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The Impact of Energy Consumption and Trade Openness on Economic Growth in Uzbekistan: A Vecm Approach

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ABSTRACT

This study aims to study the long-term impact of energy consumption and trade openness on GDP per capita growth for the economy of Uzbekistan. The study was based on data from 1990 to 2023, and long-term relationships between variables were analyzed using VECM (Vector Error Correction Model). According to the results of the analysis, a 1 unit increase in energy consumption increased GDP per capita by 3.79 units, while a 1 unit increase in trade openness decreased GDP by 12 units. This situation shows that energy consumption is one of the main factors of the economic growth of Uzbekistan, but the negative impact of trade openness is mainly related to the high share of imports and low competitiveness of the national industry. According to the results of the analysis, to ensure the positive impact of trade openness on national economic growth, it is important to introduce policies aimed at developing national industry and improving energy efficiency. The research findings provide valuable recommendations for the effective use of energy resources for the country's economy and the revision of foreign trade policies.

Keywords: Energy Consumption, Economic Growth, Trade Openness, VECM, GDP, Import, Export.
JEL Classifications: C01, F14, F41, Q43

1. INTRODUCTION

In recent years, the relationship between energy consumption, trade openness, and economic growth has become an important area of research, especially for developing countries such as Uzbekistan. As countries strive to improve their economic performance and improve the standard of living of their people, it is important to understand the key drivers of economic growth. Understanding these dynamics is essential to formulating policies that increase economic efficiency and raise living standards. Recent studies highlight the interdependence of these factors, emphasizing the importance of trade liberalization, energy efficiency, and financial development in stimulating economic growth.

Trade openness is consistently associated with increased economic growth in developing countries. Countries with less distorted external sectors tend to grow faster because trade liberalization facilitates access to larger markets and advanced technologies (Kehoe and Ruhl, 2010). In the neoclassical growth model, openness has a significant impact on growth, especially in developing countries where the share of physical capital in factor income is high. This openness leads to faster convergence rates of economic growth compared to closed economies (Gundlach, 1997). Studies conducted in developing regions confirm that energy consumption is an important factor of economic growth. In South Asia, energy consumption has a positive effect on growth, with a bidirectional relationship between energy and GDP in the long run (Khan et al., 2021). Energy consumption in China has a positive impact on economic growth along with financial development and trade. Research shows that energy is an important input to economic activity, highlighting the unidirectional causality from energy consumption to economic growth (Shahbaz et al.,

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2018). However, energy dependence poses challenges, as seen in South Asian countries where energy supply shocks can have a significant impact on economic performance. This highlights the need for energy-efficient technologies to reduce such risks (Farooqi et al., 2021). Financial development is another determinant that is interlinked with trade and energy consumption to influence economic growth. In South Asia, financial development has a positive effect on growth, along with trade and energy, with unidirectional causality from financial development to growth (Islam and Islam, 2022). The relationship between financial development and international trade shows that improving financial systems can increase trade performance and further enhance economic growth.

Assessment of the material economy in Uzbekistan by means of material flow analysis shows that material consumption and internal material consumption have increased slightly over the years. Despite excellent national economic performance, material productivity growth is relatively slow compared to industrialized countries (Raupova et al., 2014). This shows that while Uzbekistan has achieved economic growth, there is potential for further improvement through trade openness and increased energy efficiency. In general, while trade openness and energy consumption are important drivers of economic growth, the correlation between financial development and energy efficiency is equally important. Developing countries like Uzbekistan can benefit from policies aimed at liberalizing trade, improving energy efficiency, and strengthening financial systems. However, it is important to consider potential issues such as energy dependence and supply shocks that could hamper growth. Energy consumption plays an important role in the development of its economic activity in the conditions of resource-rich Uzbekistan with great energy production potential. However, globalization and trade liberalization have introduced new dynamics to the economic landscape, where the balance between import and export activities can stimulate or hinder economic growth.

Uzbekistan, whose economy is growing and its integration into the world market is increasing, is tasked with ensuring sustainable economic development in the management of its energy resources and foreign trade. This study focuses on the long-term effects of energy consumption and trade openness, a key indicator of economic performance, on GDP per capita. By analyzing these variables from 1990 to 2023, the study aims to determine whether energy consumption boosts economic growth and how trade openness affects the economy. The study uses a vector error correction model (VECM) to determine the short-run and long-run relationships between these variables. VECM is particularly useful in this analysis because it helps to detect cointegration between variables, which indicates the presence of long-run equilibrium relationships despite short-run fluctuations.

The main research question addressed in this study is whether energy consumption and trade openness have significant and persistent effects on Uzbekistan's GDP per capita. The results of this analysis are expected to provide valuable insights for policymakers, helping to formulate strategies that ensure sustainable economic growth by optimizing energy use and managing the complexities of international trade. Through this study, we aim to contribute to the body of literature on the relationship between energy, trade, and economic growth, particularly in the context of developing economies such as Uzbekistan where resource management and economic policy play a crucial role in shaping future development.

2. LITERATURE REVIEW

The relationship between energy consumption, trade openness, and economic growth has been widely studied in both theoretical and empirical studies in different countries and regions. Many researchers have tried to understand the interaction of these factors and how they contribute to the economic development of countries, especially in the context of developing countries. Energy consumption is often a key driver of economic growth because it powers industry, supports infrastructure, and improves quality of life. On the other hand, trade openness, which reflects a country's participation in international markets, plays a dual role by opening up export opportunities and exposing domestic industries to global competition.

Over the years, scholars have used a variety of econometric models and methodologies to examine these relationships, with mixed results depending on the country or region studied. Some studies find a positive correlation between energy consumption and economic growth, while others emphasize the role of trade openness in increasing economic performance. The current study seeks to build on this existing body of knowledge by focusing specifically on Uzbekistan, which is undergoing economic transformation. Using a vector error correction model (VECM), this study aims to add new insights into how energy consumption and trade openness have affected Uzbekistan's economic growth trajectory over the past few decades. We review the relevant literature on energy consumption, trade openness, and economic growth, and review key findings and methodologies used in previous studies.

2.1 The Relationship between GDP and Energy Consumption

The relationship between GDP and energy consumption is a complex and multifaceted topic that has been widely studied in different countries and economic contexts. The general consensus from the research indicates a positive relationship between GDP and energy consumption, although the nature and direction of causality may vary depending on a country's economic status and other factors. In OECD countries, there is a more pronounced bidirectional causality between energy consumption and GDP, with energy consumption and economic growth mutually reinforcing. This means that policies aimed at reducing energy consumption can have a significant impact on GDP in these developed countries (Magazzino, 2015). In contrast, non-OECD countries often show unidirectional causality from GDP to energy consumption, suggesting that economic growth drives energy consumption rather than the other way around. While there is long-run Granger causality from GDP to energy consumption for low- and high-income countries, there is bidirectional causality for lower-middle and upper-middle-income countries (Farhani and Rejeb, 2015). In low- and high-income countries, causality is largely dependent on energy consumption from GDP. This suggests that economic growth stimulates energy consumption, which justifies that as these economies expand, their energy needs increase to support further growth (Farhani and Rejeb, 2015). The policy implication in these countries is that energy conservation measures may not significantly impede economic growth because energy consumption is a consequence, not a driver, of economic activity (Chontanawat et al., 2008). For lower-middle and upper-middle-income countries, the relationship between GDP and energy consumption is characterized by bidirectional causality. This means that economic growth not only leads to increased energy consumption, but energy consumption also plays a crucial role in stimulating economic growth (Farhani and Rejeb, 2012). This interdependence highlights the need for careful balancing of energy policies in these countries to ensure that energy conservation efforts do not stifle economic growth (Saribayevich et al., 2024). Rather, economic policy must take into account the energy requirements necessary to sustain growth (Rezitis and Ahammad, 2015).

The use of panel data and advanced econometric methods, such as the Toda-Yamamoto and cointegration test approaches, have been instrumental in uncovering these causal patterns. These methods help to account for cross-country dependence and heterogeneity, providing more reliable insights into the energy-GDP relationship (Yildirim et al., 2014). While the causality scenarios identified provide a clear framework for understanding the energy–GDP relationship across different income groups, it is important to consider the broader economic and environmental context. For example, the integration of renewable energy sources and improvements in energy efficiency may change this dynamic over time. Furthermore, the role of energy prices and employment as control variables in the causality models suggests that these factors may significantly influence the observed relationships (Bruns et al., 2014). Therefore, ongoing research and flexible policy frameworks are essential to address evolving energy and economic landscapes.

In ten energy-consuming countries, there is a positive correlation between economic growth and energy consumption, which varies across economies (Xolmurotov et al., 2024). For example, in China and India, energy consumption will have less impact on economic growth at lower levels of economic growth, while in the US and Canada, energy demand will decrease as these countries improve energy efficiency (Shahbaz et al., 2018). In India, electricity consumption is a limiting factor for economic growth, and a significant elasticity of electricity consumption with economic growth is found (Mohanty and Chaturvedi, 2015). Studies of OECD countries using cointegration analysis show that international variation dominates the long-run relationship between energy consumption and GDP, with energy consumption being price elastic (Leininger et al., 2010). A long-run bidirectional relationship between GDP and energy consumption is evident in COMESA countries, as energy consumption leads to GDP in low-income countries (Chali and Mulugeta, 2009). The results show that energy policy should be adapted to the country's specific economic context. For example, policies that limit energy consumption in developing countries may hinder economic growth, while energy efficiency measures in developed countries may not have a negative impact on GDP (Keppler, 2007). A dynamic analysis of panel data shows that while GDP significantly determines energy consumption, the reverse is not significant, highlighting the importance of considering other factors such as energy prices and investments in policymaking (Nayan et al., 2013). Although the positive relationship between GDP and energy consumption is well documented, the direction and strength of this relationship can vary significantly depending on a country's economic status and energy efficiency. This complexity underscores the need for sensitive energy policies that take into account each country's unique economic and development context.

2.2. The Relationship between GDP and Trade Openness

The relationship between trade openness and economic growth, as well as its wider socio-economic effects, is a multifaceted topic that is studied in a variety of contexts. Trade openness generally refers to the degree to which a country allows free trade with other countries, which affects economic growth, the size of government, public health, and environmental quality. Trade openness can be positively and negatively related to economic growth in developing countries. There are several reasons for this. This relationship is statistically significant, and countries with freer trade policies have higher rates of economic growth. This is due to the adoption of advanced technologies and increased investment and labor force participation (Tahir and Azid, 2015). In the context of OECD countries, trade openness also facilitates economic growth, although the effect differs for different amounts of GDP growth. This suggests that while trade openness is generally growth-promoting, its effects may vary depending on a country's specific economic conditions (Jošić, 2023). The quality and variety of exports play a crucial role in how trade openness affects growth. Countries that export high-quality products and a variety of goods grow rapidly. However, there is a non-linear relationship that suggests that countries specializing in low-quality exports do not benefit much from trade openness (Huchet-Bourdon et al., 2018).

Trade openness is associated with increased economic growth, especially in developing countries. A 10% increase in trade openness is associated with a 0.80% increase in economic growth, with the strongest effect in lower-middle-income countries. This suggests that trade liberalization can lead to lifestyle changes that contribute to economic growth (An et al., 2019). In resource-dependent countries, trade openness can lead to diversification of government revenue sources, reducing dependence on variable resource revenues. This change is critical to maintaining stable public finances in the face of volatile global resource prices (Shrestha et al., 2021). Trade openness is associated with government size in democracies with high export price volatility. This is due to the increased demand for economic security, which governments address through expanded public spending (Bharati et al., 2022).

The effects of trade openness on energy use and environmental quality are complex. While this may lead to the spread of technology that reduces energy intensity, it increases energy demand due to industrialization and higher economic activity. This double effect suggests that trade openness can have both positive and negative effects on environmental quality, depending on the energy sources used (Le, 2022). Although trade openness generally promotes economic growth and diversification of government revenues, it also creates problems such as increased economic growth and environmental problems.

Overall, the relationship between trade openness and economic growth is complex and multifaceted, with several studies showing a negative correlation under certain conditions. This negative attitude can be attributed to various factors, including economic structure, governance, and stage of economic development. In highly import-dependent countries like Nepal, trade openness has no significant effect on economic growth. This is because the benefits of trade openness are not fully realized due to a lack of domestic production capacity and excessive dependence on imports (Neupane, 2023). Similarly, in Azerbaijan, the short-term benefits of trade openness are primarily related to the export of natural resources, such as oil, without significant diversification of the economy. This lack of diversification limits long-term growth potential and creates dependence on volatile global markets (Seyfullayev, 2023). In Nigeria, trade openness has a negative impact on economic growth due to poor governance and institutional inefficiencies. The study notes that while governance can promote growth, the negative effects of trade openness are exacerbated by corruption and inefficient government policies (Agada et al., 2022). The role of governance is also highlighted in the context of regional trade agreements in Africa, where uneven development and economic progress have been observed. This suggests that without strong institutions and governance, the potential benefits of trade openness may not be equitably shared (Pasara and Dunga, 2023).

The non-linear effect of trade openness on economic growth is evident in studies of developed and developing countries. Below a certain income threshold, trade openness has no significant effect on growth, indicating that the stage of economic development plays a crucial role in determining the benefits of trade openness (Ondaye, 2023). In the MENA region, trade openness is associated with increased CO_2 emissions, which could worsen environmental quality and negatively impact long-term economic growth. This suggests that the environmental costs of trade openness may outweigh its economic benefits in certain contexts (Yahyaoui and Ghandri, 2024). The presence of high trade barriers can have a negative impact on GDP in emerging economies, as seen in ASEAN countries. Excessive trade openness without adequate protection for domestic industry can have negative growth outcomes (Nam and Ryu, 2024). In contrast, trade openness in the G-20 countries is generally associated with positive economic growth, but the negative impact of tariffs highlights the importance of a balanced trade policy that balances openness and protectionism (Sowrov, 2024).

Although trade openness can potentially stimulate economic growth, its negative relationship with growth in certain contexts highlights the importance of considering economic structure, governance, and stage of development. Policymakers should focus on strengthening domestic industries, improving governance, and ensuring that trade policies are tailored to the specific needs and circumstances of their economies to mitigate the negative effects of trade openness.

3. EMPIRICAL ANALYSIS

3.1. Data

We used time series analysis in the research and used data for Uzbekistan from 1990 to 2023. The data used in the research were open data of the World Bank and the data of the country's statistics agency. In the study, we used variables such as GDP per capita (current US dollars), Energy use (kg of oil equivalent per capita) and Trade openness ((Exports + Imports)/Gross Domestic Product to GDP). Our main research question focuses on the long-term effects of energy consumption and trade openness on GDP per capita.

3.2. Methodology

We used VECM (Vector Error Correction Model) in our research. This model is particularly useful for studying long-term and short-term relationships in time series analysis. The general mathematical representation of the model is defined as follows:

$$\Delta Y_t = \prod Y_{t-1} + \sum_{i}^{k-1} \Gamma_i \Delta Y_{t-i} + \mu + \varepsilon_t \quad (1)$$

Where,

ΔY_t– The first difference of the variable (this is the growth picture of the variable,

Π– matrix of co-integration vectors (representing long-term relationships),

Γ_i– coefficients representing short-term dynamics,

μ – constant (trend),

ε_t–stochastic error (noise or randomness).

In general, the VEC model is used to estimate the association and co-interaction between several variables. If there is co-integration, it indicates that there is a long-term relationship between the variables. In the model, regression equations are given for each variable, and long-term and short-term relationships can be analyzed using their coefficients.

3.3. Empirical Results

Knowing the general descriptive information of the variables used in the research is a very important process of the analysis process. This gives us more detailed information about variables. Table 1 shows the results of descriptive statistics. According to him, there is a significant difference and variability among the variables. In particular, there is a large difference between the lowest and highest values for GDP, which indicates significant changes in the country's economy. Energy consumption is also relatively stable, but trade openness is more volatile, reflecting the impact of foreign economic activity on a country's GDP.

The first step in time series analysis is to check for stationarity of variables. In order to use the VECM model, the variables must be stationary with the first difference, otherwise we cannot use this model. We used ADF, Dickey Fuller test and Philip Perron test to test for stationarity in the study (Table 2). In these tests, the

Table 1: Descriptive statistics

Variable	Obs	Mean	Standard deviation	Min	Max
GDP per	34	1270.949	817.5464	383.3431	2753.971
Energy use	33	1828.967	254.6319	1419.478	2294.824
Trade open~s	27	57.32501	15.06634	29.1923	79.74799

Table 2: ADF and PP unit root test

Variables	ADF unit root test with drift (lag (2))		PP unit root test without drift (lag (2))	
	at Level	first difference	at Level	first difference
GDP per	−0.851	−2.26**	0.695	−14.819***
Energy use	−0.91	−3.759***	−0.492	−35.667***
Trade openness	0.0518	−2.431**	−0.184	−15.236***

(***), (**), (*) indicate 1%, 5% and 10% level of significance, respectively

Table 3: Lag-order selection criteria

	Sample: 2001 thru 2022					Number of obs=22		
Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
1	−363.344		9		1.0e+11	33.8494	33.9546	34.2958
2	−351.631	23.426	9	0.005	8.2e+10	33.6028	33.8131	34.4955
3	−334.528	34.207	9	0.000	4.4e+10*	32.8662	33.1816*	34.2052*
4	−324.763	19.529*	9	0.021	5.2e+10	32.7967*	33.2172	34.582

*optimal lag
Endogenous: GDP_per Energy_use Trade_opennes

primary hypothesis (null hypothesis) is that the series has unity, and the alternative hypothesis is that the series does not have a unit root. Another reason to test time series for stationarity is that if the time series variables are not stationary, their long-run correlation may be spurious. According to the results of the analysis, All variables are non-stationary at their level, that is, they have a unit root, which means that they are sensitive to time changes at their level. However, all variables are first difference stationary, that is, they attain stationarity when the first difference is taken. This means that the values in their first difference are stable over time and their long-term relationship can be considered. In the analysis of variables, it is appropriate to use them in the first difference, as in the analysis of time series, because they have stationarity in the first difference. This is suitable for identifying cointegration and long-term relationships.

In order to test cointegration or fit a cointegrated VECM in the analysis, we need to determine how many lags to add. In Table 2, we analyzed how many lags should be used in the analysis. This process is important for VAR (Vector Auto Regression) and VECM (Vector Error Correction Model) models because the correct choice of lag order is critical to the model's results and predictions (Table 3).

According to the analysis results, according to the AIC (32.8662), HQIC (33.1816), and SBIC (34.2052) values of lag 3, this lag was chosen as the optimal lag. Also, FPE is the smallest in lag 3 (4.4e+10). Lag 4 is also considered, but the SBIC value is slightly higher with 34.582, which does not perform well compared to lag 3. For use in the study, lag 3 was chosen as the optimal lag order because it gives the best results in terms of AIC, HQIC, and FPE. Therefore, the 3-lag allows the model to have the best accuracy and reduce forecast errors.

Johansen's cointegration test is used to determine long-term relationships (Table 4). This test allows us to assess whether there is a long-run equilibrium relationship between several time series. If the time series are cointegrated, this means that there is a long-term relationship between them, even though there may be differences between them in short-term periods. According to the results of the analysis, the trace statistic for 0 rank (no cointegration) is: 34.0895, which is higher than the critical value (29.68) at the 5% level. Therefore, the hypothesis of rank 0 is rejected, that is, there is cointegration. Trace statistic for rank 1: 12.2854, which is below the 5% critical value (15.41). This means that at rank 1 (if there is one cointegration link) the hypothesis is accepted. Statistics for ranks 2 and 3 are so low that there is no cointegration for them. The second block (Trace test): This test gives a result of 21.8041 in the case of 0 rank (no cointegration), which is below the critical value, confirming the presence of only one cointegration. In general, the results of the Johansen test show that there is one cointegration equation among the studied variables. This means that there is a long-run equilibrium relationship between the time series. Cointegrated variables move interdependently in the long run, which is important when considering their overall dynamics.

Table 5 presents the results of the VECM model to study the long-term correlation and short-term dynamics between the time series. This model estimates long-run effects between variables and corrects for short-run errors, taking into account cointegration relationships.

According to the results, the long-term relationship between the variables is estimated using the Cointegration equation. The Chi-square statistic for the _ce1 equation is: 59.38612, and P > Chi-square = 0.0000. This high significance level confirms

Table 4: Johansen tests for cointegration

Trend: Constant				Number of obs=23	
Sample: 2000 thru 2022				Number of lags=3	
Maximum rank	**Params**	**LL**	**Eigenvalue**	**Trace statistic**	**Critical value 5%**
0	21	−363.29039		34.0895	29.68
1	26	−352.38832	0.61249	12.2854*	15.41
2	29	−347.25495	0.36006	2.0187	3.76
3	30	−346.24562	0.08403		
Maximum rank	**Params**	**LL**	**Eigenvalue**	**Trace statistic**	**Critical value 5%**
0	21	−363.29039	.	21.8041	20.97
1	26	−352.38832	0.61249	10.2667	14.07
2	29	−347.25495	0.36006	2.0187	3.76
3	30	−346.24562	0.08403		

*selected rank

Table 5: Vector error-correction model

Sample: 2000 thru 2022				Number of obs=23		
				AIC=32.90333		
Log likelihood=−352.3883				HQIC=33.22615		
Det (Sigma_ml)=4.08e+09				SBIC=34.18693		
Cointegrating equations						
Equation			**Parms**	**Chi-square**	**P>Chi-square**	
_ce1			2	59.38612	0.0000	
Identification: beta is exactly identified						
Johansen normalization restriction imposed						
beta	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**95% confidence interval**	
_ce1						
GDP_per	1					
Energy_use	3.786521	0.4916734	7.70	0.000	2.822859	4.750184
Trade_opennes	−12.08287	1.965054	−1.21	0.025	−1.61401	1.44828
_cons	−7650.319					

the existence of a long-term association. Here, beta coefficients represent long-term relationships. These coefficients were determined based on Johansen normalization constraints. The coefficient for GDP per is 1 because it is a normalized variable. The coefficient for energy_use is 3.786521, which means that a 1-unit change in energy consumption has a 3.79-unit effect on GDP (GDP_per) growth in the long run. This effect is very high and $P > |z| = 0.000$, which means that this coefficient is statistically significant. Coefficient for trade_openness: −12.08287. This means that a change in trade openness has a negative effect on GDP, meaning that if trade openness increases by 1 unit, GDP decreases by 12 units. $P > |z| = 0.025$, which means that this coefficient is statistically significant. _cons: −7650.319. It is a constant member that has an overall effect on GDP.

The energy_use variable has a positive effect on GDP. This means that an increase in energy consumption will strengthen the country's economy and increase the level of GDP per capita. Trade_openness, on the other hand, has a negative effect. This result shows that an increase in trade openness has a negative effect on GDP, possibly because the variable is caused by higher imports.

The results of the VECM show that energy consumption and trade openness have a significant effect on GDP in the long run. An increase in energy consumption increases GDP, while an increase in trade openness decreases GDP. Energy positively supports GDP, therefore, the development of the energy sector in the economy contributes significantly to economic growth. The negative effect of trade openness indicates that economic policy needs more attention in matters related to foreign trade.

According to the results, the country's economic policy will have to strengthen the efficient use of energy resources and revise trade policies.

To check the reliability of this model, it is necessary to conduct several tests. Therefore, we first used the Lagrange-multiplier (LM) test (Table 6). The Lagrange-multiplier (LM) test is used to test the presence or absence of autocorrelation across lags for VECM or VAR models. The purpose of this test is to determine whether there is autocorrelation among the residual values in the model. If autocorrelation is present, the model results may be biased because autocorrelation implies that the residual errors are correlated, which violates the independence condition in the model. According to the results, $P = 0.96113$ is higher than 0.05, which means we cannot reject the null hypothesis. Therefore, there is no autocorrelation in the residuals at lag 1, Chi-square = 8.8326, $P = 0.45287$. This result also shows the absence of autocorrelation because the P-value is higher than 0.05 (0.45287). In general, according to the results of the Table, no autocorrelation was detected at both lags, since the P-value is higher than 0.05 in both cases. This means that the residuals of the model are independently distributed and it is confirmed that there is no autocorrelation. This result confirms the reliability of the model, that is, according to the LM test, there is no autocorrelation between the residual values in the VECM model, and there will be no problems using this model.

The next test we performed to verify the model is the Jarque-Bera test (Table 7). The Jarque-Bera test is used to check whether the residual (residual) values are normally distributed. This test can be used to determine whether or not the residuals have violated normality. If the residuals are normally distributed, this means that the results of the model are reliable and the conditions for estimation based on the classical OLS (Ordinary Least Squares) method are fulfilled. The Jarque-Bera test tests the hypothesis of normality. Null hypothesis (H_0): residual values are normally distributed. If the P > 0.05, the null hypothesis is not rejected and the residuals are assumed to be normally distributed. Chi-square = 0.079, P = 0.96115 for D_GDP_per. This result shows that the GDP residuals are normally distributed because the P-value (0.96115) is > 0.05. For D_Energy_use, Chi-square = 0.305, P = 0.85860. This result also indicates that the residuals for energy consumption are normally distributed because the P-value (0.85860) > 0.05. Chi-square = 3.932, P =0.13999 for D_Trade_openness. This result indicates that the residuals for the trade openness variable are normally distributed as the P-value (0.13999) > 0.05. On all variables (All) Chi-square = 4.317, P = 0.63393. This result confirms that the residuals for all variables are normally distributed, as the overall P-value is well above 0.05.

According to the results of the Jarque-Bera test, the residual values for all variables were normally distributed. This means that the residuals used in the model do not violate the conditions of normality and the parameters estimated in the model can be trusted. The results confirm the normality, so the results of the model are reliable and the analysis based on the VECM model is considered to be valid and accurately studied.

The keying test used to check the reliability of the model is the Eigenvalue stability condition (Table 8). The eigenvalue stability condition test is used to evaluate the stability (stability) of the VECM (Vector Error Correction Model) model. With the help of this test, it is determined how the dynamics of the residual values and variables of the model change over time. If the model is stable, then its predictions and results are considered reliable. An eigenvalue is used to evaluate the stability criterion. For the VECM model to be stable, all modulus values must be <1. If the eigenvalue values are equal to or >1, this means that the model lacks stability and the results may be unreliable. According to the results, the values of 1 and 1, that is, two unit modules, according to the specifications of the VECM model, indicate that the model is cointegrated and has one cointegration relationship. The remaining eigenvalues are: $-0.1024417 \pm 0.8590475i$, modulus = 0.865134; $0.6736346 \pm 0.4152547i$, modulus = 0.791341; $-0.2115506 \pm 0.4646806i$, modulus = 0.51057; −0.404228, modulus = 0.404228. All modulus values above are <1. This means that the model is stable and its dynamics slows down over time.

The results of the table show that the VECM model has stability because the modulus of all eigenvalues is <1. This shows that the model's predictions and analysis results are reliable. The stability of the model means that the long-run relationship and short-run error correction process implemented using the VECM model will be effective over time and the results will remain stable.

Overall, the study examined the long-term effects of energy consumption and trade openness on GDP per capita in Uzbekistan. The VECM (Vector Error Correction Model) model analyzed the long-term relationship between the variables, and according to the results, it has a significant positive effect on GDP per capita. A 1-unit change in energy consumption had a positive effect of 3.79 units on GDP growth per capita. GDP per capita had a negative impact. An increase in trade openness by 1 unit reduces GDP per capita by 12 units. This result may be related to the high level of imports. Countries with increased trade openness often develop a greater dependence on imports. If the country's exports are relatively weak or the export composition consists of low-value raw materials, the economy will be unbalanced with an increase in imports. In this case, an increase in imports may harm national production and make local producers uncompetitive. This leads to a decrease in the rate of economic growth. In addition, the non-competitiveness of the national industry is one of the factors that can negatively affect economic growth. Because the country does not have fully developed industries, as trade openness increases, foreign products become cheaper and better, which reduces the market share of domestic producers. As a result, domestic production will decrease, unemployment may increase, and national GDP will decrease. In this case, sectors that are not ready to compete will suffer greatly from trade openness.

Technological disruption and the lack of qualified personnel may also be influencing the negative relationship between economic growth and trade openness. Countries can import advanced technology and knowledge through trade openness. However, if a country faces a technological discontinuity (the gap between existing technologies and newly introduced technologies) or a shortage of skilled labor, the ability to properly adopt new technologies may be limited. This can have a negative impact

Table 6: Lagrange-multiplier test result

Lag	Chi-square	df	Prob>Chi-square
1	3.0779	9	0.96113
2	8.8326	9	0.45287

H_0: no autocorrelation at lag order

Table 7: Jarque-Bera test result

Equation	Chi-square	df	Prob>Chi-square
D_GDP_per	0.079	2	0.96115
D_Energy_use	0.305	2	0.85860
D_Trade_opennes	3.932	2	0.13999
All	4.317	6	0.63393

Table 8: Eigenvalue stability condition

Eigenvalue			Modulus
1			1
1			1
−0.1024417	+	0.8590475i	0.865134
−0.1024417	−	0.8590475i	0.865134
0.6736346	+	0.4152547i	0.791341
0.6736346	−	0.4152547i	0.791341
−0.2115506	+	0.4646806i	0.51057
−0.2115506	−	0.4646806i	0.51057
−0.4042282			0.404228

The VECM specification imposes 2 unit moduli on economic growth, as the economy will not be technologically ready to take full advantage. In addition, the change in the exchange rate can have a negative effect. If the country's trade openness increases and the share of imports is high, this will increase the pressure on the country's exchange rate. A devaluation of the national currency can have a negative impact on economic growth, as foreign goods become more expensive, inflation increases, and production costs increase.

Thus, the negative relationship between trade openness and economic growth can be determined by several reasons, and this situation depends on the structure of the national economy, the level of competitiveness, technological preparation and the export-import balance. Trade openness can have different outcomes in each country.

4. CONCLUSION

This study aims to determine the long-term impact of energy consumption and trade openness on the growth of per capita gross domestic product (GDP) for the economy of Uzbekistan. Using data from 1990 to 2023, long-term and short-term relationships between variables were investigated using the VECM model. According to the results of the analysis, energy consumption had a positive effect on the economic growth of Uzbekistan, that is, 1 unit increase in energy consumption increased GDP per capita by 3.79 units. This result shows that the economy of Uzbekistan is dependent on energy resources and emphasizes that the energy sector is an important factor for ensuring economic growth. At the same time, the impact of trade openness on economic growth was negative. According to the results of the analysis, an increase in trade openness by 1 unit reduced GDP per capita by 12 units. This situation may be related to problems in Uzbekistan's trade balance and excessive dependence on imports. Increased trade openness in the country has increased the impact of imports on the national economy, making the national industry uncompetitive. A high share of imports reduced domestic production and had a negative impact on the overall level of GDP. In addition, Uzbekistan's technological readiness and need for skilled labor can also be considered as a reason for the negative relationship between trade openness and economic growth. If a country cannot properly adopt new technologies or lacks skilled personnel, the expected positive effects of trade openness will not materialize. Also, as trade openness increases, pressure on the domestic currency increases, which may lead to a depreciation of the domestic currency and a slowdown in economic growth. The results show that the economic policy for Uzbekistan should focus on developing the national industry and increasing the efficient use of energy resources in order to reduce the negative impact of trade openness on economic growth. In order to make the country's economy more competitive and improve the trade balance, the introduction of technological innovations and the training of a qualified workforce are also important.

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