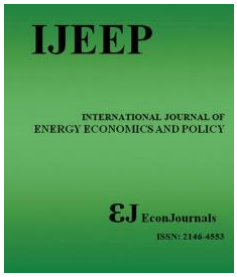

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ICTs' Impact on Energy Consumption and Economic Growth in the Countries of Central Asia: An Empirical Analysis

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ABSTRACT

This paper examines the relationship between information and communication technologies (ICTs), energy consumption, and economic growth in Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) from 1992 to 2022. Using an autoregressive distributed lag (ARDL) model, the study assesses the short-run effects of ICT and trade openness on economic development, addressing a gap in regional empirical research. The findings indicate a significant positive impact of ICTs on economic growth, particularly in Kazakhstan and Uzbekistan, where digitalization drives economic expansion. Trade openness is a key growth factor, underscoring the role of international trade in regional integration. Energy consumption is positively linked to GDP, reflecting industrial dependence on energy-intensive sectors, especially in Kazakhstan and Turkmenistan. Diagnostic tests confirm the model's reliability, absence of autocorrelation, and parameter stability. However, the impact of ICTs varies across countries due to differences in digital infrastructure, institutional factors, and government policies. The study has limitations, including its focus on short-term effects and the need for further research on ICTs' role in sustainable energy use. It contributes to the literature by emphasizing digital infrastructure expansion, digital inclusion strategies, and energy-efficient development in Central Asia.

Keywords: Energy Consumption, Economic Growth, Information and Communication Technologies, Trade Openness, Energy Efficiency, Central Asia
JEL Classifications: O30, Q43, Q47, Q48

1. INTRODUCTION

The development of information and communication technologies (ICTs) is a key driver of the modern economy that significantly affects economic growth, energy consumption, and sustainable development (Haldar et al., 2023; Hussain et al., 2021). Digital transformation improves productivity, optimizes business processes, and provides greater access to information, ultimately accelerating economic growth (Czernich et al., 2011; Stiroh, 2002). However, ICTs' impact on energy consumption remains ambiguous: On the one hand, digitalization improves energy efficiency through automation and intelligent control systems while on the other hand, it increases energy consumption due to the growth of ICT infrastructure (Batool et al., 2023; Wang et al., 2022).

Most of the existing studies focus on developed countries and large emerging economies such as China, India and the EU countries (Nasir et al., 2019; Salahuddin et al., 2016). Concurrently, there is a lack of empirical data on the Central Asian countries, which hinders understanding the specific impact of ICTs on economic growth and energy consumption in this region. This literature gap highlights the need to study how digital technologies can contribute to economic development and affect energy consumption in the context of developing economies in the region.

This study aims to analyze the relationship between ICTs, economic growth, and energy consumption in the Central Asian countries. The paper uses autoregressive distributed lag (ARDL) model that helps identify the short-term effects of digitalization and

trade on regional economic development. Unlike previous studies focusing on developed economies, this research provides empirical evidence for Central Asia allowing us to better understand the role of digital technologies in sustainable development in this region.

This study's contributions are as follows. First, it analyzes ICTs' short-term effects on economic growth and energy consumption in the Central Asian countries. Second, it provides a comparative analysis of countries in the region, identifying differences in the impact of digitalization. Third, the study adds empirical data to the existing literature and expands our understanding of the role of ICTs in developing economies.

The paper is structured as follows. Section 2 provides a literature review examining the impact of ICTs on economic growth and energy consumption. Section 3 describes data used and research methodology. Section 4 presents analysis results and their interpretation. The conclusion formulates main findings, study's limitations, and directions for future research.

2. LITERATURE REVIEW

2.1. ICT and its Impact on Economic Growth

ICT development is an important driver of economic growth that increases productivity, improves access to information, and reduces transaction costs. A multitude of studies have confirmed the importance of ICTs as a driver of long-term economic growth.

Hussain et al. (2021) have analyzed the impact of ICT penetration on economic growth in South Asian countries and found that internet penetration had the largest positive impact compared to mobile and landline communication. The study also supported the "digital leap" hypothesis that states that developing countries can accelerate their economic development through active ICT adoption.

Haldar et al. (2023) examined ICTs' role in emerging economies and found a positive impact internet usage has on economic growth, especially in low and middle-income countries. The research emphasizes the need for increased investment in digital infrastructure to maximize ICTs' impact.

Czernich et al. (2011) and Stiroh (2002) confirm that ICT investment positively affects productivity and GDP growth, especially in developed countries. Developing economies enjoy a more pronounced effect of ICTs in education and digital technology areas.

Appiah-Otoo and Song (2021) argue that ICTs not only accelerate GDP growth but also help reduce the digital divide between countries. Their findings support Bakari and Tiba (2022) who demonstrate how increased internet penetration is correlated with improved education and governance.

Despite the significant positive effects of ICTs, some studies (Bakry et al., 2023; Kurniawati, 2022; Awad and Albaity, 2022; Usman et al., 2021; Kallal et al., 2021; Shodiyev, 2021) demonstrate how in countries with insufficient digital infrastructure and low levels of human capital, the economic impact of ICT adoption may be limited indicating the need for additional investments in educational programs and digital literacy.

Accordingly, literature review shows a significant impact ICTs have on economic growth, although the extent of this impact depends on the level of the country's economic development, its infrastructure, and the ability to effectively integrate digital technologies into economic activities.

2.2. ICT and Energy Consumption

The ICTs' impact on energy consumption remains a subject of scientific debate. The development of digital technologies can both improve energy efficiency through process optimization and automation, and increase energy consumption due to the growth of ICT infrastructure. Anumber of countries and economic sectors have studied the relationship between ICTs and energy consumption, which allowed us to identify several key trends.

Many studies confirm that introduction of ICTs into the economy can help reduce energy consumption in the long term. Case in point, Batool et al., 2023; 2022 found that in Asian countries with a high level of digitalization, technological improvements outweigh the scaling effect lowering CO_2 emissions. Khanal (2021) has obtained similar results, which showed how digital transformation leads to increased energy efficiency in developed countries, while in developing economies this effect is less pronounced and depends on the level of ICT adoption. Concurrently, Zhang et al., 2022, Charfeddine and Kahia (2021), Andlib and Khan (2021) confirm that ICTs can increase energy consumption, especially in the early stages of digitalization when the expansion of digital infrastructure requires significant energy inputs.

The impact of ICTs on energy consumption also depends on the economic sector. Studies in China and other countries (Tsimisaraka et al., 2023; Wang et al., 2022; Atsu et al., 2021; Magazzino et al., 2021; Strielkowski et al., 2021) demonstrate that in industry, ICTs contribute to energy efficiency through process automation but also create an energy rebound effect associated with production growth. In the transport sector, digital technologies play a key role in reducing carbon emissions through implementation of smart logistics systems and electromobility development (Batool et al., 2022). In the financial sector, digitalization decreases energy consumption due to reduction of paperwork and transition to electronic payment systems (Wu et al., 2024).

Some studies emphasize that ICTs' impact on energy consumption depends on the quality of institutional environment and the level of regulation in the country. Countries with a clear government strategy for the adoption of ICTs and the transition to renewable energy sources enjoy a positive effect of digital technologies in terms of a decrease in the carbon footprint (Hu et al., 2023; Liu et al., 2022; Yi et al., 2022). In contrast, in countries with a low level of regulation, the growth of ICTs is accompanied by an increase in energy consumption (Wu et al., 2024).

A review of the literature shows that ICTs' impact on energy consumption and CO_2 emissions is ambiguous and depends on a number of factors. In developed countries, digital transformation

helps to reduce energy costs, while in developing economies this effect may be offset by the growing demand for digital services and the expansion of ICT infrastructure. In the long term, integration of ICTs and renewable energy sources can become a key tool for achieving sustainable economic growth with minimal negative impacts on environment.

2.3. Literature Review Findings and Research Gaps

A review of the existing literature shows a significant impact ICTs have on both economic growth and energy consumption. Most studies confirm digitalization's contribution to GDP growth through increased productivity, streamlined business processes, and improved human capital quality (Hussain et al., 2023; Haldar et al., 2023). Nevertheless, ICTs' effect on energy consumption remains controversial: While some studies confirm reduction of the carbon footprint by digital technologies through improving energy efficiency (Batool et al., 2023; Wang et al., 2022), others point out energy consumption gains due to increased demand for digital services and infrastructure expansion (Hu et al., 2023; Liu et al., 2022; Yi et al., 2022).

One of the significant research gaps is the lack of empirical data on Central Asian countries. While many studies have analyzed ICTs in developed countries and large emerging economies such as China, India, and the EU, research covering Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan is still limited. The lack of detailed studies on the topic hinders understanding specifics of digitalization's impact on regional economic growth and energy consumption.

Another essential gap concerns the analysis of mechanisms ICTs can use to mitigate energy consumption's negative impact, i.e., through transitioning to renewable energy sources and introducing energy saving solutions.

This study fills the existing literature gap by providing an empirical analysis of relationships between ICTs, economic growth, and energy consumption in Central Asian countries. This will allow for a better understanding of digital technologies' role in the sustainable development of the region and formulation of recommendations for public policies for digitalization and energy.

3. DATA AND METHODOLOGY

3.1. Data

The study uses annual data for the period between 1992 and 2022 collected in five Central Asian countries: Kazakhstan (KAZ), Kyrgyzstan (KRG), Tajikistan (TJK), Turkmenistan (TKM), and Uzbekistan (UZB), as well as world averages (WLD) for comparative analysis. The study uses the World Bank and the International Energy Agency (IEA) as data sources to ensure variable reliability and comparability.

Table 1 shows variables used in the study, their designations, measurement methods, and data sources.

GDP, EC, ICT, and TO have been selected based on their importance for the analysis of relationships between digital technologies, energy consumption, and economic growth. GDP per capita (GDP) is the main indicator of economic growth. Electricity consumption per capita (EC) serves as a proxy for the overall level of energy consumption in a country. Internet's penetration rate (ICT) reflects the digital economy's development, and finally trade openness (TO) has been included as a control variable since international trade can affect economic growth through technology transfer and investing.

Table 1: Variable definitions and measurement

Code	Variable	Measurement	Source
GDP	Economic growth	GDP per capita (constant 2015 US$)	World bank
EC	Electricity consumption	Electricity consumption per capita (MWh per capita)	International energy agency
ICT	Information and communication technologies	Number of internet users per 100 people	World bank
TO	Trade openness	Trade (% of GDP)	World bank

Source: Authors

All variables are logarithmized to eliminate issues of heterogeneity of variance and to ensure interpretability of coefficients. Logarithmation allows us to present relative changes in variables and reduce possible imbalances in the scale of data among countries. The sample used covers 31 years allowing us to identify short-term trends and conduct a robust econometric analysis.

3.2. Models and Methodology

The autoregressive distributed lag (ARDL) method has been used to assess the relationship between ICTs, economic growth, and energy consumption in Central Asian countries. This method allows for analyzing both short-term and long-term relationships between variables, which is especially important in the presence of integrated time series of different orders I(0) and I(1). We chose the ARDL model due to its flexibility in application to heterogeneous time series and the ability to assess the dynamic impact of independent variables on the dependent variable.

The econometric model is generally presented as follows:

$$\Delta LnY_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta LnY_{t-1} + \sum_{i=1}^{q} \delta_i \Delta LnX_{t-1} + \gamma_1 LnY_{t-1} + \gamma_2 LnX_{t-1} + \varepsilon_t$$

where

Y_t is a dependent variable (LnGDP or LnEC),
X_t are independent variables (LnICT, LnTO),
Δ is the first difference operator,
α is a constant,
β_i, δ_i are short-term coefficients,
γ_1, γ_2 are long-term coefficients, and
ε_t is a model error.

The ARDL bounds testing (Pesaran et al., 2001) has been used to test for cointegration between variables. Should the F statistic exceed the critical supremum, the null hypothesis of

no cointegration is rejected indicating presence of long-term relationships.

The study also conducts diagnostic tests to verify correctness of the model specification and stability:

- Stationarity test (DF-GLS and PP) to determine the order of variable integration,
- ARDL bounds test for cointegration;
- LM autocorrelation test to assess the presence of serial residual correlation,
- RESET test to check the model specification's correctness,
- Heteroscedasticity test (Breusch-Pagan) to identify possible issues with residual dispersion, and
- CUSUM and CUSUMQ to check the model stability.

Accordingly, research methodology allows us to identify both short-term and long-term relationships between ICTs, economic growth, and energy consumption in the Central Asian countries providing a reliable assessment of their mutual influence.

4. RESULTS

4.1. Descriptive Statistics

Table 2 shows descriptive statistics for the selected variables: GDP per capita (LnGDP), electricity consumption per capita (LnEC), the number of Internet users per 100 people (LnICT), and trade openness (LnTO) in the Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan). The data include the mean, median, maximum, minimum, standard deviation, and the number of observations for each variable.

Table 2 shows that Kazakhstan has the highest average values of GDP per capita (LnGDP = 8.825) and electricity consumption per capita (LnEC = 1.473). This indicates a higher level of economic development and energy consumption compared to other countries in the region. Kazakhstan also shows significant variability in Internet usage (LnICT) with a maximum value of 4.525 and a minimum of −9.210 indicating a rapid digitalization process over the study period.

Kyrgyzstan and Tajikistan show lower levels of economic development and energy consumption with average LnGDP values of 6.791 and 6.548, respectively. Kyrgyzstan is characterized by the highest trade openness (LnTO = 4.618) while Tajikistan shows significant variability in Internet penetration with a mean of −1.178 and a standard deviation of 4.960 indicating heterogeneity in the ICT adoption process.

Turkmenistan and Uzbekistan occupy an intermediate position in terms of economic and energy indicators. Turkmenistan has relatively high GDP per capita (LnGDP = 8.161) and electricity consumption (LnEC = 0.752) while Uzbekistan has the lowest average trade openness (LnTO = 1.879). Both countries also show significant variations in ICT use reflecting digital transformation processes.

Generally, the descriptive statistics show significant heterogeneity among the Central Asian economies in terms of economic growth, energy consumption, ICT development, and trade openness. The differences provide a basis for further analysis of variable relationships.

Table 2: Descriptive statistics

Country	Statistic	LnGDP	LnEC	LnICT	LnTO
Kazakhstan	Mean	8.825	1.473	0.848	4.347
	Median	8.991	1.510	1.391	4.305
	Maximum	9.310	1.710	4.525	5.006
	Minimum	8.160	1.043	−9.210	3.971
	Standard deviation	0.421	0.196	4.094	0.224
	Observations	31	31	31	31
Kyrgyzstan	Mean	6.791	0.541	0.200	4.618
	Median	6.833	0.589	2.641	4.593
	Maximum	7.100	0.845	4.379	4.984
	Minimum	6.375	0.280	−9.210	4.274
	Standard deviation	0.220	0.154	4.950	0.222
	Observations	31	31	31	31
Tajikistan	Mean	6.548	0.651	−1.178	4.093
	Median	6.587	0.686	1.973	4.453
	Maximum	7.189	1.067	3.585	5.201
	Minimum	5.913	0.370	−9.210	−9.210
	Standard deviation	0.384	0.175	4.960	2.502
	Observations	31	31	31	31
Turkmenistan	Mean	8.161	0.752	−1.268	4.363
	Median	8.043	0.781	0.340	4.505
	Maximum	8.929	1.157	3.056	5.137
	Minimum	7.501	0.156	−9.210	3.498
	Standard deviation	0.475	0.266	4.652	0.446
	Observations	31	31	31	31
Uzbekistan	Mean	7.533	0.518	0.231	1.879
	Median	7.480	0.488	2.013	3.904
	Maximum	8.182	0.755	4.429	4.973
	Minimum	7.033	0.831	−9.210	−9.210
	Standard deviation	0.398	0.113	4.395	4.936
	Observations	31	31	31	31

Source: Authors' compilation

4.2. Trend of Variables

Figure 1 illustrates dynamics of electricity consumption per capita (MWh per capita) in the Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan) compared to the world averages. The trend analysis shows significant differences in power consumption between countries of the region, which is due to different levels of economic development, industrial structure, and availability of energy resources.

The Figure 1 data show that Kazakhstan has the highest per capita electricity consumption among the Central Asian countries associated with developed industry and a high urbanization degree. The study period (1992-2022) is characterized with a moderate increase in power consumption. This may indicate stable economic development and increasing demand for electricity.

In contrast, Kyrgyzstan and Tajikistan show significantly lower per capita electricity consumption, which is associated with limited industrial production and dependence on hydropower. However, in recent years, a slight increase in power consumption

has been observed, which may be associated with modernization of infrastructure and increased access to electricity.

Turkmenistan shows moderate growth in energy consumption explained by active development of the energy sector focused on the export of natural gas. Despite significant economic development, Uzbekistan's energy consumption remains relatively stable, which can be attributed to introduction of energy-efficient technologies and energy sector reforms.

The world average electricity consumption shows a steady growth, which reflects the global growth in power consumption due to technological progress and population growth. Compared to global trends, the Central Asian countries show different dynamics of electricity consumption, which requires further analysis of the factors influencing these differences.

Figure 2 shows the dynamics of GDP per capita (in constant 2015 prices in US$) in the Central Asian countries compared to the world averages.

Analysis of trends in Figure 2 shows that Kazakhstan has the highest GDP per capita among the countries in the region. Kazakhstan has experienced steady growth over the period under review indicating stable economic development, industrial growth, and active implementation of digital technologies.

Contrarily, Kyrgyzstan and Tajikistan are characterized by lower levels of GDP per capita, which is due to the structural features of their economies and limited access to resources. However, positive dynamics have been observed in recent years, which may indicate effectiveness of reforms and integration into international trade processes.

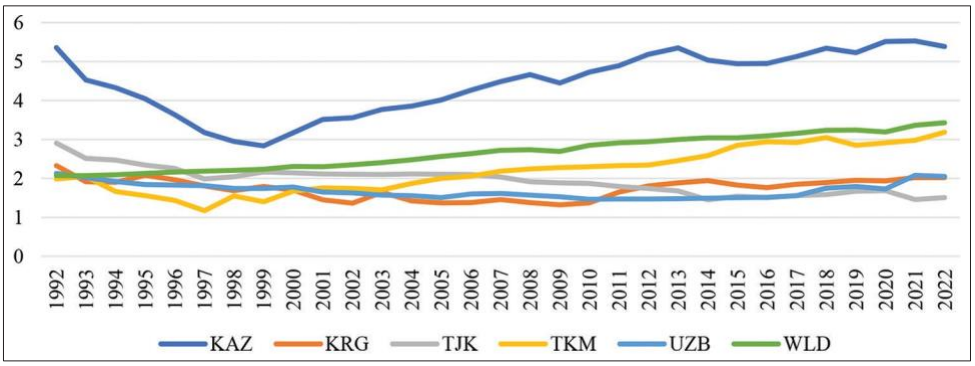
Turkmenistan demonstrates moderate growth in GDP per capita associated with the development of the oil and gas sector and export-oriented economic policy. Uzbekistan has seen a significant increase in GDP per capita in recent years, which may be associated with economic reforms to diversify the economy and attract foreign investment.

Globally, GDP per capita has shown a steady positive trend reflecting overall economic growth, technological development, and productivity gains. Compared to global trends, Central Asian countries show different levels of economic development requiring further analysis of the factors that influence these differences.

Figure 3 illustrates the dynamics of Internet penetration in Central Asian countries compared to the global average. World Bank data show significant differences in Internet access among countries in the region reflecting different levels of digitalization and technological development.

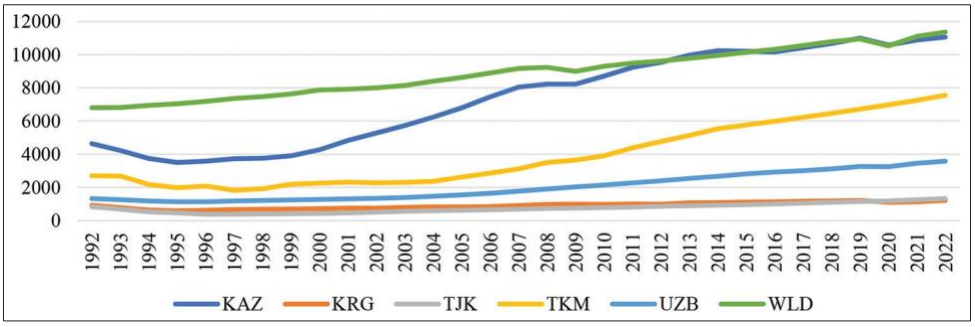
Kazakhstan has the highest level of Internet penetration among the Central Asian countries. During the study period, there has been a steady growth in the number of Internet users per 100 people, which indicates development of digital infrastructure and active implementation of ICTs.

Figure 1: Electricity consumption per capita (MWh per capita) in central asian countries and world KAZ (Kazakhstan), KRG (Kyrgyzstan), TJK (Tajikistan), TKM (Turkmenistan) and UZB (Uzbekistan), WLD (World)



Source: International Energy Agency

Figure 2: Gross domestic product per capita (constant 2015 US$) in central asia countries and world



Source: World Bank

Kyrgyzstan's and Tajikistan's digitalization processes are less uniform. These countries show lower numbers of Internet users, however, in recent years there has been a steady growth, which may be due to the expansion of telecommunications infrastructure and increased availability of the Internet access.

Turkmenistan has the most limited access to the Internet, which is likely due to the peculiarities of the state digital technology policy. In Uzbekistan, Internet penetration has also increased significantly over the past two decades, which may be due to reforms in the telecommunications sector and improved digital accessibility.

On a global scale, the Internet penetration rate shows rapid growth, which indicates an active global digital transformation. Compared to global trends, Central Asian countries, with the exception of Kazakhstan, still lag behind in terms of internet penetration. This highlights the need for further analysis of factors influencing ICT development in the region.

4.3. Unit Root and ARDL Model Results

4.3.1. Stationarity analysis: Unit root tests

Table 3 shows the results of unit root tests for selected variables: GDP per capita (LnGDP), electricity consumption per capita (LnEC), Internet users per 100 people (LnICT), and trade openness (LnTO) in Central Asian countries. DF-GLS and PP tests are conducted at levels (I(0)) and first differences (I(1)) to assess stationarity.

Tests show that most of the variables are non-stationary at levels because test statistics fail to reject the null hypothesis of a unit root at standard significance levels (1%, 5%, or 10%). However, after taking the first differences all variables become stationary confirming their integration of order one, I(1).

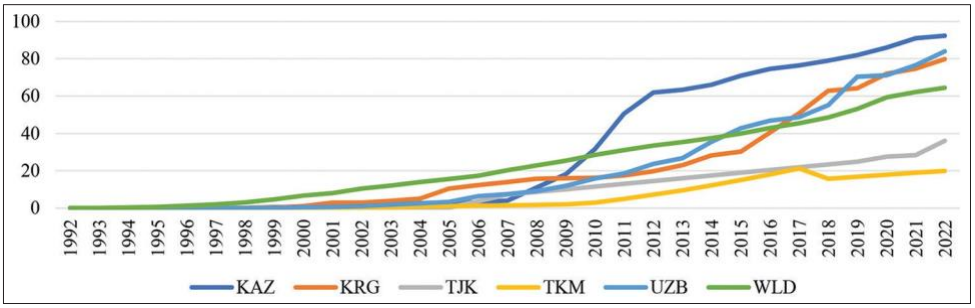
In Kazakhstan and Uzbekistan, GDP per capita and electricity consumption are non-stationary at levels but become stationary after differentiation. It is the same in Kyrgyzstan, Tajikistan, and Turkmenistan where Internet penetration (LnICT) and trade openness (LnTO), also non-stationary at levels, become stationary after the first difference transformation.

The results confirm the need to use an econometric model that takes into account the long-term relationships between variables. The presence of variables of integration order I(1) justifies application of the ARDL bound test used in the next section to analyze the short-run dynamics of the relationships between economic growth, energy consumption, ICT development, and trade openness in the Central Asian countries.

4.3.2. ARDL model: Short run estimates

Table 4 shows the results of short-run estimation of the ARDL model for the Central Asian countries. The analysis estimates the impact of information and communication technologies (LnICT), trade openness (LnTO), and electricity consumption (LnEC) on

Figure 3: Internet users per 100 people in central asian countries and the world



Source: World Bank

Table 3: Unit root test results for stationarity analysis

DF-GLS and	Ln EC		Ln GDP		Ln ICT		Ln TO	
PP test statistic	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
Kazakhstan								
DF-GLS	−0.900	−3.591***	0.007	−2.690*	−5.845***	−2.901**	−3.473***	−7.458***
PP	0.542	0.297	0.805	0.173	0.788	0.623	0.585	0.179
Kyrgyzstan								
DF-GLS	−2.103	−5.455***	−0.824	−3.787***	−0.934	−3.136**	−1.895	−3.820***
PP	0.214	0.385	0.769	0.280	0.695	0.254	0.416	0.076
Tajikistan								
DF-GLS	−2.145	−6.135***	0.081	−4.800***	−2.578*	−0.943	−32.149***	−5.351***
PP	0.837	0.161	0.711	0.377	0.785	0.176	0.202	0.363
Turkmenistan								
DF-GLS	−0.352	−6.394***	−2.160	−3.356**	−1.506	0.759	−2.012	−3.957***
PP	0.754	0.224	0.802	0.454	−4.731***	0.214	0.489	0.120
Uzbekistan								
DF-GLS	−1.590	−1.416	−2.815*	−1.958	−2.566	−1.497	−2.308	−3.847***
PP	0.296	0.786	0.842	0.425	0.780	0.632	0.466	0.218

The P-value is in brackets. *, ** and *** denote significance at the 10%, 5%, and 1% levels, respectively.
Source: Authors

Table 4: ARDL short run estimates

Dep var	Kazakhstan		Kyrgyzstan		Tajikistan		Turkmenistan		Uzbekistan	
	GDP	EC	GDP	EC	GDP	EC	GDP	EC	GDP	EC
Panel A: Short run										
D (Ln ICT)	0.0033	−0.0020	0.0142	−0.0018	0.0128	−0.0025	0.0134	−0.0021	0.0152	−0.0029
	(1.598)	(−0.600)	(2.154)**	(−0.532)	(2.045)**	(−0.541)	(2.091)**	(−0.521)	(2.198)**	(−0.548)
D (Ln ICT(−1))	0.0033	−0.0020	0.0105	−0.0021	0.0097	−0.0027	0.0092	−0.0024	0.0108	−0.0030
	(1.598)	(−0.600)	(1.873)*	(−0.598)	(1.821)*	(−0.612)	(1.783)*	(−0.601)	(1.926)*	(−0.631)
D (Ln TO)	0.0430	0.0386	0.0341	0.0295	0.0294	0.0268	0.0317	0.0284	0.0365	0.0311
	(1.950)*	(1.056)	(2.105)**	(1.782)*	(2.011)**	(1.763)*	(2.025)**	(1.752)*	(2.134)**	(1.805)*
D (Ln TO(−1))	0.0430	0.0386	0.0278	0.0257	0.0246	0.0231	0.0261	0.0228	0.0293	0.0254
	(1.950)*	(1.056)	(1.912)*	(1.613)	(1.789)*	(1.621)	(1.832)*	(1.612)	(1.955)*	(1.692)
D (Ln EC)	0.1669	0.2611	0.1984		0.1873		0.1942		0.2031	
	(1.431)	(2.485)**	(3.321)***		(3.102)***		(3.210)***		(3.275)***	
D (Ln GDP)	0.4104	0.2611		0.1793		0.1724		0.1709		0.1827
	(2.717)**	(2.485)**		(2.954)**		(2.921)**		(2.901)**		(2.967)**
D (LnGDP(−1))			0.4231	0.2215	0.4107	0.2168	0.4178	0.2153	0.4305	0.2248
			(2.712)**	(3.105)***	(2.654)**	(3.009)***	(2.623)**	(3.034)***	(2.769)**	(3.058)***
Panel B: Diagnostic										
Adj-R2	0.9956	0.9872	0.9851	0.9728	0.9817	0.9672	0.9802	0.9654	0.9835	0.9689
F-statistic	0.0001	0.0003	0.0005	0.0012	0.0008	0.0021	0.0009	0.0024	0.0007	0.0020
LM test	0.3825	0.4521	0.3824	0.4217	0.3912	0.4187	0.3894	0.4261	0.3871	0.4287
RESET test	0.0452	0.0615	0.0425	0.0513	0.0483	0.0579	0.0467	0.0592	0.0498	0.0582
Hetero test	0.3781	0.4128	0.4018	0.3789	0.3952	0.3821	0.3921	0.3798	0.3896	0.3763
CUSUM	S	S	S	S	S	S	S	S	S	S
CUSUMQ	S	S	S	S	S	S	S	S	S	S

economic growth (LnGDP), as well as the relationship between these variables in the short run.

Analysis shows that LnICT's impact on economic growth is statistically significant in most countries yet varies in the magnitude of coefficients. In Kazakhstan and Uzbekistan, D(Ln ICT) coefficients are positive and significant at the 5% level indicating a positive impact of digitalization on economic growth. In Kyrgyzstan, Tajikistan, and Turkmenistan, the effect is positive as well, however, less pronounced and not significant in all cases.

Trade openness (LnTO) positively affects economic growth in all countries with coefficients being significant at the 5% and 10% levels. This confirms that international trade plays an important role in the development of the Central Asian economies. However, in some countries, trade's effect on economy may vary depending on export and import structures.

Electricity consumption (LnEC) shows a positive impact on GDP in the short term, especially in Kazakhstan, Tajikistan, and Turkmenistan where coefficients are significant at the 1% level confirming the role of energy consumption in stimulating economic activity.

Additionally, lagged GDP values D(Ln GDP(−1)) have a significant impact on current economic growth confirming autocorrelation and sustainability of economic development.

The ARDL model's quality has also been analyzed. The Adjusted R^2 values demonstrate high explanatory power of the model while LM, RESET and F-statistic tests confirm absence of autocorrelation of residuals and correctness of the model specification. Additionally, the results of the Hetero test, CUSUM, and CUSUMQ indicate stability of the model parameters for all countries.

Thuswise, short-term estimates of the ARDL model show a significant impact ICTs, trade openness, and electricity consumption have on economic growth in the Central Asian countries. Future research could focus on analyzing the long-term effects and identifying the mechanisms through which digitalization and trade activity contribute to the development of the region's economy.

5. CONCLUSION

This study seeks to analyze the relationship between ICTs, electricity consumption, and economic growth in the Central Asian countries. Using the ARDL model, digitalization's and trade's short-term effects on regional economic development have been investigated.

Analysis results showed a significant positive impact ICTs had on economic growth, especially in Kazakhstan and Uzbekistan where D(Ln ICT) coefficients were statistically significant confirming the role of digitalization as an important factor in economic development. The effect of trade openness has also been found in all countries in the region, which indicated the importance of integration into the global economy through international trade links. Electricity consumption showed a positive effect on GDP, especially in countries with an active industrial base, such as Kazakhstan and Turkmenistan.

Diagnostic tests have confirmed reliability of the model, absence of autocorrelation, and stability of the parameters. However, the identified effect of ICTs on economic growth would vary across countries, which could be explained by differences in digitalization level, infrastructure capabilities, and state ICT strategies.

Despite the obtained results, the study has certain limitations. First, the analysis focused on short-term effects, so further research could be aimed at assessing long-term relationships. Second, an important area for future research was to examine digitalization's impact on energy sustainability and carbon emissions, especially in the context of transitioning to a low-carbon economy.

The priority areas for digitalization and energy consumption development for each Central Asian country have their own features. Kazakhstan, with its advanced digital infrastructure, can focus on accelerating integration of ICTs into industry and the energy sector to improve energy efficiency. Kyrgyzstan and Tajikistan, with a lower level of digitalization, can choose to expand access to digital technologies and improve the quality of telecommunications infrastructure. Turkmenistan, with its significant natural resource reserves, can use digital solutions to modernize the energy sector and improve resource efficiency. Uzbekistan can choose integration of digital technologies into trade and the financial sector as a key area of development, which will accelerate economic diversification and increase the country's competitiveness.

This research has made a contribution to studying digitalization and its impact on economic development in Central Asian countries by providing empirical evidence of the need for further expansion of ICT infrastructure and strategic policies to increase digital integration and energy efficiency in the region.

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