“The impact of renewable energy consumption on unemployment rates in Uzbekistan: An ARDL approach”

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THE IMPACT OF RENEWABLE ENERGY CONSUMPTION ON UNEMPLOYMENT RATES IN UZBEKISTAN: AN ARDL APPROACH

Abstract

This study investigates the intricate interplay between the utilization of renewable energy sources and the fluctuations in unemployment rates in Uzbekistan during the period from 2000 to 2022, utilizing the Autoregressive Distributed Lag model. The analysis leverages World Bank data to explore both short-term and long-term impacts, offering critical insights for policymakers and stakeholders. The findings reveal that an increase in renewable energy consumption has a statistically significant and negative impact on unemployment rates in the long run, with a 1% rise in renewable energy usage leading to a 1.86% decrease in unemployment. In addition, gross fixed capital formation and government expenditure significantly contribute to job creation, while domestic credit to the private sector shows a positive association with unemployment, suggesting inefficiencies in credit allocation. The results emphasize the crucial role of strategic investments in renewable energy as a pathway to address economic and environmental challenges. By promoting renewable energy initiatives, Uzbekistan can align its economic growth with sustainability goals, reduce carbon emissions, and create employment opportunities. This study provides empirical evidence supporting the expansion of renewable energy infrastructure as a means to foster economic development and social well-being. It also underscores the necessity of enhancing financial policy frameworks to ensure efficient credit distribution and maximize the employment benefits of renewable energy projects. The policy recommendations derived from this study advocate for targeted investments, financial sector reforms, and the development of specialized training programs to cultivate a skilled workforce in renewable energy sectors.

Keywords renewable energy, unemployment, energy consumption, economic growth, ARDL, employment, sustainability, environmental

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INTRODUCTION

The increasing global importance of renewable energy reflects its dual role in promoting economic growth and addressing environmental challenges. Renewable energy sources, including solar, wind, geothermal, and bioenergy, not only help reduce greenhouse gas emissions but also support sustainable development by offering cleaner alternatives to fossil fuels. These sources are vital in tackling pressing issues such as energy security and economic inequality, particularly in countries with growing energy demands and environmental concerns.

In Uzbekistan, the strategic push toward renewable energy arises from the nation's pressing economic and environmental challenges. High unemployment rates persist, negatively impacting living standards

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and economic growth. At the same time, Uzbekistan has significant potential for renewable energy development, particularly in solar and wind power. Despite this potential, limited research has been conducted on the link between renewable energy consumption and unemployment in the country, creating a gap in understanding the socio-economic benefits of adopting renewable energy technologies. Addressing this gap is crucial for formulating effective policies that promote employment and sustainable economic development.

1. LITERATURE REVIEW

There has been a lot of attention in the economic literature regarding the connection between unemployment and gross fixed capital formation (GFCF). The fundamental idea is that investing in fixed assets can boost employment and economic expansion, which will lower unemployment. According to Pasara and Garidzirai (2020), who studied cause-and-effect relationships between South Africa's GDP, unemployment, and gross capital formation, the goal of gross capital formation (GCF) is to increase GDP and employment. Rawal et al. (2021) analyzed unemployment and its relationship with gross capital formation and economic growth in the case of India by employing the VAR model with the data of 2010–2019. The results reveal that the unemployment rate is affected negatively by the rise of GCF. Meyer and Sanusi (2019) studied this relationship in South Africa. According to the empirical results, there is a long-term correlation between employment, domestic investment, and economic growth; the causal relationship is from investment to economic growth rather than the other way around. The findings also show that investment has a long-term, favorable effect on employment.

While there is evidence of unidirectional causality from investment to employment, the empirical evidence also points to a bidirectional causal relationship between employment and economic growth. Hegelund and Taalbi (2023) investigate the long-term relationship between unemployment and macroeconomic variables by using a long-term perspective of macroeconomic history. They apply band spectrum regressions to examine the relationship between unemployment, GDP, investment, interest rates, and productivity, as well as wavelet analysis to break down time series spanning ten countries from 1913 to 2016 into short-, medium-, and long-term variations. By estimating cross-country regression models, they discover compelling evidence of a negative correlation between unemployment and long-term investment components.

Researchers have extensively studied the impact of general government final consumption expenditure on unemployment, showing mostly negative results. Saraireh (2020) researched Jordan from 1990 to 2019 by employing the ARDL model. The study found that unemployment was observed to drop by roughly 0.43 percentage points in the same year, and government spending rose by 1% of GDP. Ceesay et al. (2022) analyzed the relationship between employment and the final consumption expenditure of the general government in Gambia for the period from 1977 to 2017. Through investment multiplier effects on aggregate demand, levels of government consumption expenditure raise productivity, investment, and employment levels in the population. Pham (2024) studied 35 Asian countries from 2000 to 2022 using the dynamic ordinary least squares and fully modified ordinary least squares technique. The findings demonstrate that higher government spending and improved institutions lower the unemployment rate.

It is interesting to note that higher institutional quality will exacerbate the detrimental effects of government spending on unemployment. A rise in government spending has a greater effect on employment and national income than a drop in government spending. Therefore, the government has a significant impact on raising the national income and creating job possibilities (Sinha, 2022). Sergi et al. (2023) mentioned that government investment in education has increased, but more work is required to lessen income inequality. This shift requires improved productivity, economic performance, and state institutions of the highest caliber. The article examined how economic growth affects inequality, focusing on how governments act as intermediaries in the case of 11 post-Soviet nations and runs from 2000 to 2020.

The positive impact of private sector credit on unemployment is a multifaceted issue influenced by the allocation of credit and the economic context in which it is distributed. While private sector lending can stimulate economic growth and reduce unemployment by providing businesses with the necessary capital to expand and hire more workers, the misallocation of credit can lead to increased debt burdens and higher unemployment rates. This occurs when credit is directed toward low-income or high-risk sectors that do not contribute significantly to economic efficiency.

The misallocation of credit can lead to credit contractions, significantly increasing unemployment rates. This is particularly evident during downturns following excessive credit booms, which have been shown to contribute to rising unemployment. While financial deepening initially supports job creation, it may lead to rising unemployment if the private sector becomes overly leveraged. Such over-leverage can result in firms' inability to service their debt, leading to bankruptcies and job losses. In Australia, the accumulation of external debt in the private sector has been linked to higher unemployment, highlighting the risks of excessive borrowing and the importance of managing external debt levels.

The impact of financial variables on unemployment is highly dependent on the context of the labor market. Increased intermediary credit can reduce unemployment in countries within the Organization for Economic Co-operation and Development (OECD), where labor markets are well-regulated and coordinated. However, in less-regulated environments, it can exacerbate unemployment. The global financial environment also plays a critical role. For instance, in emerging markets, large capital inflows can drive rapid credit growth. If not managed properly, this can lead to financial imbalances and increased unemployment.

While private sector lending has the potential to reduce unemployment by stimulating economic growth and creating jobs, its effectiveness depends on the efficient allocation of credit and the broader economic and regulatory context. Misallocation of credit to inefficient sectors can exacerbate debt burdens and lead to higher unemployment rates. This underscores the need for prudent financial management and policy interventions to ensure that credit supports sustainable economic development.

Kozar et al. (2022) analyzed the employment impact of renewable energy in the Netherlands using a neo-Keynesian CGEM three-ME model. Their finding highlights a positive relationship between renewable energy production and employment. Furthermore, the employment impact of renewable technologies shows that renewable electricity generation creates more long-term jobs than nuclear or natural gas technologies, as demonstrated in the UK (Osei et al., 2023). In addition, the ongoing green transition in the EU energy sector examines the growth of renewable energy sources and its impact on the creation of green jobs (Sánchez Diéguez et al., 2021). Together, these findings support and substantiate the idea that investing in renewable energy generation can lead to job growth and sustainable economic growth and contribute to environmental goals.

Koyuncu Çakmak et al. (2023) found unidirectional causality from employment to non-hydro renewable energy consumption in low- and middle-income countries and positive causality in high-income countries, suggesting that renewable energy may not have a direct positive effect on unemployment. In addition, research on the relationship between green energy and employment in developing countries shows the positive impact of green energy on employment and the Human Development Index, highlighting the importance of green energy for economic growth and job creation (Azam et al., 2023). Furthermore, the impact of unemployment on health outcomes in sub-Saharan Africa highlights the complex and asymmetric effects of unemployment on life expectancy and under-fives, suggesting the broader impact of labor market dynamics on societal well-being (Ibadullaev et al., 2024).

Apergis and Salim (2015) analyzed 80 countries from 1990 to 2013 using advanced methodologies such as unit root, cointegration, and non-linear Granger causality in panel data. Their analysis discovered mixed results on the impact of renewable energy consumption on unemployment. However, the overall findings showed a positive relationship

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between renewable energy consumption and unemployment. Specific regional data for Asia and Latin America showed a positive employment impact of renewable energy consumption (Wu et al., 2023). The study highlighted the employment potential of renewable energy generation and the importance of continued investment in renewable energy sources for sustainable economic development and job creation in these regions (Saidmamatov et al., 2021).

This study aims to address the scientific problem of how renewable energy consumption impacts unemployment in Uzbekistan, focusing on the period from 2000 to 2022. By leveraging the Autoregressive Distributed Lag (ARDL) approach, this study seeks to contribute to the broader discourse on renewable energy's role in fostering sustainable economic development.

2. METHODS

This study employs the Autoregressive Distributed Lag (ARDL) approach to investigate the impact of renewable energy consumption on unemployment rates in Uzbekistan from 2000 to 2022. The ARDL model, developed by Pesaran et al. (2001), is particularly suitable for analyzing both short-run and long-run relationships between variables, irrespective of whether the regressors are purely I(0), purely I(1), or mutually cointegrated. This flexibility makes ARDL an appropriate choice for small sample sizes and policy-driven analyses.

The study utilizes annual time-series data obtained from the World Bank database, covering the period from 2000 to 2022. The variables employed in the model include:

- Unemployment Rate (UnR) – the percentage of the total labor force that is unemployed.
- Renewable Energy Consumption (REC) – the share of renewable energy in total final energy consumption (%).
- Gross Fixed Capital Formation (INV) – investment in fixed assets as a percentage of GDP.
- Government Final Consumption Expenditure (GOVE) – total government spending as a percentage of GDP.
- Domestic Credit to the Private Sector (CRED) – financial resources provided to the private sector by banks as a percentage of GDP.

Descriptive statistics and summary measures of the variables are presented in Table 1, providing insights into their central tendency, dispersion, and distribution characteristics.

Unit root testing is used to determine the stationarity properties of the variables. The Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Dickey-Fuller Generalized Least Squares (DF-GLS) tests were conducted. The results confirmed that all variables were stationary at first difference, I(1), ensuring the appropriateness of the ARDL bounds testing approach. The general form of the ARDL model used in this study is as follows:

$$\Delta UnR_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta UnR_{t-i} + \sum_{j=0}^{q} \gamma_j \Delta REC_{t-j} + \sum_{k=0}^{q} \delta_k \Delta X_{t-k} + \mu EC_{t-1} + \varepsilon_t, \quad (1)$$

where ΔUnR_t: Change in an unemployment-related variable (e.g., unemployment rate). α: Constant term. β_i: Coefficients of the lagged dependent variable. p: Number of lags for ΔUnR_t. REC_{t-j}: A variable related to recession or economic recovery at time $t - j$. γ_j: Coefficients associated with REC_{t-j}. X_{t-k}: Other explanatory variables influencing ΔUnR_t. δ_k: Coefficients associated with X_{t-k}. EC_{t-1}: Error correction term from a long-run equilibrium relationship. μ: Coefficient of the error correction term. ε_t: Error term (residuals).

3. RESULTS AND DISCUSSION

Table 1 presents descriptive statistics. The average unemployment rate in the selected research period is 4.6%. The formation of gross fixed capital (percentage of GDP) was 25.28%. The state's final consumption expenditure (percentage of GDP) is 15.21%. Domestic loans from banks to the private sector (relative to GDP) are 13.52%, and renew-

able energy consumption (% of total final energy consumption) is 1.31%. According to the Jarque-Bera statistic, almost all variables are normally distributed.

Table 1. Descriptive statistics

Variable	Mean	Standard deviation	Jarque-Bera statistics
UnR	4,6063	3.3742	1.0484 (0.5920)
INV	25,2863	5.6651	5.1161(0.0774)
GOVE	15,2136	2.0348	1.1674(0.5578)
CRED	13,5208	10.4222	7.9352(0.0189)
REC	1,3156	0.4351	2.6703(0.2631)

Note: UnR is the unemployment rate, REC is renewable energy consumption, CRED is domestic credit to the private sector. INV is investment, and GOVE is government expenditure.

Table 2 presents the correlation results among the variables selected for the study. These results show the direction and strength of the relationships between the variables. Furthermore, the correlation analysis can be utilized as a diagnostic test to identify potential multicollinearity issues among the variables.

Based on the analysis results, the correlation coefficient between the unemployment rate and renewable energy consumption is 0.5075, indicating a moderate positive correlation. This suggests a relationship between unemployment rates and renewable energy consumption, with a tendency for both to increase together, although not perfectly. The correlation coefficient between the unemployment rate and gross fixed capital formation is 0.7617, reflecting a strong positive correlation. This indicates a robust relationship, where higher unemployment rates are associated with higher levels of gross fixed capital formation. The correlation coefficient between the unemployment rate and domestic credit to the private sector by banks is 0.8205, indicating a very strong positive correlation. This suggests a significant linkage, where higher unemployment rates are strongly associated with higher levels of domestic credit extended to the private sector. Overall, the variables exhibit notable relationships. According to Table 2, the correlations between the independent variables are below 0.8, indicating that multicollinearity is not a concern in this study. A correlation coefficient exceeding 0.8 is often considered indicative of multicollinearity; however, this is not a strict rule (Zainodin & Yap, 2013).

Table 2. Correlation analysis

Variable	UnR	REC	INV	GOVE	CRED
UnR	1	–	–	–	–
REC	0.5075	1	–	–	–
INV	0.7617	0.3001	1	–	–
GOVE	−0.3437	−0.185	0.2356	1	–
CRED	0.8205	0.6081	0.7578	0.0988	1

Note: UnR is the unemployment rate, REC is renewable energy consumption, CRED is domestic credit to the private sector. INV is investment, and GOVE is government expenditure.

Augmented Dickey-Fuller and Phillips-Perron tests are widely used to test for unit roots in time series data (Qodirov et al., 2024). However, they have been criticized for their low power, especially when the variables are stationary but the root is close to the stationary boundary. This problem is exacerbated by systematic breaks and other complexities in the data.

Table 3 presents the results of the ADF, PP, and DF-GLS tests. The test results are shown separately for levels and first difference. These tests are used to test for stationarity of data series:

H_0: *The data series is not stationary (there is a unit root).*

H_1: *The data series is stationary.*

If the test statistic is smaller than the critical value or the *p*-value is smaller than 0.05, the null hypothesis is rejected and the series is considered stationary. According to the UnR analysis results, all tests at the levels rejected stationarity (the null hypothesis was not rejected). All tests at the first difference confirmed stationarity (p-value < 0.05). For REC, all tests at the levels rejected stationarity (the null hypothesis was not rejected). All tests at the first difference confirmed stationarity (p-value < 0.05). For INV, the ADF and PP tests at the levels rejected stationarity, but the result in the DF-GLS test is partially significant ($p = 0.0989$). All tests at the first difference confirmed stationarity (p-value < 0.05). For GOVE, all tests at the levels rejected stationarity. All tests at the first difference confirmed stationarity. For CRED, all tests rejected stationarity in the levels. All tests confirmed stationarity in the first difference.

All variables were found to be stationary at the first difference (I(1)), indicating that they can be used

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Table 3. Unit root tests: With intercept only

Variable	Levels			First difference		
	ADF	PP	DF-GLS	ADF	PP	DF-GLS
UnR	–0.8899	–0.8899	–0.6629	–4.847	–4.8470	–4.8676
				(0.0010)	(0.0010)	(0.0001)
REC	–1.8137	–1.8137	–1.8173 (0.0835)	–6.1867	–6.2676	–6.2851
				(0.0001)	(0.0000)	(0.0000)
INV	–1.6783	–1.1810	–1.7350 (0.0989)	–3.5348	–3.6662	–3.6012
				(0.0178)	(0.0130)	(0.0020)
GOVE	–1.7773	–1.7339	–1.4129 (0.1723)	–3.5579	–3.4902	–3.6510
				(0.0164)	(0.0189)	(0.0016)
CRED	1.8817	1.3245	–0.8282 (0.4205)	–3.1822	–1.9975	–3.2870
				(0.0372)	(0.0155)	(0.0046)

Note: UnR is the unemployment rate, REC is renewable energy consumption, CRED is domestic credit to the private sector. INV is investment, and GOVE is government expenditure.

for cointegration analysis. The results of the DF-GLS test were utilized for higher accuracy, as this test is considered more reliable in small samples.

This paper investigates how various factors influence Uzbekistan's unemployment rate by employing the ARDL model. This approach presents notable benefits compared to other cointegration methods. In particular, while tests like Johansen's cointegration method demand that every variable has the same order of integration, the ARDL framework is versatile enough to accommodate variables integrated at different orders (Panopoulou & Pittis, 2004). Second, the ARDL approach is reliable even with small sample sizes. Finally, the technique can use a reduced-form equation instead of the system-based approach adopted by techniques like Johansen's test (Abonazel & Elnabawy, 2020). Before estimating the ARDL model, unit root tests are conducted to determine the integration order of the variables and confirm the absence of second-order integrated variables. Such variables could lead to the failure of the ARDL approach (Abdulkadr et al., 2024).

The ARDL bounds testing procedure relies on estimating an unrestricted error correction model via ordinary least squares. One of its significant advantages is that it can be applied whether the series is level stationary (I(0)), requires first differencing (I(1)), or a mix of both. However, this method is not appropriate if any variables are integrated of order two (I(2)). Therefore, initial tests are conducted using conventional integration methods solely to ensure that none of the variables are I(2) (Bertsatos et al., 2023).

For this study, the ARDL model is proposed as follows:

$$\begin{aligned}\Delta UnR_t &= \alpha_0 + \sum_{i=1}^{p}\alpha_{1i}\Delta UnR_{t-1} \\ &+ \sum_{i=1}^{p}\alpha_{2i}\Delta REC_{t-1} + \sum_{i=1}^{p}\alpha_{3i}\Delta NREC_{t-1} \\ &+ \sum_{i=1}^{p}\alpha_{4i}nCRED_{t-1} + \sum_{i=1}^{p}\alpha_{5i}\Delta INV_{t-1} \\ &+ \sum_{i=1}^{p}\alpha_{6i}\Delta GOVE_{t-1} + \varphi_{1i}UnR_{t-1} \\ &+ \varphi_{2i}REC_{t-1} + \varphi_{3i}NREC_{t-1} + \varphi_{4i}CRED_{t-1} \\ &+ \varphi_{5i}INV_{t-1} + \varphi_{6i}GOVE_{t-1} + \varepsilon_t,\end{aligned} \quad (2)$$

where *UnR* – is the unemployment rate, *REC* – is renewable energy consumption, *CRED* – is domestic credit to the private sector. *INV* – is investment, and *GOVE* – is government expenditure. The first difference operator is denoted by Δ, the free component is given by α_0, and ε_t is the normal white noise.

The results of the ARDL bounds test are shown in Table 4. The results confirm the existence of a long-term relationship between the unemployment rate, renewable energy consumption, gross fixed capital formation (percentage of GDP), government spending, and domestic lending by banks to the private sector (percentage of GDP). This is because the unemployment *F*-statistic (3.71) is greater than the upper critical threshold value of 3.49 at the 5% level of significance. The null hypothesis of no cointegration is rejected at the 5% significance level.

Table 4. Bound test results

F-statistics	Critical values					
	1%		5%		10%	
3.7132**	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
	3.29	4.37	2.56	3.49	2.2	3.09

Note: ** Indicates significance at the 5 % level.

Estimated coefficients of long-term relationships are shown in Table 5. According to the REC analysis, Coefficient: –1.8634, *T*-statistic: –1.226, *P*-value: 0.0391. The long-term effect of renewable energy consumption on unemployment is negative and statistically significant ($p < 0.05$). This means that a 1% increase in renewable energy consumption reduces unemployment by 1.86%. This result is consistent with economic theory and can be used as a basis for policy recommendations. For INV, Coefficient: –0.2756, *T*-statistic: 2.2723, *P*-value: 0.0382. The long-term effect of investment is negative and statistically significant. A 1% increase in investment reduces unemployment by 0.28%. This result suggests that investment can help increase employment. For GOVE, Coefficient: –1.0124, *T*-statistic: –5.6522, *P*-value: 0.0000. The long-run effect of government spending is negative and highly statistically significant. A 1% increase in government spending reduces the unemployment rate by 1.01%. This indicates the effectiveness of government spending in increasing employment. For CRED, Coefficient: 0.1939, *T*-statistic: 2.3438, *P*-value: 0.0333. The long-run effect of private sector lending is positive and statistically significant. This indicates that a 1% increase in lending increases the unemployment rate by 0.19%. This result may indicate a misallocation of credit or short-term restructuring processes. As for constant, Coefficient: 12.8426, *T*-statistic: 2.8387, *P*-value: 0.0124. The constant variable represents the constant component of the model. Its statistical significance is important in representing the overall effect of the factors included in the model.

Table 5. Long-run coefficients ARDL (1,1,0,0,0)

Variable	Coefficient	T-statistic	Prob
REC	–1.8634	–1.226	0.0391
INV	–0.2756	2.2723	0.0382
GOVE	–1.0124	–5.6522	0.0000
CRED	0.1939	2.3438	0.0333
C	12.8426	2.8387	0.0124

Note: UnR is the unemployment rate, REC is renewable energy consumption, CRED is domestic credit to the private sector. INV is investment, and GOVE is government expenditure.

The REC and GOVE variables play an important role in reducing unemployment. This provides policymakers with recommendations to strengthen energy and government spending strategies. The positive impact of the CRED variable indicates the need for effective credit allocation and control. INV investments are an effective tool for increasing employment, and it is important to attract them in a targeted manner.

Based on the information presented in Table 5, a long-term model can be formulated as follows:

$$UnR = 12.84 - 1.86REC - 0.27INV - 1.01GOVE + 0.19CRED. \quad (3)$$

Table 6 presents the results of the Error Correction Model. The ECM model is used to study the speed of adaptation to long-term equilibrium and short-term dynamics. According to the analysis results, the coefficient of ECM(–1) is negative and statistically significant ($p < 0.01$). This means that the deviation from long-term equilibrium is corrected by 76.77% in each period. This high speed indicates rapid adaptation and, in economic terms, indicates the stability of the model. The *R*-squared value is 0.5791. This value accounts for 57.91% of the total variance explained by the independent variables in the model. This is relatively satisfactory and indicates that the model has good explanatory power. Durbin-Watson statistic value is 2.14. The DW statistic is used to test autocorrelation. Ideally, the DW value should be close to 2. This value indicates the absence of residual autocorrelation in the model (2.14), that is, the residual terms are randomly distributed.

In general, the coefficient of ECM(–1) means that a large part of the deviation from equilibrium is quickly corrected in the next period. This confirms the stability of the system. The explanatory power of the model is good, but additional independent variables can be added to increase it. The absence of autocorrelation ensures the reliability of the model residual results.

Table 6. ECM form

Variable	Coefficient	T-statistic	Prob
ECM(–1)	–0.7677	–5.4503	0.0001
R squared	0.5791	–	–
DW stat	2.14	–	–

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Several diagnostic tests are necessary to ensure the reliability of the ARDL model results. These tests help identify problems such as autocorrelation, heteroscedasticity, model stability, and residual normality, which can affect the validity of the model conclusions. The Breusch-Godfrey LM test, Breusch-Pagan test, Ramsey RESET test, and residual normality test are commonly used for these purposes. Each test serves a specific function in diagnosing potential problems in the model (Xolmurotov et al., 2024).

The Breusch-Godfrey LM test is widely used to detect autocorrelation in the residuals of a regression model. It is particularly robust to models with non-normally distributed error terms, making it suitable for a variety of econometric applications (Shukur, 2000). The test is applicable to high-order autocorrelation and is asymptotically equivalent to the Durbin-Watson test for first-order autocorrelation (Rois et al., 2012).

The Breusch-Pagan test is designed to detect heteroskedasticity, which occurs when the variation of errors across observations is not constant. This test is essential to ensure that the model's assumptions about error variances are not violated (Baum, 2023). The Ramsey RESET test is used to check for model stability and specification errors. It tests whether nonlinear combinations of fitted values help explain the dependent variable, indicating potential misspecification (Gerrard & Godfrey, 1998). Stability tests such as CUSUM and CUSUMSQ are also used to assess the systematic stability of the model over time (Al-Adayleh, 2015). Residual normality tests are necessary to check whether the model residuals follow a normal distribution, which is a key assumption in many statistical models. This ensures the accuracy of the inference drawn from the model (Godfrey & Tremayne, 1998).

Table 7. Diagnostic tests

Test	Statistics	Probability
Ramsey RESET test	4.8724	0.1445
Serial Correlation	0.1873	0.8314
Heteroscedasticity	1.0527	0.4315

Table 7 presents the results of the diagnostic tests. According to the analysis results, Ramsey RESET test statistics: 4.8724, *P*-value: 0.1445. Ramsey RESET test checks whether the functional form of the model is correctly determined (Saribayevich et al., 2024). Since the *P*-value (0.1445) is greater than 0.05, the null hypothesis is not rejected, that is, the functional form of the model is accepted. There is no sufficient reason to believe that the functional form of the model is incorrect. Serial correlation test statistics: 0.1873, *P*-value: 0.8314. This test checks whether there is autocorrelation between the residual terms. The *P*-value (0.8314) is greater than 0.05; that is, the null hypothesis is not rejected. This means that there is no autocorrelation between the residual terms. The residual terms are randomly distributed, which confirms the reliability of the model results. Heteroscedasticity test statistics: 1.0527, *P*-value: 0.4315. This test checks for the constancy of the residual variance (homoscedasticity). The *P*-value (0.4315) is greater than 0.05, which means that the null hypothesis is not rejected. This means that the variance of the residual terms is constant. This confirms that the model does not have a heteroscedasticity problem.

As a result, no problem was detected in the functional form of the model. The model is satisfactory. There is no autocorrelation between the residual terms, which indicates the reliability of the model results. The residual variance is constant, which ensures the stability of the model.

CONCLUSION

The primary aim of this study was to examine the relationship between renewable energy consumption and unemployment rates in Uzbekistan during the period 2000–2022, utilizing the Autoregressive Distributed Lag model. The analysis revealed that renewable energy consumption significantly reduces unemployment rates in the long term, while gross fixed capital formation and government expenditures also play vital roles in job creation. Conversely, inefficiencies in the allocation of domestic credit to the private sector were found to contribute to rising unemployment.

These findings emphasize the importance of expanding renewable energy infrastructure and aligning financial policies to optimize credit allocation for economic efficiency. Investments in renewable energy not only promote environmental sustainability but also serve as a viable strategy for addressing persistent unemployment challenges. Additionally, targeted public spending and workforce development programs in renewable energy sectors can further amplify these positive effects.

The study underscores the need for Uzbekistan to strengthen its commitment to renewable energy initiatives as part of a broader strategy to achieve sustainable economic growth and improve social welfare. Policymakers are encouraged to prioritize strategic investments, reform financial frameworks, and develop specialized training programs to build a skilled workforce capable of supporting the country's transition to a greener economy.

AUTHOR CONTRIBUTIONS

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