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Food Security of Kazakhstan in the Context of Global Challenges of the Green Economy, Renewable Energy: ARDL and NARDL Assessment

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ABSTRACT

In the face of global challenges such as depletion of natural resources, rapid urbanization, and soil degradation, the issue of ensuring food security for the state's population is more urgent than ever. The purpose of this research is to assess the level of food security in Kazakhstan in the context of global issues such as green economy, renewable energy, and environmental security. For this purpose, the authors used linear and nonlinear autoregressive distributed lag (ARDL and NARDL) econometric estimation models. The following indicators were taken as available indicators for the period 1996-2021: Bonilla index (calculated by authors), Rural population (% of total population), Agricultural land (% of total land), Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal), Renewable electricity output (% of total electricity output), Total natural resources rents (% of GDP), Carbon dioxide (CO_2) emissions from Agriculture (Mt CO_2e). As a result of the two models: In the long run, it was determined that Rural population, renewable electricity output have a positive impact on food availability, and Annual freshwater withdrawals, Total natural resources rents and Carbon dioxide (CO_2) emissions from Agriculture have a negative impact on food import dependence. In the short run, it was determined that changes in Rural population, lag variable and changes and changes in lag variable of Annual freshwater withdrawals have a negative impact, and lag variable of renewable electricity output and change in lag variable of renewable electricity output have a positive impact. The results of the study indicate that the principles of green economy can be applied to ensure food security It shows the need to adhere to the most environmentally friendly methods and use renewable energy sources.

Keywords: Bonilla Index, Green Growth, Renewable, Food Security, Autoregressive Distributed Lag, NARDL
JEL Classifications: Q18, Q10, Q19

1. INTRODUCTION

A green economy entails the implementation of green technology in agriculture, such as organic farming and sustainable water management, which help to promote food security by preserving natural resources and decreasing environmental damage. Improving food security by developing a green economy contributes to the implementation of a number of sustainable development goals, in particular: Ending poverty (SDG 1), ensuring adequate food and nutrition (SDG 2), promoting health and well-being (SDG 3), ensuring sustainable management of water and sanitation (SDG 6), and reducing emissions that cause climate change (SDG 13). The consumer approach that has dominated society for the last 2-3 centuries must be fully replaced by a new philosophy of sustainable economic development and food supply expansion for the world's expanding population. Deteriorating production circumstances and resource depletion will prevent a growing humanity from developing at the same rate as it would with a sustainable food base (Fedotova et al., 2023). The increasing energy demand in agriculture, along with depleting fossil fuel reserves, necessitates a shift to renewable energy sources (Naman and Kaundal, 2025). In light of globalization, the escalation of environmental concerns, and the world's population expansion, providing food while limiting environmental damage has emerged as an urgent task of our time (Sauranbai et al., 2022; Scordia et al., 2025; Kurmanov et al., 2025). Government policies have a strong impact on the development of the green economy (Tambovceva et al., 2020; Wai Mun et al., 2022; Andabayeva et al., 2025; Har et al., 2022). In the context of globalization, rational resource use and the introduction of innovative technologies are becoming determining factors for economic growth and development, as well as the balanced, proportional increase of all branches of the economic complex, including agriculture and overall societal life support. As a result, it is critical to emphasize the need of developing a «green» economy for the agro-industrial complex, as well as its inclusion as a significant aspect in national ecology and food security policies (Saparbayev et al., 2022). Also, development of rural areas is highly dependent on food availability (Demchenko et al., 2023). With the increasing human population, food security is more critical than ever (Montesclaros et al., 2024).

In this regard, the purpose of this study is to evaluate green economy factors that impact food security in the country.

Article is organized as follows: Introduction, Literature review, Methodology, Data and findings, conclusion.

2. LITERATURE REVIEW

Using for decades, food security and sustainability have been viewed as distinct issues, with food security having a stronger association with sustainability dimensions such as environmental, economic, and social-cultural factors that influence human well-being. The "New Food Equation" notion has recently emerged, followed by food price increases, depleted natural resources, land grabbing tactics, societal instability, and the effects of climate change. The fast loss of energy and material resources in recent decades is unlikely to be sustained. A "social-ecological system" is required to accurately determine sustainability (Mikalauskiene et al., 2018; Rabbi et al., 2021). Despite different opinions and definitions among stakeholders, the "green economy" is commonly viewed as one that seeks growth while also supporting sustainable development through more efficient resource usage. Energy transition and green growth also accelerates economic growth (Idris and Rahman Razak, 2025). The goal of a green economy, which is associated with sustainability ideals, is to work toward economic development, environmental protection, and increased social welfare while also reducing dependency on fossil fuels and nonrenewable resources (Fan et al., 2012; Nwachukwu, 2023). As the many knows, Agriculture is the world's largest use of land, occupying about 38% of the Earth's terrestrial surface (Dobermann and Nelson, 2013). Even this single example demonstrates how tightly tied food security is to land, air, and water, i.e. ecology and green growth. Pretty et al. (1996) saw the solution to the problem in the development of sustainable agriculture. Balanced agricultural development still remains actual (Amangeldiyeva et al., 2025).

Using a non-systematic literature analysis and annual data from 2005 to 2022, Oyadeyi and Oyadeyi (2025) explored the relationship between climate change, green economy, and their combined influence on food security in 39 Sub-Saharan African nations. Their findings highlight the need for strategic policy interventions to support climate-smart agricultural techniques focusing on food security, sustainable land management practices, and inclusive renewable energy efforts. Also, He et al. (2024) and Kinda (2021) study's results revealed that renewable energy, green economic growth has positive impact on food security, while industrialization has negative impact on food security in Sub-Saharan Africa. Using Random fixed model, Yunus et al. (2023) evaluated the impact of sustainable energy systems, innovation, and green finance on environmental efficiency and sustainable economic development in the context of high carbon emissions. The findings highlight the need of promoting long-term economic development and environmental sustainability. Using generalized method of moments, Osabohien et al. (2023) showed that for Sub-Saharan Africa, when economy is green, food security increases. Elhassan (2025) studied the links between green technology innovation, green financing, economic growth, and environmental sustainability in G7 countries, utilizing annual data from 1990 to 2022. The findings highlight the significance of balanced policies that priorities green finance in the short term to mitigate environmental damage while also encouraging long-term investments in green technology innovation. Applying Generalized Method of Moments, the Fully Modified Ordinary Least Squares, and the Dynamic Ordinary Least Squares methods, Ajeigbe and Ganda (2024) looked studied the relationship between food security, environmental sustainability, and sustainable growth from a global viewpoint of 63 economies from 2010 to 2021.

Authors claim that to reduce global inequality, international measures aimed at enhancing food security collaboration based on nations' different natural endowments must be promoted. To ensure food security and meet the SDGs, innovative and sustainable land use and food processing must be encouraged to reduce emissions and other types of pollution and boost eco-fishing, aquaculture, and agriculture. The adoption of new technology and innovations in the energy industry can help to ensure food and environmental security (Kaliyeva et al., 2025). For instance, Althani et al. (2025) found that renewable energy has a favorable impact on food availability. Ceesay and Ndiaye (2022) used the Vector Autoregressive Approach, Granger Causality Approach, Autoregressive Distributed lag mode approach, and Error Correction Approach to examine the impact of climate change on food security as well as economic growth, population expansion, and the agricultural sector. According to their findings, food security growth has a strong positive correlation with the agriculture sector but a negative correlation with rainfall variation, and population growth has a significant negative impact on food security in the short term but a negligible negative impact in the long term. Hasan and Adnan (2025) investigated the long-term links between CO_2 emissions, food security, energy efficiency, foreign direct investment, and economic development in emerging economies. The study shows that boosting food security in a developing economy has a significant positive impact on both CO_2 emissions and energy intensity.

2.1. Kazakhstan Case

Previously, authors such as Tleuberdinova et al. (2025), Syrbek et al. (2025), Kakizhanova et al. (2024) studied the food security of Kazakhstan in the context of environmental and energy security. Kazakhstan, the world's ninth largest country by land area and the largest in Central Asia, is on course to meet sustainable development targets. The country's mission is to increase its people's well-being by combining food security with a green economy, all while reducing its environmental impact (Satybaldin et al., 2020; Bespayeva et al., 2022; Baidalinova et al., 2025). However, high-yield risks (Praagai et al., 2023) still discourage investors from Kazakhstan's agro-industrial sector. As a country based on raw material exports, we will face a difficult transition to a green economy (Shakeyev et al., 2023). There is a strategy in place to expand Kazakhstan's agro-industry until 2050 (Konyrbekov, 2015); nevertheless, attracting investment and integrating cutting-edge technologies into this sector, as well as meeting the needs and providing support to regular farmers, has become a challenge. Human-caused climate change, characterized by increased CO_2 emissions, jeopardizes agricultural crop productivity by generating global warming. While a small increase in CO_2 and temperature may initially boost crop growth, crossing key thresholds interrupts photosynthesis, lowers leaf area, and shortens plant longevity, resulting in lower output (Yadav et al., 2026). A strong agricultural sector serves as the foundation for food security. And it has been shown that if food production is not stable during a pandemic, global shocks can cause unforeseen shocks (Yeszhanova et al., 2021, Zhenshkhan et al., 2022). In addition to growing agriculture and guaranteeing food security, Kazakhstan must consider environmental sustainability by increasing the use of renewable energy in the agricultural sector and good water management.

3. METHODS

We discovered after reading a lot of research and literature that agriculture and food security are crucial components in fostering green growth. Ensuring food security is a complicated and diverse phenomena with various elements that influence it. Our study looked at the Bonilla index, which is a key indication of a country's food security.

Diaz-Bonilla et al. (2000) proposed that the ratio of a country's food import expenditure to the value of its total exports is a relevant indication of a country's access to global food supply. We name this ratio the Bonilla index. To estimate it at the national level, we can write:

$$BI = \frac{value\ of\ food\ imports\ in\ local\ currency}{value\ of\ total\ exports\ in\ local\ currency} \quad (1)$$

The Bonilla Index is a reliable indicator of a country's ability to cover food imports with exports. In this light, it is an intriguing measure of the susceptibility of food security to commerce in developing countries, particularly net food importers. As an importer/exporter, the Bonilla Index considers the ratio of food import spending to total export earnings, highlighting the importance of international trade and its impact on national food security.

Taking into account the findings of the previous section's reviews, we investigate the relationship between the Bonilla index (BI) in the period 1996-2021 and factors that influence the Republic of Kazakhstan's green economy, such as rural population, agricultural land, annual freshwater withdrawals, renewable electricity output, total natural resource rents, and carbon dioxide (CO_2) emissions from agriculture. BI is calculated using the following equation:

$$BI = f\,(RPTP,\ AL,\ AFWA,\ REO,\ TNRR,\ CO_2EA) \quad (2)$$

Where all of their definitions and measurements are given in the Table 1.

Based on the ADF test results, it was discovered that all of the studied independent variables are stationary at the level of I(0) or first differences I(1) (Table 2), with the exception of the variable REO, which is non-stationary only in the case of 1^{st} difference with Trend and intercept. Given the dynamic nature of these variables and the necessity to account for both short- and long-term effects, the autoregressive distributed lag (ARDL) model was determined to be adequate. Also, the ARDL approach provides flexibility in modeling various relationships, taking into account variables with different orders of integration, and works well with small samples. Furthermore, the method is particularly good in dealing with serial correlation and heteroscedasticity, resulting in trustworthy estimates and simple coefficient interpretation.

A logarithmic NARDL model was built based on the findings of the Granger causality test with the first difference (Table 3), and long-term and short-term studies of the relationship between the variables were carried out. Furthermore, the coefficients from the regression equation (2) can be interpreted as percentage changes, indicating elasticity. Additionally, robustness testing methods were employed to confirm the reliability and validity of the findings.

The order of variable integration is assessed to establish the applicability of the NARDL model for the study; using a unique test, a maximum of two lags were chosen (Table 4).

Table 1: Model variables and sources

Variables	Definitions	Sources
BI	Bonilla index $BI = \frac{value\ of\ food\ imports}{value\ of\ total\ exports}$	Authors' calculation based on World Development Indicators (WDI) (2025)
RPTP	Rural population (% of total population)	World Development Indicators (WDI) (2025)
AL	Agricultural land (% of total land)	World Development Indicators (WDI) (2025)
AFWA	Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal)	World Development Indicators (WDI) (2025)
REO	Renewable electricity output (% of total electricity output)	World Development Indicators (WDI) (2025)
TNRR	Total natural resources rents (% of GDP)	World Development Indicators (WDI) (2025)
CO_2EA	Carbon dioxide (CO_2) emissions from Agriculture (Mt CO_2e)	World Development Indicators (WDI) (2025)

Source: Compiled by authors

Table 2: ADF unit root tests

Variables	Intercept			Trend and intercept			None		
	Level	First difference	Order of integration	Level	First difference	Order of integration	Level	First difference	Order of integration
BI	−3.653** (0.012)	−6.77*** (0.000)	I (0)	−4.350** (0.011)	−6.65*** (0.000)	I (0)	−1.515 (0.012)	−6.899*** (0.000)	I (1)
RPTP	−2.584 (0.109)	−7.56*** (0.000)	I (1)	−2.799 (0.210)	−2.727*** (0.000)	I (1)	−0.412 (0.524)	−7.690*** (0.000)	I (1)
AL	−1.796 (0.374)	−4.646** (0.001)	I (1)	−1.848 (0.651)	−4.546* (0.007)	I (1)	−0.186 (0.609)	−4.742*** (0.000)	I (1)
AFWA	−2.720 (0.085)	−5.96*** (0.000)	I (1)	−2.137 (0.502)	−6.592*** (0.000)	I (1)	−1.479 (0.127)	−5.750*** (0.000)	I (1)
REO	−1.407 (0.563)	−3.976** (0.006)	I (1)	−1.472 (0.812)	−3.213 (0.106)	>I (1)	−0.500 (0.490)	−4.054*** (0.000)	I (1)
TNRR	−2.311 (0.176)	−5.13*** (0.000)	I (1)	−2.261 (0.438)	−5.017** (0.003)	I (1)	−0.289 (0.572)	−5.197*** (0.000)	I (1)

1) *, **, *** denote statistically significant at the 10%, 5% and 1% levels, respectively. P-value is inside brackets

Table 3: Noncausality tests in the sense of Granger for the vector autoregressive (1) (1996-2021)

Direction of causality	F-statistic	Probability
Dependent variable: LOG (BI)		
LOG (RPTP) does not Granger Cause LOG (BI)	3.471164	0.1763
LOG (AL) does not Granger Cause LOG (BI)	2.846882	0.2409
LOG (AFWA) does not Granger Cause LOG (BI)	3.751895	0.1532
LOG (REO) does not Granger Cause LOG (BI)	4.295316	0.1168
LOG (TNRR) does not Granger Cause LOG (BI)	3.005769	0.2225
LOG (CO2EA) does not Granger Cause LOG (BI)	4.666375	0.1970

In a nonlinear autoregressive model with distributed lags, the NARDL technique determines if the selected variables are cointegrated. The boundaries test evaluates the long-run relationship; the results are shown in Table 5. In the nonlinear autoregressive model with distributed lags, the NARDL technique is described by two equations:

$$LOG(BI_t) = \beta_0 + \sum_{k=1}^{l}\beta_1 LOG(BI_{t-k}) + \sum_{k=0}^{m}\beta_2 LOG(RPTP_{t-k}) + \sum_{k=0}^{n}\beta_3 LOG(AL_{t-k}) + \sum_{k=0}^{p}\beta_4 LOG(AFWA_{t-k}) + \sum_{k=0}^{q}\beta_5 LOG(REO_{t-k}) + + \sum_{k=0}^{r}\beta_6 LOG(TNRR_{t-k}) + \sum_{k=0}^{s}\beta_7 LOG(CO2EA_{t-k}) + \gamma_1 RPTP_{t-i} + \gamma_2 AL_{t-i} + \gamma_3 AFWA_{t-i} + \gamma_4 REO_{t-i} + \gamma_5 TNRR_{t-i} + \gamma_6 CO2EA_{t-i} + \varepsilon_t \quad (3)$$

Where, operator Δ represents the differencing operation, LOG denotes the natural logarithm. Coefficients $\beta_1,\ldots,\beta_7$ represent the long-run effects, while coefficients $\gamma_1,\ldots,\gamma_6$ capture the short-run dynamics.

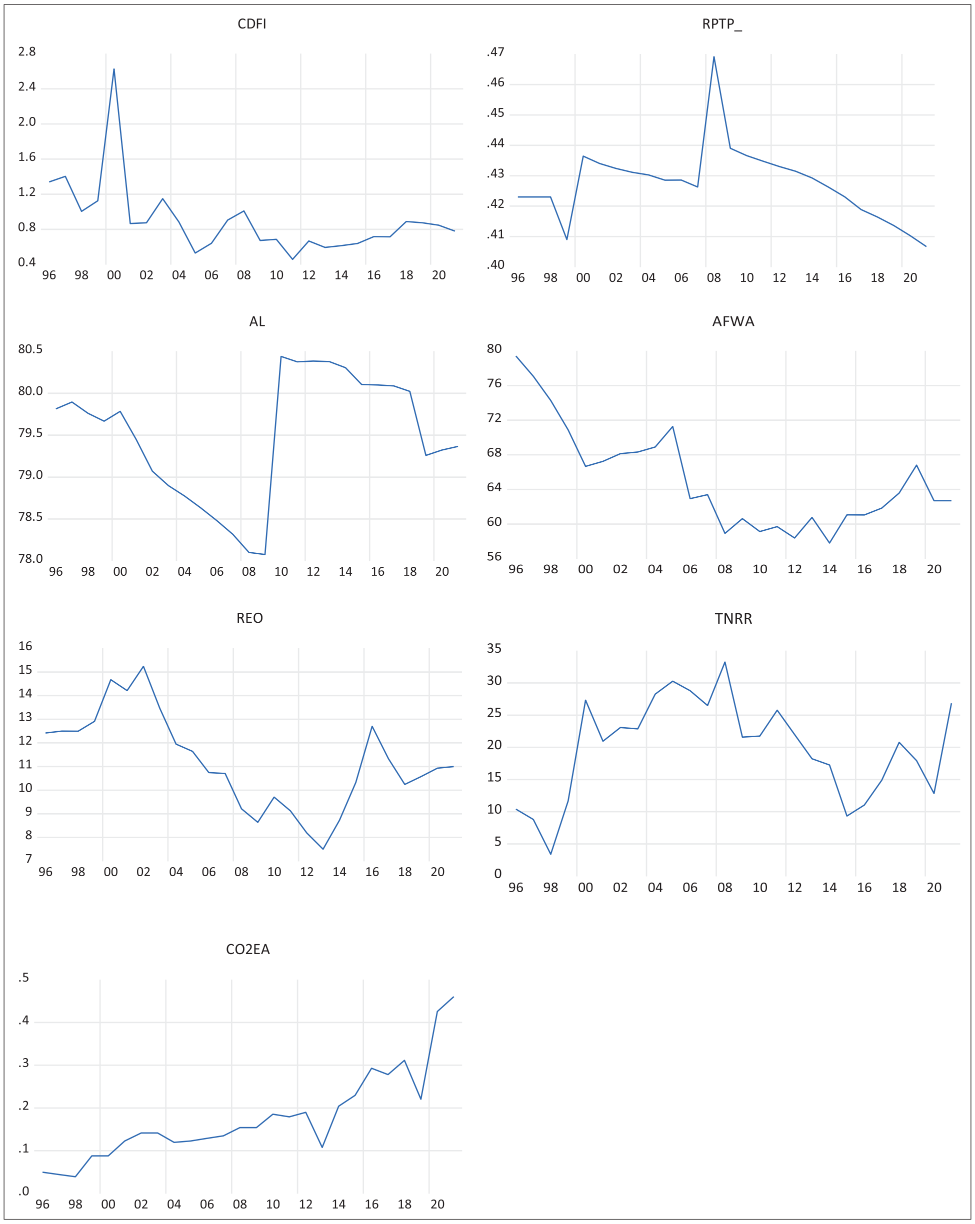
4. DATA AND FINDINGS

4.1. Data

This study investigates the effects of the major elements on the Bonilla Index in the Republic of Kazakhstan. The study makes use of data from the World Data Bank (WDI) spanning the years 1996-2021. This study's explanatory variables are rural population, agricultural land, annual freshwater withdrawals, renewable power generation, total natural resource rents, and agriculture-related carbon emissions. All of indicators definitions and measurements are given in the Table 1 below.

The dynamic change of all indicators presented in the table in the period 1996-2021 is depicted in the following Graph 1:

Graph 1: Evolution of all variables for Kazakhstan (1996-2021)



Source: Compiled by authors

Table 4: Selection order criteria

NARDL (2, 2, 1, 2, 2, 2, 2)						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**SC**	**HQ**
0	203.7576	NA	1.79e−16	−16.39647	−16.05287	−16.30531
1	364.9870	214.9725	1.86e−20	−25.74892	−23.00013	−25.01966
2	480.9261	86.95431*	2.66e−22*	−31.32718*	−26.17319*	−29.95982*

Table 5: Results of cointegration test

Model	F-statistics	Critical bounds I (1)	Decision
NARDL (2, 2, 1, 2, 2, 2, 2)	12.10069	2.87-4.05	Cointegration

Critical bounds are reported at 1% (***) and 10% (**) level of significance

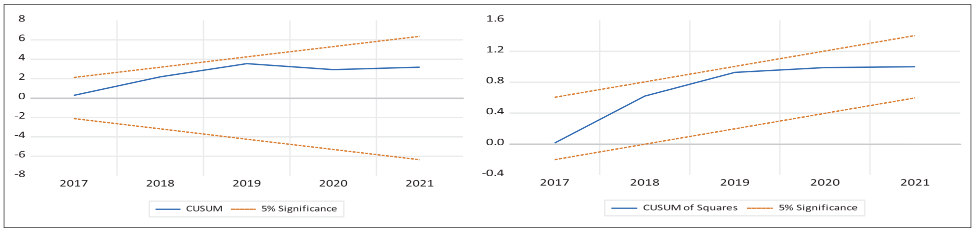
It is clear from the analysis of the graph shown in Graph 2 that the study variables are suitable for analysis. The graph shows obvious, consistent and stable time patterns, indicating that changes in the variables are suitable for further study.

4.2. Empirical Findings

Descriptive statistics enable you to examine many features of a data set in greater detail.

Table 6 of the original data shows that the BI indicator has a mean of 0.904 and a median of 0.856, with a range of 0.457-2.627 and a standard deviation of 0.422, showing very consistent values. It has a somewhat positive skewness (2.750) and a positive kurtosis (11.831). Furthermore, the RPTP averages 43.258% of the overall population, with a median of 43.282%, indicating considerable

Graph 2: CUSUM and CUSUMSQ



Source: Compiled by authors

Table 6: Values of descriptive statistics of the displayed series

Values	BI	RPTP	AL	AFWA	REO	TNRR	CO_2EA
Mean	0.904	43.258	79.495	65.136	11.199	19.838	0.177
Median	0.856	43.282	79.714	63.163	10.965	21.274	0.148
Maximum	2.627	44.057	80.439	79.416	15.238	33.248	0.461
Minimum	0.457	42.179	78.077	57.804	7.505	3.401	0.039
Standard deviation	0.422	0.567	0.747	5.842	2.019	7.693	0.106
Skewness	2.750	−0.204	−0.504	0.862	0.151	−0.295	1.153
Kurtosis	11.831	1.912	2.045	2.930	2.334	2.211	3.971
Jarque-Bera	117.270	1.463	2.087	3.223	0.579	1.051	6.777
Probability	0.000	0.481	0.352	0.200	0.749	0.591	0.034
Sum	23.507	1124.702	2066.867	1693.533	291.177	515.796	4.613
Sum Sq. deviation	4.448	8.045	13.967	853.142	101.870	1479.491	0.280
Observations	26	26	26	26	26	26	26

variability ranging from 42.179% to 42.179% of the whole population and a standard deviation of 0.567.

It has slight negative skewness (0.204) and positive kurtosis (1.463), indicating normalcy. The mean values of AL, AFWA, REO, TNRR, and CO_2EA are 79.495, 65.136%, 11.199%, 19.838%, and 0.177 Mt CO_2e, with standard deviations of 0.747, 5.842%, 2.019%, 7.693%, and 0.106 Mt CO_2e, respectively. The distribution of AL and TNRR is slightly negative (−0.504 and −0.295, respectively), while AFWA, REO, and CO_2EA are positive (0.862, 0.151, and 1.153, respectively). The excess for all factors is positive, indicating that there is no major deviation from normality.

4.3. Unit Root Test

Before investigating long-term links between series, it is necessary to assess whether they are stationary. This study used Augmented Dickey-Fuller (ADF) unit root tests to investigate the levels or differences of stationary variables. Some variables can be employed at the I(0) level, whereas others are stationary at the first difference, I(1). In addition, other cointegration methods are sensitive to the sample periods. For the purposes of this study, we can construct ARDL. Table 2 presents the results of the extended lag Dickey-Fuller (ADF) unit root test for the series at level and first difference, since the 2 optimal lag is the second in the dimension of ARDL models. ADF tests the non-stationary null hypothesis, which is rejected if ADF is more negative or exceeds the absolute critical values of 1%, 5%, and 10%. The results show that all explanatory variables are stationary at first difference.

As a result, we can utilize these parameters to estimate ARDL models. The unit root results are consistent with the initial assumptions, implying that an ARDL model test is required to confirm the presence of long-term links between Kazakhstan's BI and the study's postulated explanatory elements for the green economy.

4.4. Granger Causality Test

To investigate the causative relationship between the selected variables and BI, the Granger test is used, which tests the null hypothesis that changes in the dependent variable are not causal (noncausality).

According to Table 3, the null hypothesis is not accepted for all variables, thus we cannot reject the hypothesis that the explanatory variables under consideration are not the cause of Granger growth.

4.5. Co-Integration Test

The ARDL bounds testing procedure is used in this study to examine the long-term relationship between the selected variables of green economy and BI of the Republic of Kazakhstan. Before conducting the cointegration test, it is important to determine the lag length criterion. To examine the long-term relationship between the variables, the ARDL method was chosen using a small sample size. The lag length criterion is determined based on LR, FPE, AIC, SC and HQ. Table 4 presents the results of the selected lag. As can be seen from Table 5, the selected lag length is 2, since it has more stars and was used throughout the study.

4.6. Results of Long- and Short Run Relationship

In the study, the nonlinear NARDL model (Equation 2) was estimated using logarithms and first difference from the ADF test results, and to conduct long-run and short-run analysis of the relationship between the variables, the results are presented in the following Table 5. The results of the cointegration F-test for NARDL (Table 5) show that the obtained F-statistic (12.10069) exceeds the upper limit of 4.05 and is statistically significant at

1-10% significance levels. The results show that the selected variables are cointegrated and in the case of Kazakhstan, there is a long-run relationship between them.

Given that the selected variables are cointegrated in the long run, we can proceed to the next step, which requires estimating the long-run and short-run coefficients. Given that NARDL (2, 2, 1, 2, 2, 2, 2) we can estimate how changes in the explanatory variables affect the dependent variable in both the long and short run.

In Kazakhstan, in the long run, LOG(AFWA), LOG(TNRR) and LOG(CO_2EA) are negatively correlated with ΔLOG(BI) with the corresponding elasticity coefficients of −4.679065, −0.527302 and −0.553845, ceteris paribus (Table 7). The results show that LOG(REO) is positively correlated with ΔLOG(BI) with the corresponding coefficient of 1.618661, all other things being equal.

The obtained empirical data (Table 7) show that in Kazakhstan Internal R&D costs by branches of science (IRDC) also in the short term negatively and significantly correlate with ΔLOG(GVACI) with a coefficient of −4.98E−06.

In addition, if the coefficient of the lagged variable LOG(GVACI[−1]) in the period t-1 in the short term turned out to be negative (−1.793469), and the positive relationship of the lagged variable LOG(REO[−1]) with ΔLOG(BI) and the negative relationship of LOG(AFWA[−1]), LOG(TNRR[−1]) with ΔLOG(BI) was confirmed, the change in DLOG(RPTP), DLOG(AFWA), DLOG(TNRR) in the short term negatively and significantly correlates with ΔLOG(BI) with the corresponding coefficients of −1169.747, −3.602305, −0.513517. The change in lagged variables DLOG(AFWA) is positive (3.287423) and DLOG(REO[−1]) is negative (−1.980188) correlated with ΔLOG(BI) in the short run.

4.7. Diagnostic Tests

Diagnostic tests were run to ensure the nonlinear NARDL model's stability (Table 8). These tests include serial correlation, normalcy, and heteroscedasticity. For this model, the null hypothesis of no serial correlation, homoscedasticity, and normality is not rejectable.

Table 8 presents the results of the diagnostic tests. For the NARDL model, the Serial correlation is 7.851935, the probability value is 0.1151. As a result, in this analysis we conclude that there is no serial correlation in the model. The heteroscedasticity test showed that the F-statistic is 2.726473, and the probability is 0.1708, both values are greater than the significance level of 0.05%, which indicates homoscedasticity of the model. The model accepts the null hypothesis of the normality test and concludes that the residuals are normally distributed, as evidenced by the F-statistic of 0.014959 and the probability value of 0.9925, both indicators have a significance level >5%. Finally, all diagnostic tests for serial correlation with the Langrange multiplier, the Jarque-Bera normality test and the heteroscedasticity test were successful, which indicates the robustness of the NARDL model. This indicates that the NARDL model is free of serial correlation and heteroscedasticity.

Table 7: Results of NARDL estimation (1996-2021)

Model - results of NARDL estimationΔLOG (BI)				
Variable	**Coefficient**	**t-statistic (Prob.)**	**Variable**	**Coefficient**
Short run				
LOG (BI[−1])*	−1.793469***	0.266920	−6.719134	0.0011
LOG (RPTP[−1])	21.82475	10.85330	2.010886	0.1005
LOG (AL[−1])	−12.60038	8.066756	−1.562014	0.1790
LOG (AFWA[−1])	−8.391760**	2.202830	−3.809535	0.0125
LOG (REO[−1])	2.903019***	0.656955	4.418900	0.0069
LOG (TNRR[−1])	−0.945700**	0.366363	−2.581318	0.0494
LOG (CO_2EA[−1])	−0.993304**	0.362952	−2.736738	0.0410
DLOG (BI[−1])	0.510990	0.187357	2.727361	0.0414
DLOG (RPTP)	−1169.747**	385.3295	−3.035705	0.0289
DLOG (RPTP[−1])	396.4628	472.5000	0.839075	0.4397
DLOG (AL)	−2.509651	7.256856	−0.345832	0.7435
DLOG (AFWA)	−3.602305*	1.562198	−2.305920	0.0693
DLOG (AFWA[−1])	3.287423*	1.460480	2.250919	0.0742
DLOG (REO)	0.751073	0.532239	1.411158	0.2173
DLOG (REO[−1])	−1.980188*	0.840159	−2.356921	0.0650
DLOG (TNRR)	−0.513517**	0.144521	−3.553232	0.0163
DLOG (TNRR[−1])	0.283265	0.223240	1.268878	0.2603
DLOG (CO_2EA)	−0.388455	0.312656	−1.242435	0.2692
DLOG (CO_2EA[−1])	0.285175	0.353871	0.805873	0.4569
Long run				
LOG (RPTP)	12.16901*	5.705450	2.132874	0.0861
LOG (AL)	−7.025702	4.291932	−1.636956	0.1626
LOG (AFWA)	−4.679065***	1.128025	−4.148017	0.0089
LOG (REO)	1.618661***	0.343339	4.714470	0.0053
LOG (TNRR)	−0.527302*	0.175986	−2.996271	0.0302
LOG (CO_2EA)	−0.553845*	0.153628	−3.605116	0.0155

1) coefficients are statistically significant at ***1%, **5%, *10% level of significance. 2) compiled by the authors

Table 8: Short-run diagnostics

Test	F-statistics	P-value
Serial correlation LM	7.851935	0.1151
Heteroskedasticity	2.726473	0.1708
Jarque-Bera	0.014959	0.9925

4.8. Stability Tests

The CUSUM and CUSUM Squares tests are used to test whether the coefficients of the estimated models remain unchanged over time, which is an indicator of the stability of the model.

Graph 2 shows the results of the CUSUM and CUSUMSQ robustness tests. At a 5% significance level, failing to exceed critical thresholds implies that the model is robust. This test is also used to investigate the long-term behavior of regression.

5. CONCLUSION

The article's objective is to evaluate the green growth elements that support food security. For this purpose, the following indicators were taken as available indicators for the period 1996-2021: Bonilla index (calculated by authors), Rural population (% of total population), Agricultural land (% of total land), Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal), Renewable electricity output (% of total electricity output), Total natural resources rents (% of GDP), Carbon dioxide (CO_2) emissions from Agriculture (Mt CO_2e). As a result of the two models: In the long run, it was determined that Rural population, renewable electricity output have a positive impact on food availability, and Annual freshwater withdrawals, Total natural resources rents and Carbon dioxide (CO_2) emissions from Agriculture have a negative impact on food import dependence. In the short run, it was determined that changes in Rural population, lag variable and changes and changes in lag variable of Annual freshwater withdrawals have a negative impact, and lag variable of renewable electricity output and change in lag variable of renewable electricity output have a positive impact. The results of the study indicate that the principles of green economy can be applied to ensure food security It shows the need to adhere to the most environmentally friendly methods and use renewable energy sources. The analysis of the two models revealed that, in the long term, the rural population and renewable electricity generation positively influence food availability, while annual freshwater withdrawals, total natural resource rents, and carbon dioxide emissions from agriculture negatively affect food import dependence. Changes in the rural population, the lag variable, and the lag variable of annual freshwater withdrawals were found to have a negative effect in the short term, while changes in the lag variable of renewable electricity output and the lag variable of renewable electricity output had a positive effect. The study's findings suggest that food security may be guaranteed by implementing the green economy's tenets. It demonstrates the necessity of using renewable energy sources and the most ecologically friendly practices.

5.1. Policy Implications

Pandemics such as Covid-19 and conflicts between neighbors have raised the issue of comprehensively considering the security of Kazakhstan. At present, the situation in Kazakhstan's agriculture is not satisfactory. However, in order to ensure food availability, it is necessary to create conditions for the training of agricultural specialists, support scientific institutions in this field, and also enshrine in law the priority of domestic store chains for the first purchase of food produced in Kazakhstan. In addition, the mass migration of rural people to cities in search of work, the deterioration of rural infrastructure, and the gap in monthly incomes between rural and urban areas are also negatively affecting agriculture. We believe that before promoting a green economy in order to ensure food security, it is better to start by unifying and solving problems in the agricultural sector.

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