectricity potential and substantially consume less natural gas, but the ratio of renewable energy consumption happens 3 percent in total.

Considering that coal and gas form most of the energy consumption in Central Asia, import and export of coal and gas markedly gives an opinion about energy import/export dependencies in

Central Asia. Accordingly, Table 1 provides total import and export of coal and gas in Central Asia.

Table 1. Import and export of coal and gas in Central Asia (Terajoule (TJ) = 278 megawatt/s)

	Coal Import	**Coal Export**		**Gas Import**	**Gas Export**
1995	54.467	393.581	**1995**	447.655	1.119.956
2000	42.424	640.356	**2000**	272.897	1.707.111
2005	58.800	457.650	**2005**	527.212	2.804.381
2010	45.728	576.610	**2010**	155.161	1.594.839
2015	68.422	542.481	**2015**	230.138	3.390.061
2019	81.647	479.990	**2020**	616.006	3.648.610

Source: ORASAM (Orta Asya Enerji Raporu), 2022

Central Asian countries (excluding Kyrgyz Republic and Tajikistan) are net exporter of both gas and coal and inherently this situation is reflected in their energy consumption. 77 percent of renewable energy production is provided by Kyrgyz Republic and Tajikistan, which consume much more renewable energy (hydroelectricity) less gas and coal (ORASAM, 2022). Accordingly, it can be inferred that energy consumption in Central Asia is parallel to energy production. That infrastructure challenges lead to an increase in investment cost may be one reason to prefer existing energy resources to use. However, meeting the increasing energy consumption in the most effective way, especially with sustainable and eco-friendly resources, should be the goal. Energy consumption should be balanced and harmonized with factors such as nature, environmental issues, and current economic conditions. Otherwise, the increase in energy consumption worldwide can cause many problems not only in the economy but also in more areas. For instance, unregulated or unchecked energy consumption leads to environmental problems. Furthermore, we basically know that resources are limited in the world so this type of consumption can cause conflict between countries. For this reason, investigating the determinants of energy consumption and developing a policy based on balanced energy consumption has become more important in recent times.

Our main objective is to provide valuable information on which factors are determinant for energy consumption in the long term in Central Asia. This study is expected to contribute to existing literature in two ways. First, this study differs from existing studies by considering the effect of socio-economic and institutional structure of the country on energy consumption. Accordingly,

the role of financial development, trade openness and institutional quality on energy consumption is examined. At the same time, urbanization rate and GDP per capita in constant prices are also used as control variable. Second, to the best of our knowledge, this is the first study to examine the relationship between the relevant variables for a panel of five Central Asian countries which comprise Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The econometric method has been determined by taking into account the period of continuous data in the 5 countries of Central Asia. Static panel data estimation methods including pooled OLS, fixed effects (FE) and random effects (RE) models are employed covering 1996–2014 period. The empirical results are obtained using the Driscoll and Kraay standard error estimator, which is robust to cross-sectional dependence, autocorrelation and heteroskedasticity.

The rest of the paper is structured as follows: The next part provides different studies in this context. The third one gives data and empirical model used in the study to analyze the impact of variables on the energy consumption. The fourth part describes the methodology, and the fifth part discusses the empirical results. The last part concludes the issue as a summary.

2. LITERATURE REVIEW

The literature that includes energy consumption issues is pretty extensive since many studies have been conducted to prove its relationship with the other economic factors. The paper by Kraft and Kraft (1978) is an early study to understand the driving forces of energy consumption, including gross national product. According to Chang (2014), while income has a positive effect on energy consumption in developing economies, the same effect happens in advanced economies in the condition in which the economy achieves a threshold level of income. Abosedra et al. (2015) have provided that economic growth results in an increase in energy consumption in Lebanon, while Al-Tal and Al-Tarawneh (2021) have suggested that negative relationship between economic growth and energy consumption exists in the MENA region. For Central Asian countries, Nguyen (2019) has found that GDP per capita has a negative impact on per capita energy consumption in the region. This discrepancy may be due to the people's energy consumption habits affected by the administration’s energy policy results, bringing structural change in the relationship between energy consumption and GDP (Lee and Chang, 2007). Different from those, Doğan and Değer (2016) have suggested a unidirectional causality correlation from total energy consumption to economic growth in BRIC countries in 2000-2012 period. In a similar way, Mohsin et al. (2022)

and Abosedra et al. (2015) have found that energy consumption increases economic growth respectively in European and Central Asian Countries and in Lebanon.

Chunyu et al. (2021) for European and Central Asian Countries, using ARDL approach, and Farhani and Öztürk (2015) for Tunisia, have proved that there is a positive influence of energy consumption on carbon emissions in the short-term. Latter one has also claimed that there is a short-run unidirectional effect from energy consumption capita to financial development and trade openness. Abosedra et al. (2015) have indicated that financial development does influence on energy consumption positively. In a similar way, Sadorsky (2010) for 22 emerging markets, Shahbaz and Lean (2012) for Tunisia and Mahalik et al. (2017) for Saudi Arabia have showed that financial development has affected energy consumption in a positive way. Baloch et al. (2019) have researched non-linear relationship between financial development, economic growth, and energy consumption covering the period of 1980-2016 in OECD countries. Conducting the Driscoll–Kraay standard errors panel regression model, they have indicated that the relationship between financial development and energy consumption as well as between economic growth and energy consumption have an inverted U-shape. Having partially different results, Chiu and Lee (2020), in their paper for 79 countries, have shown that different types of financial development can cause different results. Similarly, according to Chang (2014) financial development leads to an increase in energy consumption in emerging countries but it causes a decline slightly in advanced economies.

Rafindadi and Öztürk (2017) and Duan and Guo (2021) have suggested that financial development and trade openness add to energy consumption, in South Africa and China respectively. The findings of Nasreen and Anwar (2014) about the effect of trade openness on energy consumption have also supported this result. Haider and Adil (2019), to analyze the impact of macro-level financial development and trade openness on energy consumption in the industrial sector in India, have conducted the ARDL bounds testing approach. According to the results, while financial development has positive and significant effects, the effect of trade openness is statistically insignificant. Destek (2015), differently, in his paper for Turkey, has found that trade openness has positive effect on energy consumption whereas financial development has negative effect. In contrast with those findings, Rafindadi (2015) has revealed that an increase in financial development and trade openness leads to a decline in energy consumption in Germany. Disparately, Shahbaz et al. (2014) have found that the relationship between trade openness and

energy consumption is different in high income countries and low-income countries, it is inverted U-shaped and U-shaped, respectively. In a nutshell, differences in nexus between energy consumption and financial development and trade openness are based upon countries and methods picked in research.

Chang et al. (2018) for OECD countries and Azam et al. (2020) for 66 developing countries, have suggested that institutional quality has significant influence on energy consumption. Godil et al. (2021) have said that effect of institutional quality on energy consumption is negative whereas that of financial development is positive for India. Al-Tal and Al-Tarawneh (2021), on the other hand, has analyzed the impact of government's effectiveness and political stability on energy consumption in the Middle East and North Africa region and found negative effect. Kartal et al. (2022) and Adebayo (2022) have researched how political stability affects consumption-based carbon emissions. The existing studies generally demonstrate a negative effect implying that an increase in institutional quality causes a decrease in energy consumption. However, the number of studies linking institutional quality and energy consumption is very few, indicating a considerable gap in literature. Considering that institutional quality -based on political efficiency- can be a notable determinant of energy consumption supports the motivation of the study. Furthermore, the fact that our analysis includes this relationship for Central Asian countries is noteworthy.

Sardosky (2013) and Salim and Shafiei (2014) have investigated the linkage between urbanization and energy consumption in OECD countries using different methods and the results say if urbanization level increases, energy consumption increases correspondingly. Similarly, Liu (2009), Wang et al. (2014), and Ren et al. (2015) for China and Jones (1991) for 59 developing countries have reached to the same result. Liu et al. (2017) have reviewed urbanization effect and its spatial spillover effect on energy consumption in China. Surprisingly, the findings show that an increase in the urbanization level implies a decrease in energy consumption level but the spatial spillover effect on adjacent areas is positive. Differently from these findings, Poumanyvong and Kaneko (2010) have indicated that urbanization has different effects on energy consumption according to the income group. The findings demonstrate that urbanization decreases energy consumption in the low-income group, while it does the opposite effect in the middle- and high-income groups.

As it is seen in this part, the relationship between the given factors and energy consumption varies based on different elements such as country, economic structure, and income group. There is not any consensus about how these factors affect energy consumption. To the best of our knowledge, there is also a gap in this issue for the countries on which we analyze.

3. DATA AND EMPIRICAL MODEL

To investigate the effects of financial development, trade openness and institutional quality on energy consumption in Central Asia, panel regression models are performed. A balanced panel sample of five Central Asian countries (Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan) covering the period from 1996 to 2014 is used. The variables are included in the empirical model in original forms. Based on the theoretical framework and literature review presented in the earlier section, empirical panel data model is specified as follows:

$$ENERGY_{it} = \alpha_0 + \alpha_1 FD_{it} + \alpha_2 OPEN_{it} + \alpha_3 POLSTAB_{it} + \alpha_4 GDPPC_{it} + \alpha_5 URB_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where the subscripts i and t denote the cross-sectional unit (country) and the time period, respectively. The subscripts it indicates the observations vary across country and time period. μ_i is individual effect, λ_t is time effect and ε is the error term. The dependent variable, ENERGY is energy use measured in terms of kilograms of oil equivalent per capita. FD refers to financial development index from IMF database created by aggregating sub-indices of financial markets and financial institutions. OPEN indicates trade openness which measured in trade as a percentage of GDP. Among the other explanatory variables, GDPPC in constant prices as a proxy for real income is GDP per capita in 2015 constant US dollars and URB indicates urban population percentage of total population. Urbanisation and GDP per capita are two critical factors influencing energy consumption. In the literature, the relationship between these variables has usually been described as positive. Urbanisation increases the demand for energy due to the increase in the need for infrastructure and economic activities. In particular, urban areas with more intensive industrialisation and trade consume more energy than rural areas. At the same time, the increase in GDP per capita leads to a higher level of individual well-being and a higher demand for energy (Burney, 1995; Liu, 2009; Wang et al., 2019; Zhao and Wang, 2015).

POLSTAB as a proxy of institutional quality refers to political stability and absence of violence/terrorism which measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism produced by Kaufman, Kraay and Mastruzzi (2010). Political stability and the absence of violence play an important role in the design of an energy policy. A stable political environment and the absence of violence create a secure and predictable environment. This encourages energy investment. This is particularly important for international investors planning to invest in energy infrastructure for the long term. Political stability allows for more effective regulatory enforcement and helps manage energy resources efficiently. Furthermore, energy policies in countries with low levels of violence and terrorism tend to be more comprehensive and sustainable. Such nations can more effectively implement national energy security strategies and reduce energy dependence through energy diversification (Deese, 1979; Alesina and Perotti, 1996; Darby, 2004; Wang et al., 2024).

The data of ENERGY, OPEN, GDPPC, URB were obtained from World Bank World Development Indicators Database (WDI) and POLSTAB was downloaded from World Governance Indicators (WGI) Database of World Bank. In addition, FD was extracted from IMF International Financial Statistics database. All estimations were performed using the Stata 15 software. The descriptions of the variables and data sources are presented in Table 2.

Table 2. Data source and description of the variables

Abbreviation	Variables	Description	Data Source
$ENERGY$	Energy use	kg of oil equivalent per capita	World Bank WDI
FD	Financial Development Index	Index	IMF
$OPEN$	Trade openness	% of GDP	World Bank WDI
$POLSTAB$	Political stability and absence of violence	-2.5 and 2.5	World Bank WGI
$GDPPC$	GDP per capita	Constant 2015 US$	World Bank WDI
URB	Urbanization	The ratio of urban population to the total population	World Bank WDI

Before regressing the model, it is advisable to check the properties of the variables. To this end, the first step was to check the variance inflation factors for the presence of multicollinearity

between the independent variables. If the variance inflation factors (VIF) of variables is less than 5, there is no multicollinearity problem. If the VIF values exceeds 10, it can be said that variables are highly collinear (Gujarati and Porter, 2009, 340).

Table 3. Test for multicollinearity

Independent Variables	VIF	$1/VIF$
FD	3.77	0.265321
$OPEN$	1.83	0.545770
$POLSTAB$	2.17	0.460123
$GDPPC$	5.46	0.183111
URB	3.80	0.263021
$Mean\ VIF$	3.41	

VIF of the explanatory variables in this study are reported in the Table 3. The fact that the VIF values are below the commonly accepted level is an indication of low multicollinearity between the explanatory variables.

Table 4. Correlation matrix

Variable	$ENERGY$	FD	$OPEN$	$POLSTAB$	$GDPPC$	URB
$ENERGY$	1.000					
FD	0.508 (0.00)	1.000				
$OPEN$	0.367 (0.00)	0.451 (0.00)	1.000			
$POLSTAB$	0.718 (0.00)	0.334 (0.00)	0.263 (0.01)	1.000		
$GDPPC$	0.807 (0.00)	0.778 (0.00)	0.245 (0.01)	0.621 (0.00)	1.000	
URB	0.815 (0.00)	0.684 (0.00)	0.534 (0.00)	0.627 (0.00)	0.765 (0.00)	1.000

Note: Numbers in parenthesis are p-values.

Table 4 reports the correlation matrix between the variables. Energy consumption has a positive and significant relationship with the FD, OPEN and GDPPC at the 99% level of significance. In addition, there is a positive and significant relationship with political stability and the rate of urbanization at the 95% level of significance. In addition, there is no high correlation between the independent variables according to the results of the correlation analysis.

4. METHODOLOGY

Hsiao (2003), Baltagi (2005), and Andreß, Golsch and Schmidt (2013) list several advantages of using panels. The obvious benefit is that it allows the study of a large sample with more degrees of freedom. If a panel has N cross-sections and T time series, a total of NxT observations can be analyzed. Another advantage is that heterogeneity can be accounted for by using country-specific individual variables.

Panel data consists of two components: individual effect and time effect. Characteristics of cross-sectional units such as geographic location, climate, ability, gender and social class, which remain constant over time but vary for each unit, are expressed in individual or country-specific effects. Time effects are characteristics such as economic crisis, natural disasters, policy changes that are constant across units but vary over time (Baltagi, 2005; Cameron and Trivedi, 2005).

If both individual (country-specific) and time effects are absent, the pooled OLS provides consistent estimates. In the pooled OLS, both the constant and slope parameters remain constant across units and time. In other words, they take on homogeneous values. However, if the slope parameter is constant and the fixed parameter varies across units and/or time, individual effect model, time effect model and two-way (individual and time effect) models will emerge. F test, Lagrange Multiplier test (LM) and Likelihood Ratio (LR) test are used to test the existence of these effects (Park, 2009).

$$y_{it} = x'_{it}\beta + \alpha_i + \varepsilon_{it} \qquad t = 1,2,\dots,T \qquad i = 1,2,\dots N \tag{2}$$

The panel data regression model is shown in Equation 2. Unobservable individual characteristics that remain constant over time are included in the equation as α_i. These models, which include unobserved effects constant over time, are fixed-effects (FE) models. The FE model assumes that the error term is related to other explanatory variables and accepts individual effects as part of the constant term (Wooldridge, 2010, 285).

Differences between cross-sectional units can also arise randomly. The random effects (RE) model assumes that country-specific differences are determined at random and are considered in the error term (Greene, 2003, 285). The basic assumption of the RE model is that the correlation between individual (country-specific) effects and explanatory variables is zero. The fixed effects (FE)

model, on the other hand, assumes that the correlation between individual effects and explanatory variables is different from zero (Cameron and Trivedi, 2005, 700).

There are a few tests for the choice between fixed effects and random effects estimators. The Hausman (1978) specification test is the mostly used method in the literature (Torres-Reyna, 2007). The Hausman test confirms whether there is a systematic difference between the FE and RE estimates (Baum, 2006, 230). Under the null hypothesis, both estimators are consistent and but only RE model are efficient. Under the alternative hypothesis FE models are consistent but RE model is inconsistent (Cameron and Trivedi, 2005). In light of this, the RE estimator is consistent and more efficient than the FE estimator under null hypothesis while only FE remain consistent under the alternative. Accordingly, if the null hypothesis is rejected, the FE model should be preferred instead of the RE model (Baltagi, 2005, 66).

Hausman test statistic shows an asymptotic chi-square distribution and is calculated using Equation 3 (Sheytanova, 2014, 12-13).

$$H = \left(\hat{\beta}_{FE} - \hat{\beta}_{RE}\right)' \left[var(\hat{\beta}_{FE}) - var(\hat{\beta}_{RE})\right]^{-1} \left(\hat{\beta}_{FE} - \hat{\beta}_{RE}\right) \quad (3)$$

5. RESULT AND DISCUSSION

Panel data regressions can be estimated using static panel data estimation methods including pooled OLS, fixed effects (FE) and random effects (RE) models. However, pooled OLS estimation results are not reliable in the presence of individual and time effects. F and LR tests provide information of the presence of these effects. F test is used to determine either pooled OLS or FE model is preferable, while LR test is used to choose between pooled OLS and random effect models.

The F and LR test results in the Table 5 assert that the null hypothesis of no individual and time effects is rejected at 99% significance level. The F test suggest that FE model with individual effects is more appropriate than pooled OLS, while the results of LR test confirms that the RE model is preferred to pooled OLS. Pooled OLS model is no longer valid and Hausman test will be conduct the compare between the FE and RE models.

Table 5. Testing individual and time effects with F and LR statistics

	Individual Effect		Time Effect		Individual and Time Effect	
	Statistics	Prob.	Statistics	Prob.	Statistics	Prob.
F	123.07	0.00	0.45	0.97	5.18	0.00
LR	143.91	0.00	0.03	0.99	143.91	0.00

Hausman Test		
Robust Hausman	7.59	0.1804

The null hypothesis of the Hausman test states that the coefficients of both the FE and RE models are consistent. However, only the coefficients of the RE model are efficient. The alternative hypothesis denotes that the FE models are consistent but RE model is inconsistent. Accordingly, the FE model should be preferred to the RE model when rejecting the null hypothesis.

Under the same hypotheses, the Robust Hausman (rhausman) test gives more reliable results than the Hausman test. According to R-Hausman test statistic in Table 5, the null hypothesis cannot be rejected and the results of RE model are more consistent and efficient than the FE model. Hence, the coefficients will be estimated using RE model with individual effect.

Panel data estimations often violate the standard assumptions of the regression. Therefore, it is important to perform some diagnostic tests such as autocorrelation, heteroskedasticity, normal distribution and cross-sectional dependence. In this study, the estimates of the RE model with individual effects are checked for the basic assumptions and the results of diagnostic tests are shown in Table 6.

Table 6. Results of diagnostic test for RE model with individual effects

	Test	Statistics	Prob.
Autocorrelation	Bhargava, Franzini and Narendranatha (1982) Durbin-Watson Test	0.5337	
	Baltagi and Wu (1999) LBI	0.7612	
Heteroskedasticity	Levene (1960)	W0 = 8.006	0.00
	Brown and Forsythe (1974)	W50 = 5.029	0.00
		W10 = 7.679	0.00

Cross-sectional dependence	Friedman (1937)	14.640	0.005
	Pesaran (2004)	-0.553	0.580
	Frees (1995, 2004)	0.989	Critical values
			Alpha=0.10: 0.1360
			Alpha=0.05: 0.1782
			Alpha=0.01: 0.2601
Normal Distribution	D'Agostino, Belanger and D'Agostino (1990)	e=1.47	0.47
		u=8.88	0.01

The modified Bhargava et al. (1982) Durbin-Watson test and the Baltagi and Wu (1999) LBI test are used to check for the presence of autocorrelation. It was determined that there was a first order autocorrelation problem in the RE model with individual effects, as the DW and LBI statistics were less than 2. The null hypothesis of the Pesaran (2004), Friedman (1937) and Frees (1995, 204) is cross-sectional independence, while the alternative hypothesis is cross-sectional dependence. Friedman (1937) and Frees (1995, 2004) statistics indicate that the presence of cross-sectional dependence. To test for the existence of constant variance, Levene (1960) and Brown and Forsythe (1974) tests were carried out. According to the results, the null hypothesis of constant variance is rejected. Finally, D'Agostino-Belanger- D'Agostino (1990) test results reveal that both the individual effect and the error term are normally distributed.

Driscoll and Kraay (1998) estimator is used to obtain standard errors that are robust to autocorrelation, heteroscedasticity, and cross-sectional dependence. The parameter estimation results of the Driscoll and Kraay of RE model are presented in Table 7.

Table 7. Random effects estimates with Driscoll and Kraay standard errors

Variable	Coefficient	Driscoll-Kraay Standard Error	t-statistics
FD	822.31***	224.74	3.66
$OPEN$	6.466***	2.1032	3.07
$POLSTAB$	25.075**	11.164	2.25
$GDPPC$	0.4259***	0.0435	9.79
URB	60.357***	7.9200	7.62
$Constant$	127.51	238.59	0.53
Wald stat	2191.79 (0.000)		
R^2	0.8366		

Observation	95

Note: ***, ** and * indicates the statistical significance and 1, 5, and 10% level, respectively. Numbers in parenthesis are p-values.

The Wald test confirms that a number of independent variables are jointly significant at the 1% level. R-squared statistics represent that 83% of the variation of the dependent variable is explained by the independent variables.

The results of the Driscoll-Kraay standards errors for RE with individual effects indicate that financial development and trade openness have positive and significant relationship with energy consumption. Recent literature suggests that financial development is an important determinants of energy demand. Financial development positively affects aggregate demand and energy consumption because it increases banking activity, lowers borrowing costs and encourages financial capital inflows into the country. The positive coefficient of the FD indicates that financial development in the five Central Asian countries in the panel has made it easier for individuals and firms to access funds for new investments and expenditures, thereby increasing energy demand. This result is in line with many previous studies, such as Abosedra et al. (2015), Sardosky (2010), Shahbaz and Lean (2012), Mahalik et al. (2017), Rafindadi and Öztürk (2017), and Duan and Guo (2021). The positive impact of trade openness on energy consumption is also confirmed by several authors in the literature (e.g. Rafindadi and Öztürk (2017), Duan and Guo (2021), Nasreen and Anwar (2014), Haider and Adil (2019) and Destek (2015). The positive and significant coefficient of OPEN implies that trade openness leads to an expansion of production in many sectors and, therefore, to an increase in energy consumption.

Also, the coefficient of political stability and absence of violence as a proxy of institutional quality is positive and statistically significant at 95%. This finding that increasing institutional quality positively affects energy consumption supports studies by Wang et al. (2024), Ummalla and Goyari (2024), Sun et al. (2025). The absence of violence and a stable political environment together establish a predictable and secure environment. This promotes investment in energy. This is especially significant for international investors intending to invest in energy infrastructure for the long run. Political stability facilitates more effective regulatory enforcement and enhances the management of energy resources. Furthermore, more comprehensive and sustainable energy policies are typically found in nations with low levels of terrorism and violence. These countries

are better equipped to carry out national energy security plans and lessen their reliance on energy by diversifying their sources.

In addition, GDP per capita and urbanization are found to be positively significant with energy consumption indicating that an increase in real income and urbanization in Central Asian countries in the panel leads to increase in the energy consumption.

Robustness tests

Generalised Least Squares (GLS) method is used to estimate linear panel data models. It provides more effective results in cases where OLS is not efficient due to heteroskedasticity or serial correlation problems. In this study, the results of random effects estimation with Driscoll and Kraay standard errors were checked using GLS estimator. The GLS results were obtained using xtgls command in the STATA software. Table 8 shows the coefficients estimated by the GLS method.

Table 8. GLS estimation results for robustness test

Variable	Coefficient	Standard Error
FD	787.1***	174.66
$OPEN$	0.2715**	0.141
$POLSTAB$	24.812**	10.09
$GDPPC$	0.2027***	0.0118
URB	69.504***	1.209
$Constant$	-19.29.2***	47.27
Wald stat. (prob)	11389.24 (0.00)	
Observation	95	

Note: ***, ** and * indicates the statistical significance and 1, 5, and 10% level, respectively. Numbers in parenthesis are probability values.

The GLS results in Table 8 are quite similar to the results of random effects estimates with Driscoll and Kraay standard errors in Table 7. Financial development, GDP per capita and urbanisation have positive signs and significant effects on energy consumption at the 99 % significance level. The positive effect of political stability and trade openness on energy consumption is significant at the 95 per cent level of significance. The Wald statistic shows that the model is significant

overall. It can be said that the results are consistent as GLS is a method that takes into account heteroskedasticity, autocorrelation and cross-sectional dependence.

6. CONCLUSION

It is so clear that energy is an essential element both as final goods and as intermediate goods in the production of almost all goods and services. Correspondingly, energy consumption is expanding gradually based on some factors. Considering limited resources, this consumption should be balanced and harmonized with nature, environmental issues, and current economic conditions. The only way for that is initially to decide on which variables to affect energy consumption and then to apply suitable policies. In this respect, our aim in this paper is to investigate determining variables of energy consumption for Central Asia which comprises Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. Although these factors can differ by country, we can count principal variables we think they substantially affect energy consumption in these countries: financial development, trade openness, institutional quality, urbanization and GDP per capita.

Theoretically, the links between these variables and energy consumption can be expressed in different channels. In relationship between financial development and energy consumption, consumer effect, business effect and wealth effect are the main three channels. In addition to these, using efficient technologies can have an important influence in determining linkage between financial development and energy consumption. The effect of GDP per capita on energy consumption is expected to be positive because of the consumer effect as in financial development. Differently, the relationship between trade openness and energy consumption emanates from scale effect, technique effect and composite effect. Another one we search for, political stability as an indicator of institutional quality affects energy consumption by consumption and production decisions since efficient policies by government are crucial on the energy utilization attitude of residents. Political stability and absence of violence create a secure and predictable environment for energy investment. This is especially important for international investors planning long-term investments in energy infrastructure. Many studies show that political stability increases energy investment, which contributes positively to economic growth and energy security. Political stability also allows for more effective implementation of energy-related regulations and more efficient resource allocation. Lastly, urbanization can be related to energy consumption in three ways. Two of them, rapid growth in population and increase in living standard of households, are

considered as driving of energy consumption. In third way, urbanization enhances energy efficiency thanks to advancements in urbanization-based industry, technology, and products and so urbanization causes a decrease in energy consumption.

Within this scope, there are really extensive related literature demonstrating these linkages from different perspectives for different countries. However, it is clear that the studies in this field are not enough for Central Asian countries and the studies are not comprehensive. In other words, the papers especially for Asian countries are mostly about carbon emissions and economic growth. To our best knowledge, a comprehensive study analyzing energy consumption -including the variables of financial development, trade openness, institutional quality and urbanization- for these countries is unavailable.

Accordingly, we firstly aimed to determine the relationship between energy consumption, financial development, trade openness and political stability in these countries. For this purpose, the annual data for the period from 1996 to 2014 is investigated using static panel data estimation methods. At the same time, urbanization rate and GDP per capita which measured by GDP per capita in constant prices also used as control variable. We found that all variables which we search for their relationship to energy consumption have positive and significant effect on energy consumption. That is, an increase in financial development, trade openness, institutional quality and urbanization leads to an upward trend in energy consumption, vice versa. Naturally, the fact remains that each one has positive effect on it but at different rates.

We propose to the policy makers to develop the energy policies that specifically address the socio-economic and environmental issues. The findings clearly show that energy is needed for financial development, trade openness, urbanization and sustainability of growth. In the same way, political stability can have an upward effect on output, investment and energy demand by influencing expectations. The policies should be on efficient energy consumption, considering the impact of the variables on energy consumption. Efficient energy consumption can be provided with energy consumption which are well harmonized with the other sectors and environment. Otherwise, we seem to live in clover in the short term but may not experience the same generosity in the long run. Banks and financial institutions should have incentives to invest in low-carbon projects rather than in energy-intensive sectors. Special funds and incentives can be provided for energy efficiency projects. In particular, there can be an increase in financial support for energy-efficient projects in

the building, industry and transport sectors. Smart city technologies should be promoted in order to limit the increase in the impact of urbanisation on energy consumption. Energy-efficient buildings, public transport systems and the integration of renewable energy into urban planning can optimise energy consumption. In addition, it can also implement energy policies and effective regulation based on transparency, accountability and long-term sustainability in the energy market. Given the stimulating effect of trade openness on energy consumption, trade in energy-efficient technologies and renewable energy equipment could be given priority over imported energy-intensive products. This can be achieved through tariffs and incentives.

DECLARATION OF ETHICAL STANDARDS

The authors of the paper submitted declare that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Şerife Özşahin: Data collection, methodology, econometric analysis, interpreting the findings.
Emel Akbal: Introduction, literature review, conceptual framework, theoretical backround.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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