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Impact of Energy Consumption on Agricultural Economics in Uzbekistan: An ARDL Approach

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ABSTRACT

This study focuses on the relationship between renewable energy production, fossil fuel energy consumption, energy imports and total energy consumption, and examines the impact of energy consumption on the agricultural sector of Uzbekistan. learns Using data from 1990 to 2022 and using an autoregressive distributed lag (ARDL) model, the study aims to understand the short-term and long-term effects of these variables on the agricultural economy. The results show significant relationships with renewable energy production and energy imports having a positive effect on the agricultural economy, while fossil fuel consumption has a negative effect. The results emphasize the importance of energy policy in shaping the economic performance of the agricultural sector and emphasize the need to increase investments in renewable energy sources to ensure the sustainable development of agriculture in Uzbekistan.

Keywords: ARDL, Energy, Agricultural, Renewable Energy, Energy Consumption
JEL Classifications: Q13, Q29, Q43

1. INTRODUCTION

Today, environmental problems arising from various socio-economic activities are becoming increasingly evident and are becoming one of the most pressing problems for humanity, leading to various direct and indirect consequences for human life. Energy plays a decisive role in both current environmental problems and the availability of future resources. The historical development of human societies is closely related to the use of energy, developing from basic forms such as the use of fire to modern electricity and clean fuels (Kaygusuz, 2007). Fossil fuels, the primary energy source for many economies, not only contribute significantly to environmental problems such as climate change, but this type of energy is a finite resource (Lund, 2017). The environmental impact of energy production, particularly fossil fuels, is enormous, leading to air pollution, health risks, and ecosystem degradation (Ernst, 2012). The transition to renewable energy sources, despite the initial costs, is essential to mitigate these negative impacts and ensure sustainable development (Medvedkina and Khodochenko, 2020). Taking a multidisciplinary approach to energy solutions is essential to address the interrelated challenges of climate change, environmental degradation, security, poverty and health, and to ensure a sustainable future for future generations (Lund, 2017). This is understandable, given the level of global energy consumption for various economic and social activities, for example, it is impossible to imagine our life without electricity. The efforts made by several countries to date in the field of renewable energy (RE) give confidence to overcome the obstacles that may be encountered in this direction. The agricultural sector, as a source of RE such as biofuels and biomass, can offer other types of income to farmers, and can play a decisive role in this regard. As highlighted in various studies, biofuel production faces difficulties due to competition for land with other crops (Bajpai, 2023). Despite these challenges, it is important not to overlook the indirect benefits of biomass production, such as forest fire prevention. The environmental and economic impacts of fossil fuels have led to increased investment in biofuels to meet sustainability goals, although technological challenges and regional factors still hinder widespread adoption (Barbosa et al., 2022). Furthermore, the choice of feedstock and technological options plays a key role in determining the environmental impact of biofuel production, with concerns about the sustainability of first-generation biofuels due to their impact on food supply and competition for resources (Avagyan and Singh, 2019). To address these issues and maximize the benefits of biofuel production, a holistic approach is needed, taking into account environmental, economic, and social factors.

Agriculture and the agro-industry are the main sources of employment in Uzbekistan. However, as Uzbekistan has made significant strides towards industrialization in recent years, we can see that the share of agriculture in GDP has been declining (Figure 1).

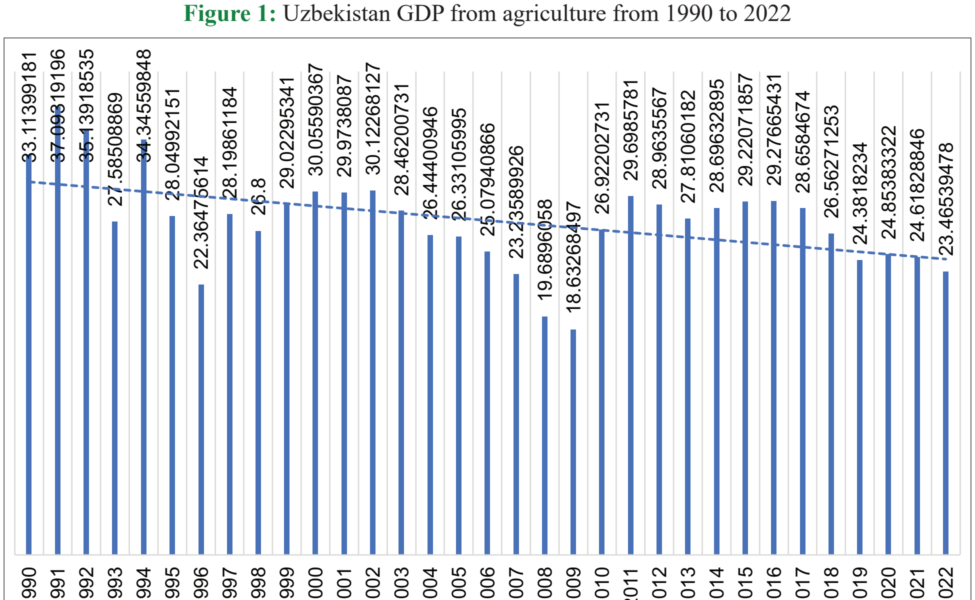
The agricultural sector plays a key role in Uzbekistan, one of the largest producers of products such as cotton and arable crops. In recent decades, Uzbekistan's imports of horticultural products have been steadily increasing, indicating that Uzbeks have a better food supply than in previous years. The fact that horticultural exports from Uzbekistan have increased by almost $5 billion in recent years is an indication of increasing food security (Muminova, 2023). At the same time, the balance of food supply and demand in the country is a constant concern, with unstable crop production leading to variability in growth rates and shifts in land resource carrying capacity patterns from oversupply to surplus and balance, especially for grains and calories (Yang et al., 2023). Despite the growth in food consumption and exports, challenges remain in meeting the increasing demand due to factors such as population growth, water scarcity, and inefficient land use, which creates the need for sustainable production and consumption strategies to ensure food security and resource protection (Jia et al., 2022). Developing logistics infrastructure and an innovative economy is also crucial for increasing the efficiency of the agricultural sector and meeting changing food demands (Sobirov and Eshonqulov, 2023).

2. LITERATURE REVIEW

Energy is undoubtedly a crucial factor affecting both the energy landscape and the economy of a country. As various research papers have pointed out, energy plays a crucial role in economic efficiency and industrial growth, accounting for one-tenth of production costs and driving industrial expansion (Atchuthen and Muthu Kumar, 2023a). Energy demand continues to grow globally due to population growth, improving living standards, and increased consumption affecting economic activity and development (Jamil et al., 2022). Energy efficiency, foreign direct investment and GDP are closely linked, showing a positive relationship between energy dynamics and economic progress in countries such as the UK and India (Atchuthen and Kumar, 2022). Furthermore, the sustainable socio-economic development of regions largely depends on a well-coordinated energy system, highlighting the indispensable role of energy in ensuring energy security and supporting economic growth (Панасюк, 2022).

Energy plays a crucial role in agriculture, especially in countries that rely heavily on the sector for food and economic growth. As the world's population continues to grow, demand for agricultural products is increasing, requiring increased energy consumption in farming operations (Safa, 2022). Agriculture not only consumes energy, but also contributes to energy production through bioenergy, increasing food security, adding value, and rural economic development (Giri et al., 2020). As agriculture is an energy-intensive industry due to mechanization and the use of commercial fertilizers, efficient use of energy becomes paramount to meet the food demands of the population and achieve broader social and economic goals (Shilpha, 2018).

Figure 1: Uzbekistan GDP from agriculture from 1990 to 2022



The demand for agricultural products is leading to an increase in the demand for renewable and non-renewable energy. The increasing demand for rare earth elements (REEs) has had a negative impact on the environment, and to address these problems, REE production (REO-renewable energy output) has been required. Industrialized livestock farming practices such as concentrated animal feeding operations (CAFOs) have been activated to meet the growing demand for animal products, which has led to significant environmental costs such as air, water, and soil pollution (Kraham, 2017). Similarly, REO production from primary sources is associated with various environmental and social impacts, including resource depletion and water consumption, highlighting the need for sustainable practices in REE production (Jouini et al., 2022).

Furthermore, the environmental impact of electricity generation, especially from non-renewable sources, highlighted the importance of switching to renewable sources to reduce environmental damage and ensure a sustainable future (Cole et al., 1994). These findings highlight the critical importance of balancing the high demand for REEs with minimizing environmental degradation through responsible production practices.

The energy sector is undoubtedly the backbone of any country's economy, significantly influencing economic efficiency and industrial growth. Modern economies rely heavily on energy, which accounts for a large portion of production costs and drives industrial expansion (Atchuthen and Muthu Kumar, 2023b). For example, in both the UK and India, energy efficiency is positively correlated with GDP growth and employment, underscoring the sector's important role in economic development. In general, the relationship between energy consumption and economic growth is complex and multifaceted. For example, the Energy-Environment Kuznets Curve (EKC) hypothesis, which also covers tourism, reveals a non-linear relationship between energy consumption and production levels, suggesting that large economies and the use of renewable energy can mitigate the environmental impact of increased energy consumption (Pablo-Romero et al., 2023). In Iran, the energy sector, particularly oil and gas, has historically been a major source of revenue, financing government spending and shaping the country's economic landscape. However, its focus on traditional energy sources leaves Iran vulnerable to geoeconomic risks, underscoring the need for diversification and modernization to achieve sustainable development (Chuvakhina et al., 2023).

The tourism sector also plays an important role in economic development by creating jobs, attracting investment, and stimulating other sectors. For example, in Uzbekistan, tourism has become a strategic sector, contributing to economic growth and international relations (Juraeva, 2023). However, the energy demands of tourism activities, particularly in the transport and commercial sectors, require policies that encourage high-quality tourism to control energy consumption and environmental impacts. The agricultural sector, another mainstay of the economy, supports national income and economic growth, especially in times of economic crisis. However, problems such as low productivity, insufficient human resources and lagging behind technological innovation need to be addressed through effective public policies (Batubara and Pane, 2023).

Overall, the energy sector's interactions with other sectors, such as tourism and agriculture, underpin its important role in shaping a country's economic trajectory. Effective policy frameworks, technological advances, and sustainable practices are essential to harness the energy sector's full potential, mitigate its environmental impacts, and ensure economic sustainability (Musti, 2023). Thus, a comprehensive approach that combines energy efficiency, renewable energy, and grid connectivity is essential for sustainable economic development.

As global warming intensifies, the need for renewable energy (RE) generation is becoming increasingly important, especially for the agricultural sector, which is highly dependent on energy for various activities. The integration of smart energy systems in agriculture can revolutionize this sector by managing energy consumption more efficiently, minimizing environmental impact, and increasing efficiency, thereby solving the challenges of global food security (Salaria and Rakhra, 2024). Initiatives such as the European Green Deal and Fit for 55 justify the need to reduce greenhouse gas (GHG) emissions in the energy sector, encouraging the use of renewable energy sources (RES), such as biofuels from organic waste, which can bring significant benefits to agriculture (Gradziuk et al., 2022).

Co-producing food and energy on the same land through technologies such as agrovoltaics can lead to sustainable intensification by optimizing light distribution, thereby increasing land and water efficiency and potentially improving soil health (Camporese and Abou Najm, 2022). In India, renewable energy sources such as biomass, solar, wind, hydro and geothermal offer a viable alternative to fossil fuels, supporting a sustainable environment and creating employment opportunities that are crucial for financial inclusion and economic health (Kar et al., 2023). The role of energy in agriculture extends beyond post-production to domestic rural needs and livestock production, requiring secure, affordable and sustainable energy systems powered by renewable sources. Engineering interventions and advanced technologies such as IoT, artificial intelligence and robotics are essential to generate and use energy efficiently in rural areas, promote the use of locally available renewable sources and reduce dependence on fossil fuels (Gangil and Mehta, 2022). Over the past 50 years, global agricultural food production has increasingly relied on non-renewable resources, particularly fossil fuels, which are now recognized as unsustainable due to their contribution to GHG emissions and climate change (Rempelos et al., 2023). The Food and Agriculture Organization (FAO) highlights the need to replace fossil fuels with low-carbon energy sources, noting that the agriculture and food supply chain contribute significantly to global GHG emissions. Renewable energy technologies such as electric tractors and agricultural robots offer promising alternatives, and their adoption can be facilitated through technical improvements, cost reductions, and government incentives (Gorjian et al., 2022). Therefore, the survival and sustainability of the agricultural sector is inextricably linked to the production and adoption of renewable energy, which not only solves the problems caused by global warming, but also ensures energy security, economic growth and environmental sustainability.

Renewable (RE) and non-renewable energy sources have a significant impact on the country's agricultural productivity and environmental sustainability. The increasing demand for energy to support a growing population has led to overexploitation of natural resources and overuse of fossil fuels, leading to environmental degradation and climate change (Sharma et al., 2023). Renewable energy sources such as solar, tidal, geothermal and wind are increasingly gaining attention to address the energy crisis and ensure environmental sustainability. Studies have shown that renewable energy consumption can reduce carbon emissions and thus improve environmental quality. For example, in SAARC countries, renewable energy consumption reduces CO_2 emissions, while non-renewable energy consumption increases them (Akbar et al., 2024).

Similarly, in African countries, renewable resources and trade openness reduce carbon emissions, while non-renewable resources, population density, urbanization, and foreign direct investment contribute to increased emissions (Wen et al., 2022). Renewable energy and economic growth in India have a negative impact on the ecological footprint, suggesting that renewable energy can help mitigate environmental degradation (Roy, 2023). Furthermore, renewable energy consumption in South Asian countries is leveling off carbon dioxide emissions, supporting the Environmental Kuznets Curve hypothesis, which states that economic growth initially leads to environmental degradation, but after a certain level of per capita income, the trend reverses, leading to environmental improvements. Renewable energy consumption in North America has had a positive impact on economic growth in Mexico and Canada, justifying the use of renewable energy to support sustainable economic development (Mendoza-Rivera et al., 2023).

The agricultural sector, in particular, benefits from renewable energy technologies to improve productivity and sustainability. For example, renewable energy is increasingly being used in agriculture to improve energy efficiency and reduce the environmental impact of agricultural practices. The integration of renewable energy in agriculture not only supports sustainable farming practices, but also contributes to the overall environmental health of the country. In addition, energy efficiency (EE) is crucial for achieving sustainable economic growth while minimizing environmental impacts. Studies in G20 countries show that, while incorporating renewable energy consumption can slightly reduce energy productivity, it improves EE on average (Shah et al., 2023). Technological advances in energy use and the introduction of environmentally friendly production processes are essential to improve environmental quality and support sustainable development. In general, the transition to renewable energy sources and the efficient use of non-renewable resources are crucial for increasing agricultural productivity, reducing environmental degradation, and promoting sustainable economic growth in different regions.

The importance of agriculture is undoubtedly increasing globally, especially in countries with fertile soils that are focusing on sustainable agricultural development. This sector is crucial not only for providing employment and contributing to gross domestic product, but also for ensuring food security and socio-economic well-being (Sharma et al., 2024). Energy plays a crucial role in improving agricultural efficiency, as modern agricultural practices are very energy-intensive. In South Asian countries such as India and Pakistan, energy consumption in agriculture exceeds 12%, excluding energy used to produce fertilizers and pesticides.

The transition to sustainable agricultural practices requires the integration of non-conventional energy sources such as solar, wind, biomass and biofuels to make agriculture more efficient and profitable for farmers. The global trend of increasing energy consumption in agriculture justifies the need for efficient energy management to increase the investment attractiveness of regions for agricultural enterprises, which reduces economic risks and promotes sustainability (Godlewska-Majkowska and Komor, 2021). Sustainable agriculture also addresses the environmental challenges that have arisen as a result of the Green Revolution and subsequent liberalization, privatization, and globalization trends, which have led to the overexploitation of natural resources (Singh, 2024).

Adopting sustainable agricultural practices that focus on biodiversity, living soils, and cyclical nutrient flows is essential to meet the needs of the current population without compromising the ability of future generations to meet their own food needs. Energy efficiency is another important factor, as it directly affects crop production efficiency. Strategies such as the use of high-quality seeds, minimal tillage systems, and effective weed control can increase energy efficiency and thus increase the overall sustainability of agricultural systems (Eskandari, 2023).

The link between agriculture and economic growth is well documented, with sustained growth in agricultural incomes contributing positively to national income and stimulating economic growth. However, countries with limited natural resources for energy production face high prices for agricultural products due to their reliance on imported energy sources. This calls for innovative approaches and public-private partnerships to create an enabling innovation environment that enables the adoption of sustainable practices and technologies in agriculture (Xolmurotov et al., 2024). The bioeconomy, which focuses on the production of high-tech, innovative agricultural products that meet safety, provenance, technology and ethical standards, is becoming increasingly important in this context.

Addressing global challenges such as inequality, environmental degradation, and resource constraints requires comprehensive and concerted efforts from countries, regions, companies, and individuals (Saribayevich et al., 2024). By using agriculture as a tool for development, countries can modernize their farming systems, value chains, and local non-agricultural economies, contributing to overall development and sustainability. Therefore, integrating sustainable energy practices into agriculture is not only a necessity for environmental and economic reasons, but also a strategic imperative to ensure long-term food security and socio-economic sustainability.

3. METHODOLOGY

In this paper, we attempted to examine the impact of REO, fossil fuel energy consumption (FFEC), energy imports (EI), and energy use (EU) on the agricultural economy in Uzbekistan. The data for the study were obtained from the WDI and the country's statistical authorities, and the period from 1990 to 2022 was selected. The equation is given as follows:

$$AE_t = \alpha_0 + \beta_1 REO_t + \beta_3 FFEC_t + \beta_4 EI_t + \beta_5 EU_t + e_t \quad (1)$$

Where:
AE- Agricultural Economics
t- Time Period
REO- Renewable Energy Output
FFEC- Fossil Fuel Energy Consumption
EI- Energy Import
EU- Energy Use
e- Error term

We chose the agricultural economy as the dependent variable in the study, and it is measured as Agriculture, Forestry and Fisheries, Value Added (relative to GDP). In addition, five independent variables were used, namely REO - Renewable electricity output (% of total electricity output), FFEC - Fossil fuel energy consumption (% of total), EI - Energy imports, net (% of energy use), and EU - Energy use (kg of oil equivalent per capita). Table 1 shows all the variables studied in the study and their measurements.

We also included descriptive statistics results showing the mean and standard deviation of the variables in the study and to know the maximum and minimum values of the variables under study (Table 2). In addition, we also examined the correlation matrix to determine the relationship between the variables in the study. In addition, we also conducted the Augmented Dickey-Fuller (ADF) test to check for unit root between the variables in the study.

In this paper, we used the ARDL model to study the relationship between variables, and it is the best model when some constructs are stationary at the level and some constructs are stationary in the first difference. The autoregressive distributed lag (ARDL) model is indeed a reliable choice for studying the relationship between variables, especially when dealing with constructs that exhibit different degrees of stationarity - some are stationary at the level, others in the first difference. This flexibility is one of the main advantages of the ARDL approach, as it allows the inclusion of the I(0) and I(1) variables without prior testing for unit roots, which is a significant limitation in other time series such as VAR (Pashkov, 2022).

The ARDL model is also suitable for small samples because there are 33 observations in this paper. In addition, the ARDL model captures both short-run and long-run associations between the constructs. The ARDL model equation is given below:

$$\begin{aligned} \Delta AE_t &= \alpha_0 + \sum \delta_1 \Delta AE_{t-1} + \sum \delta_2 \Delta REO_{t-1} + \\ &\sum \delta_3 \Delta FFEC_{t-1} + \sum \delta_4 \Delta EU_{t-1} + \varphi_1 AE_{t-1} + \\ &\varphi_2 REO_{t-1} + \varphi_3 FFEC_{t-1} + \varphi_4 EI_{t-1} + \varphi_5 EU_{t-1} + e_t \end{aligned} \quad (2)$$

4. RESULTS AND DISCUSSION

As a result of the analysis, we obtained descriptive statistics showing the mean and standard deviation of the variables. The results are as follows, the mean value of AE is 27.66%, and the mean value of REO is 16.94%. In addition, the mean value of FFEC is 98.34%. Finally, we can see that the mean value of EI is −14.31%, and the mean value of EU is 1828.96%. In general, most variables have skewness values close to zero, which indicates that they are close to a symmetric distribution. FFEC has a more significant negative skewness and EI has a moderate positive skewness. The kurtosis values indicate that REO and EI have a flatter distribution. The standard deviation values provide an idea of the variability of each variable (Table 2).

In the study, we used a correlation matrix to examine the relationship between variables (Table 3). The purpose of the correlation matrix is to identify the relationship between variables and assess their impact on the agricultural economy (AE). According to the results of the analysis, REO (−0.46): This negative correlation is noted, indicating that renewable

Table 1: Variables with measurments

Variable	Measurement	Sources
Agricultural economics (AE)	Agriculture, forestry, and fishing, value added (% of GDP)	WDI
REO	Renewable electricity output (% of total electricity output)	WDI, stat.uz
FFEC	Fossil fuel energy consumption (% of total)	WDI, stat.uz
EI	Energy imports, net (% of energy use)	WDI, stat.uz
EU	Energy use (kg of oil equivalent per capita)	WDI, stat.uz

Table 2: Descriptive statistics

Variable	Obs	Mean	Median	Standard deviation	Min	Max	Skewness	Kurtosis
AE	33	27.66	28.04	3.96	18.63	37.09	0.06	3.46
REO	33	16.94	17.98	3.82	11.13	22.99	−0.07	1.41
FFEC	33	98.34	98.41	0.56	96.51	99.15	−0.95	4.46
EI	33	−14.31	−17.49	12.91	−28.47	17.56	1.07	3.35
EU	33	1828.96	1823.31	254.63	1419.47	2294.82	0.01	1.88

energy production (REO) is inversely related to AE. This may reflect the investment requirements of renewable energy technologies or the limitations in increasing their efficiency in the agricultural sector. FFEC (0.46): Fossil fuel consumption is positively related to AE, indicating that this type of energy still plays a major role in the agricultural sector. EI (0.66): Energy imports have a strong positive correlation with AE. This indicates that external energy resources play an important role in agriculture. EU (0.55): Energy consumption is also positively correlated with AE. This indicates the importance of energy in agricultural processes and the need for its efficient management.

The correlation results show that the agricultural economy is in interaction with renewable energy, fossil fuels, energy imports and consumption. The results suggest that energy policies should be oriented to support agricultural development. In particular, positive results can be obtained by increasing the focus on renewable energy sources. The positive correlation between fossil fuels and AE emphasizes the need to develop alternative energy sources to reduce their negative environmental impact.

We conducted the ADF test to check for unit root between the variables. The results of the ADF test showed that AE is stationary at its level and we can see that all variables are stationary at first difference. Table 4 shows these results.

We also used the ARDL linked test to test for cointegration during the study. The results in Table 5 show that the calculated f-statistic (4.01) is greater than the critical values at the 5% significance level, indicating the presence of cointegration and the possibility of using the ARDL model.

The results shown in Table 6 show that REO, FFEC, EI and EU have a positive relationship with the agricultural economy in Uzbekistan in the short run. The results show that 66% of the changes in the agricultural economy are due to all predictors used in the study.

Table 3: Matrix of correlations

Variable	AE	REO	FFEC	EI	EU
AE	1				
REO	−0.46	1			
FFEC	0.46	−0.82	1		
EI	0.66	−0.74	0.65	1	
EU	0.55	−0.82	0.85	0.84	1

The results showed that all variables have $P < 0.05$, indicating that they are statistically significant in the long run. REO and EI have positive coefficients, indicating that they have a positive effect on the dependent variable. FFEC has a negative coefficient, indicating that it has a negative effect on the dependent variable. EU has a positive but very small coefficient, indicating that it has a small positive effect (Table 7).

4.1. Renewable Energy Output (REO)

The results of the analysis show that renewable energy production (REO) has a positive and significant impact on the agricultural economy. According to the results of the long-term assessment, the REO coefficient is 1.45, which indicates that it has a significant positive impact on the agricultural economy. This result emphasizes the importance of renewable energy, such as solar, wind and biomass, as an environmentally sustainable energy source in agriculture. Also, the short-term impact of REO is negative, at −0.47, which indicates that the results are not immediately reflected in the short term due to the costs associated with investment and infrastructure.

4.2. Fossil Fuel Energy Consumption (FFEC)

The results of the analysis confirm the negative impact of fossil fuel energy consumption (FFEC) on the agricultural economy. In the long term, the FFEC coefficient is −4.13, which indicates that environmental degradation and climate change problems have a negative impact on agricultural production. Also, the positive correlation between FFEC and AE (0.46) indicates that this type of energy still plays a major role in agriculture, which emphasizes the need to gradually abandon fossil fuels.

4.3. Energy Imports (EI)

Energy imports (EI) have a significant positive impact on the agricultural economy. The long-term assessment results show that the coefficient of EI is 0.07, which indicates that external energy sources play an important role in the agricultural sector. The correlation between EI and AE (0.66) also reinforces this effect. However, dependence on energy imports can increase exposure to global energy market fluctuations and geopolitical risks. Therefore, the development of domestic renewable energy sources should be considered as a long-term strategy.

4.4. Energy Use (EU)

The impact of energy consumption (EU) on the agricultural economy is positive but relatively small, with a coefficient of 0.03 in the long run. This result indicates the need for efficient energy management in agriculture. The correlation between EU and AE

Table 4: Unit root test results (include in test equation - intercept)

Variable name	ADF test		PP test	
	At level	First-difference	At level	First-difference
AE	−3.07 (0.031)	−5.46 (0.000)	−2.58 (0.106)	−6.65 (0.000)
REO	−1.54 (0.497)	−10.25 (0.000)	−1.85 (0.348)	−12.02 (0.000)
FFEC	−0.37 (0.902)	−5.57 (0.000)	0.56 (0.986)	−5.48 (0.000)
EI	−2.61 (0.101)	−5.11 (0.000)	−2.67 (0.089)	−5.11 (0.000)
EU	−1.63 (0.453)	−5.96 (0.000)	−1.63 (0.453)	−7.61 (0.000)

Table 5: Bound test results

Model	Significance level	Lower bound	Upper bound
AE/(REO, FFEC, EI, EU)	F-statistics - 4.01, k=4		
	90%	2.2	3.09
	95%	2.56	3.49
	97.5%	2.88	3.87
	99%	3.29	4.37

Table 6: Short-run estimation results

Variable	Coefficient	Standard error	t-Statistic	Prob
Short-run				
D (REO)	−0.47	0.19	−2.49	0.02
D (REO)	−0.88	0.22	−3.86	0.001
D (EI)	0.59	0.12	4.75	0.0001
D (EU)	0.02	0.005	4.25	0.0004
D (EU)	−0.01	0.004	−3.88	0.001
CointEq(−1)	−0.71	0.12	−5.51	0.00
R-squared	0.66	Mean depend var		−0.44
Ad-R-squares	0.58	Standard deviation depend var		3.32

Table 7: long-run estimation results

REO	1.45	0.62	2.32	0.03
FFEC	−4.13	3.44	−1.21	0.03
EI	0.07	0.14	0.53	0.01
EU	0.03	0.01	2.28	0.03

(0.55) reflects the role of this type of consumption in agriculture. Modern agricultural practices, such as precision agriculture and irrigation technologies, require efficient management of energy consumption.

5. CONCLUSION

The analysis of the impact of energy consumption on the agricultural sector in Uzbekistan, using the ARDL model, provides important insights into the dynamics between energy variables and agricultural economic performance. The results confirm that renewable energy output and energy imports positively contribute to the value added by agriculture, forestry, and fishing, indicating that sustainable energy practices can bolster the agricultural sector. Conversely, the negative impact of fossil fuel consumption underscores the environmental and economic drawbacks of relying on non-renewable energy sources. These findings suggest that policymakers should prioritize the development and integration of renewable energy sources to promote sustainable agricultural growth. Investments in renewable energy technologies and infrastructure will not only enhance agricultural productivity but also contribute to environmental sustainability, aligning with the broader goals of economic development in Uzbekistan. This study provides a foundation for future research on energy consumption and its sector-specific impacts, advocating for policies that balance economic growth with environmental stewardship.

Based on the results of the study, the following recommendations were developed for the further development of agriculture and improvement of energy policy in Uzbekistan:

Developing renewable energy infrastructure: Increasing investment in renewable energy sources such as solar, wind, and biomass, Providing subsidies and tax breaks to encourage the adoption of renewable energy technologies in agriculture.

Fossil fuel decarbonization strategy: Introduce energy-efficient technologies to gradually reduce fossil fuel consumption in agricultural energy, and strengthen public-private sector cooperation in the development of alternative energy sources.

Increasing energy efficiency: Widespread use of modern technologies and methods that increase energy efficiency in agriculture (precision agriculture, drip irrigation systems, etc.), Strengthening funding for research and innovation in energy efficiency.

Ensuring local energy security: Developing local renewable energy sources to reduce dependence on energy imports, expanding local production capabilities, and ensuring energy independence.

Protecting the environment: Reducing greenhouse gas emissions by reducing the use of fossil fuels, Ensuring environmental sustainability by expanding renewable energy technologies.

Improving public policy: Introducing legislation and policy mechanisms that encourage the efficient use of energy resources in agriculture, and attracting investments in renewable energy by strengthening cooperation between the public and private sectors.

REFERENCES

Akbar, A., Gul, A., Sohail, M., Hedvicakova, M., Haider, S.A., Ahmad, S., Iqbal, S. (2024), Impact of renewable and non-renewable energy resources on CO_2 emission: Empirical evidence from SAARC. International Journal of Energy Economics and Policy, 14(1), 141-149.

Atchuthen, M., Kumar, S.S.M. (2022), How the energy sector is affecting economic growth? - Comparing the United Kingdom with India. European Journal of Accounting, Auditing and Finance Research, 10(9), 13-23.

Atchuthen, M.T.J., Muthu Kumar, S.S. (2023a), How the energy sector is affecting economic growth - comparing the United Kingdom with India. International Journal of Economic Sciences, 12(1), 1-31.

Atchuthen, M.T.J., Muthu Kumar, S.S. (2023b), How the energy sector is affecting economic growth - comparing the United Kingdom with India. International Journal of Economic Sciences, 12(1), 1-31.

Avagyan, A.B., Singh, B. (2019), Barriers in the biofuel-producing chain and revision of environmental impacts. Biodiesel: Feedstocks, Technologies, Economics and Barriers, 2019, 113-126.

Bajpai, P. (2023), Challenges to biofuel production. Cellulases in the Biofuel Industry, 2023, 67-89.

Barbosa, F.G., Sánchez-Muñoz, S., Mier-Alba, E., Castro-Alonso, M.J., Hilares, R.T., Marcelino, P.R.F., Prado, C.A., Campos, M.M., Cardoso, A.S., Santos, J.C., Da Silva, S.S. (2022), Challenges and perspectives on application of biofuels in the transport sector.

Bioethanol, 2022, 463-499.
Batubara, M., Pane, M.M. (2023), Pengaruh pertanian terhadap pendapatan nasional. Jurnal Penelitian Ekonomi Akuntansi, 7(1), 74-81.
Camporese, M., Abou Najm, M. (2022), Not all light spectra were created equal: Can we harvest light for optimum food-energy co-generation? Earth’s Future, 10(12), e2022EF002900.
Chuvakhina, L.G., Nasirbeik, A., Yarygina, I.Z., Ustinova, O.E., Terskaya, G.A. (2023), The role of the energy sector in the Iranian Economy. International Journal of Energy Economics and Policy, 13(1), 382-388.
Cole, J.J., Caraco, N.F., Kling, G.W., Kratz, T.K. (1994), Carbon dioxide supersaturation in the surface waters of lakes. Science, 265(5178), 1568-1570.
Ernst, W.G. (2012), Overview of naturally occurring Earth materials and human health concerns. Journal of Asian Earth Sciences, 59, 108-126.
Eskandari, H. (2023), Improving energy efficiency in agronomical systems. Iranica Journal of Energy and Environment, 14(3), 221-227.
Gangil, S., Mehta, CR. (2022), Application of renewable energy in Indian agriculture. Journal of Rice Research, 15, 8034.
Giri, P., Behera, B., Behera, B., Khanda, C., Behera, S.D. (2020), Energetics of raising varying duration rice varieties under different establishment methods. International Journal of Current Microbiology and Applied Sciences, 9(9), 592-599.
Godlewska-Majkowska, H., Komor, A. (2021), Energy as a factor of investment attractiveness of regions for agricultural enterprises. Energies, 14(9), 2731.
Gorjian, S., Fakhraei, O., Gorjian, A., Sharafkhani, A., Aziznejad, A. (2022), Sustainable food and agriculture: Employment of renewable energy technologies. Current Robotics Reports, 3(3), 153-163.
Gradziuk, P., Klepacki, B., Stolarski, M.J. (2022), Energy Supply within Sustainable Agricultural Production: Challenges, Policies and Mechanisms. Switzerland: Mdpi AG.
Jamil, M.N., Khan, R.Y., Corresponding, P. (2022), Critical analysis of energy consumption and its impact on countries economic growth: An empirical analysis base on Countries income level. Journal of Environmental Science and Economics, 1(2), 1-12.
Jia, M., Zhen, L., Zhang, C. (2022), Analysis of food consumption and its characteristics in uzbekistan based on the emergy method. Journal of Resources and Ecology, 13(5), 842-850.
Jouini, M., Royer-Lavallée, A., Pabst, T., Chung, E., Kim, R., Cheong, Y.W., Neculita, C.M. (2022), Sustainable production of rare earth elements from mine waste and geoethics. Minerals, 12(7), 809-809.
Juraeva, F. (2023), The role of the tourism activity in the development economy of our country. International Journal of Economics and Innovative Technologies, 11(4), 415-427.
Kar, S.K., Pradhan, N.C., Swain, S.S., Kar, S. (2023), Applicability of Various Renewable Energy Sources to Agricultural Applications. In: Handbook of Energy Management in Agriculture. Germany: Springer Nature. p1-19.
Kaygusuz, K. (2007), Energy for sustainable development: Key issues and challenges. Energy Sources Part B-Economics Planning and Policy, 2(1), 73-83.
Kraham, S.J. (2017), Environmental impacts of industrial livestock production. International Farm Animal, Wildlife and Food Safety Law, 2017, 3-40.
Lund, P.D. (2017), Global Challenges: Energy. Global Challenges, 1(1), 7-8.
Medvedkina, Y.A., Khodochenko, A.V. (2020), Renewable Energy and Their Impact on Environmental Pollution in the Context of Globalization. In: 2020 International Multi-Conference on Industrial Engineering and Modern Technologies, FarEastCon.
Mendoza-Rivera, R.J., García-Pérez, L.E., Martínez, F.V. (2023), Renewable and non-renewable energy consumption, CO_2 emissions, and responsible economic growth with environmental stability in North America. International Journal of Energy Economics and Policy, 13(4), 300-311.
Muminova, R. (2023), Phytophagous insects of malus in Uzbekistan. Бюллетень Науки и Практики, 6, 86-89.
Musti, K.S. (2023), Energy sector growth and sustainability. Practice, Progress, and Proficiency in Sustainability, 2023, 186-203.
Pablo-Romero, M.P., Sánchez-Braza, A., García-Soto, M.A. (2023), The impact of tourism on energy consumption: A sectoral analysis for the most visited countries in the world. Economies, 11(10), 263.
Pashkov, S. (2022), Peculiarities of ARDL modeling in sociological time series analysis (the case of economic news in the dynamics of CSI in 2010-2017). Sociology: Methodology, Methods, Mathematical Modeling (Sociology: 4M), 27(53), 39-82.
Rempelos, L., Kabourakis, E., Leifert, C. (2023), Innovative organic and regenerative agricultural production. Agronomy, 13(5), 1344-1344.
Roy, A. (2023), The impact of foreign direct investment, renewable and non-renewable energy consumption, and natural resources on ecological footprint: An Indian perspective. International Journal of Energy Sector Management, 18(1), 141-161.
Safa, M. (2022), Measuring and auditing on-farm energy use. In: Burleigh Dodds Series in Agricultural Science. p3-32.
Salaria, A., Rakhra, M. (2024), Analysis on Future of Farming: Smart Energy Systems in Agriculture. 2024 11th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions), ICRITO 2024. p1-5.
Saribayevich, X.F., Sariyevich, X.X., Davlatov, S., Turobova, H., Ruziyev, S. (2024), Analysis of factors affecting CO_2 emissions: In the case of Uzbekistan. International Journal of Energy Economics and Policy, 14(4), 207-215.
Shah, W.U.H., Hao, G., Yan, H., Zhu, N., Yasmeen, R., Dincă, G. (2023), Role of renewable, non-renewable energy consumption and carbon emission in energy efficiency and productivity change: Evidence from G20 economies. Geoscience Frontiers, 15(4), 101631-101631.
Sharma, M., Kargwal, R., Atheaya, D., Kumar, A. (2024), Role of energy in the development of agriculture sector in South Asia. In: The South Asian energy corridor: Toward Sustainability and Security. United States: CRC Press. p313-333.
Sharma, S., Sharma, M., Singh, J., Dhir, B., Kumar, R. (2023), Non-renewable resources and environmental sustainability. Technology for a Sustainable Environment, 1-16. Doi: 10.2174/9789815124033123010004
Shilpha, S.M. (2018), Energetics in various cropping systems. International Journal of Pure and Applied Bioscience, 6(4), 303-323.
Singh, V. (2024), Agriculture and food resources. In: Textbook of Environment and Ecology. Germany: Springer Nature. p155-174.
Sobirov, S., Eshonqulov, A. (2023), The importance of agricultural products in the development of logistics infrastructure and innovative economy in the Republic of Uzbekistan. Modern Trends of Innovative Development of Science and Education in the Global World, 1(1), 263-265.
Wen, Y., Onwe, J.C., Haseeb, M., Saini, S., Matuka, A., Sahoo, D. (2022), Role of technological innovation, renewable and non-renewable energy, and economic growth on environmental quality. Evidence from African countries. Frontiers in Energy Research, 10, 958839.
Xolmurotov, F.S., Xolmuratov, X.S., Yakubova, Y.R. (2024), Assessment of the impact of agriculture on the regional socio-economic development. E3S Web of Conferences, 548, 01003.
Yang, Y., Xiao, C., Zhang, C., Liu, Y., Wang, Y., Wang, J., Liang, Y., Song, X., Yang, Y., Xiao, C., Zhang, C., Liu, Y., Wang, Y. (2023), Spatiotemporal characteristics of food supply-demand balance in Uzbekistan under different scenarios. Foods, 12(10), 2065-2065.
Панасюк, B.B. (2022), Conceptual foundations and features of functioning of regional energy systems. Vestnik Brestskogo Gosudarstvennogo Tehničeskogo Universiteta, 127(1), 106-111.