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Article

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Impact of Energy Consumption and Food Security on Income Inequality: NARDL Approach from Kazakhstan

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ABSTRACT

As one of the main socio-economic categories, income inequality has always been a prime focus of many researchers. And Kazakhstan's income inequality has complex nature. To better understand the functioning of socio-economic mechanisms to find a balance between economic policy and social justice, the relationship of different variables to income inequality is examined. It also helps to develop targeted policies and programs to reduce inequality, thus the poverty. Recently, effect of energy consumption and food safety on income inequality has been under the scrutiny of scientific researchers. These three categories contain many variables. However, due to the availability and breadth of statistical data, the final energy consumption and food import/export ratio were taken into account. We retrieved data from World Bank and it covers the periods from 1996 to 2022. Our study's aim is to determine the effect of final energy consumption and food security on income inequality. Analyzing data, we used Nonlinear Autoregressive Distributed Lag (NARDL) approach. The NARDL results show that final energy consumption impacts on income inequality positively in both short and long terms, while food security affects negatively on both periods. Results from the model have significant socio-economic and political implications for addressing income inequality.

Keywords: Income Inequality, Gini Index, Final Energy Consumption, Food Security, Nonlinear Autoregressive Distributed Lag
JEL Classifications: Q2, Q3, I32, Q18

1. INTRODUCTION

Poverty does not only include a lack of income and industrial resources, but it also includes, among other things, hunger and malnutrition, restrictions on education as well as other basic activities, social discrimination and non-interference in decision-making in society (UN, 2021b). The problem of poverty reduction, which has developed into a global problem, belongs to one of the main goals of international institutions. The major issues within the framework of the sustainable development goals (SDGs) are the combating of poverty, reducing income inequality, eradicating hunger and the availability of modern energy sources. Within the framework of the Sustainable Development Goals, the elimination of all types and forms of poverty is the first priority. Even the reduction of all forms and sizes of poverty is considered to be the long-term main condition for the development goals until 2030. According to the World Bank (2021), for the 1st time in 20 years, poverty rates worldwide increased in 2020 due to the COVID-19 pandemic. In addition, about 100 million people live below the poverty line, and this statistic is expected to grow gradually. There are 736 million people living in extreme poverty, which means they make up 10% of the world's population. About 1.3 million people live in multidimensional poverty. Half of the people living in poverty are under the age of 18 (UN, 2021a). In addition, poverty and inequality are becoming even more stressful due to climate change and global health pandemics, macroeconomic shocks (Adeleye et al., 2020).

In particular, while the impact of income inequality on poverty reduction is higher than that of economic growth, change in

poverty levels often associates with change in average income (Bergstrom, 2020). In most developed countries and some emerging market countries, we are seeing a steady increase in income inequality. In developed countries, the poverty rate is low, but since the 1980s, the country's GDP growth has been growing more slowly every 10 years. And the poverty rate in developing countries is decreasing, since GDP in developing countries has been growing at a high rate since the 2000s (Cerra et al., 2021). In addition, despite the steady growth of economic growth in developing countries, poverty and income inequality still persist (Adeleye et al., 2020).

Today, Kazakhstan is moving forward on economic and social inequality, although territorial inequality remains the main task of the country. Since gaining independence, Kazakhstan, like many post-Soviet countries, has pursued a policy of shock therapy, and the well-being of the 10% of the country's population receiving the highest incomes has increased dramatically. As a result of the socio-economic policy of the 1990s, the average standard of living of the population decreased, which led to a special polarization of society. These consequences are still affecting the country's economy. Indicators and methods determining income inequality and differentiation are varied, but the Gini coefficient is a very important indicator for determining poverty and social inequality in society (Kudasheva et al., [2018]. It combines information about the distribution of the country's income among the population into one quantitative indicator. The index is numbered from 0 to 1, where 0 represents absolute equality (the entire population has equal income) and 1 represents absolute inequality (the total state income is concentrated in the hands of one person). In Kazakhstan, the Gini index was 0.366 in 2001, which indicates relatively high income inequality. The index fell to 0.267 in 2009 over the next few years. This confirms the effective policy of the state in relation to the elimination of income inequality. After 2009, the Gini index had small fluctuations, but nevertheless remained between 0.26 and 0.29. In 2020, the index rose to 0.291, when income inequality was affected by the COVID-19 pandemic. The decrease to 0.285 in 2022 proves effective policy methods to eliminate post-pandemic income inequality (Bureau of national statistics of RK, 2024).

A further key factor influencing poverty reduction is energy. Energy is a fundamental indicator, that affects both the development of production and the development of the human factor, and it is the main condition for the stability and development of the economy (Rafindadi and Ozturk, 2017). The lack of access to clean, adequate and inexpensive energy will have a negative impact on both living conditions and human health, as well as on the development of the manufacturing sector.That is, accordingly, the level of poverty in the country is increasing (Khobai, 2021; Hussein and Leal, 2012). Energy can be used in developing countries as a poverty reduction medium (Hussein and Leal, 2012). For example, renewable energy can help reduce poverty by providing new jobs to the population (Jairaj et al., 2017). The consumption of renewable energy sources is fully consumed by the GDP of the country as a whole (Ito, 2017; Narayan and Doytch, 2017; Inglesi-Lotz, 2016). Lack of access to modern energy sources, especially in rural areas, further increases poverty (Pereira et al., 2010). The main factor influencing economic development is energy consumption. Ensuring energy availability for poor areas is one of the most effective means of reducing poverty (Diaz-Chavez et al., 2015).

Food security is another important factor in the elimination of poverty and income inequality. They are not provided with the necessary nutritious foods due to the lack of resources and money. About 90% of this population lives in low- and middle-income countries (FAO et al., 2019). Subramanyam et al. (2011) identified a statistically non-trivial link between economic growth and child malnutrition in India, while Harttgen et al. (2013) conducted a similar analysis in sub-Saharan Africa and accurately estimated a significant average feedback. Smith et al. (2017) analyzed the impact of GDP and unemployment on food security in low- and middle-income countries and Latin America included in the Gallup Global Survey dataset, and concluded that the growth of food insecurity is strongly influenced by low levels of education, low household income and income inequality.

Therefore, this study provides a more detailed analysis of the impact of final energy consumption and food security on income inequality and, consequently, the impact on poverty reduction. Given the link between the above income inequality and energy, income inequality and food security, the following hypotheses will be tested:

HO: Food security affects negatively on income inequality

H1: Final energy consumption affects negatively on income inequality

The rest of the paper is as follows: Section 2 describes the theoretical basis of the study. Section 3 describes the methods that we used. Section 4 consists of data and findings. Section 5 provides conclusions.

2. LITERATURE REVIEW

2.1. Gini Coefficient of Income Inequality

Basically, income inequality can be understood as the inequality between the rich and the poor. The expected result is the existence of income inequality between the territories of the country as a whole. The problem of income inequality was raised due to the diversity of the distribution of public resources to the population, the acquisition of resources, and demographic conditions. That is, well-developed and underdeveloped regions are always found throughout the country (Sjafrizal, 2012). According to Kuncoro (1997), inequality is the relative standard of living of different groups of a country due to differences in regions, which leads to uneven production, distribution of resources and factors in each industry in each region. The presence of heterogeneous factors of production and resources leads to inequality in income distribution, diversity in the level of development of the country, which, in turn, leads to a discrepancy between rich and poor.

At the initial stage of economic growth, income inequality is observed, which then improves and begins to be divided equally, the inverted U curve explains. As a result, income growth and decline are phenomena accompanied by the development trend of each country (Todaro, 2000). According to Taresh et al. (2020), inequality arises from a variety of factors, which include: Inflation, GDP, human development index, government spending,

consumption, unemployment, health, increased urbanization, and the minimum wage. According to Triyono et al. (2021), financial instability affects income inequality, and economic growth contributes to the impact of investment on regional inequality.

Income inequality is calculated using the Gini index and this coefficient is a very important indicator for determining poverty and social inequality in society. The Gini index measures the degree of difference between income in the economy and the distribution of consumption among the population from an absolute equal distribution (World Bank Metadata). The exponent has values from 0 (which means absolute equality) to 1 (which means absolute inequality). In another interpretation, the Gini index is 0 in a state in which the entire population receives the same income, and the Gini index is 1 if the entire income of the state is concentrated only in the hands of one person, and none of the other people receives income (Hayes, 2023).

This indicator is named after the Italian statistician and demographer Corrado Gini. Corrado Gini published a mathematical formula for calculating this indicator in 1912. To calculate this indicator, full information on government revenues will be required, of course, in some countries this information is sometimes insufficient or incorrect (Lidia and Paolo, 2012). According to the most recent information on today's Gini coefficient, income inequality occurs in all countries and has a wide range of income inequalities. According to World Bank (2024), the highest income inequality is observed in South Africa (0.63), and the lowest income inequality is in Norway (0.22).

2.2. Income Inequality and Food Security

In a context, eliminating hunger and food insecurity are directly related to adequate food production which, accordingly, is due to adequate consumption and adequate composition of food (World Food Summit, 1996). According to the Food and Agriculture Organization of the United Nations, in 1961, the average caloric intake per capita worldwide was 2,196 kcal, and in 2019 this figure rose to 2,963 kcal (FAO, 2022). In addition, in 1990, the level of malnutrition and starvation of people decreased from 18.9% (FAO et al., 2013) to 8.4% in 2019 (FAO et al., 2021). Even with the calculation of about 2,500 calories per capita, sufficient food energy is produced in the world. However, these are the global statistics above, which cannot show the difference in improvements between states. In recent years, the problem of inequality in access to food has attracted the attention of scientists (Bell et al., 2021; D'Odorico et al., 2019; Hasegawa et al., 2019; Wood et al., 2018; Khamjalas, 2024).

A recent FAO analysis shows that the problem of eradicating hunger in the world is currently not only slowing down, but also moving backwards. Despite the increasing availability of food in the world since 2015, the number of people living on hunger is growing sharply, which, according to statistics, is observed in sub-Saharan Africa (FAO et al., 2021). If, along with economic growth, there is high income inequality in the state, the poor cannot enjoy the benefits of state income, even if it is growing, they are still forced to choose between the quality or quantity of products consumed due to lack of access to food (FAO et al., 2019). Worldwide, 26% of the population has an average and acute food shortage, and even in some regions this figure is very high: 34% in South Asian countries and 57% in South African countries. These statistics once again confirm the data of the World Bank (2020) that billions of people in the world still cannot meet their most basic needs (including food, medical care, education).

By eliminating income inequality, economic growth can become a tool in solving food security problems in low- and middle-income countries (Holleman and Conti, 2020). Sustainable and low income inequality is of great political importance in addressing food security issues. These include: Economic growth strategies aimed at eradicating hunger, developing food security, that is, eliminating mass poverty, direct investment for the population who could not meet their most basic needs due to low access to food (Mary et al., 2018). According to the results of several food studies, the main factors influencing an effective method of economic growth and reducing child growth retardation are sanitation, government nutrition programs, public administration, education, food production and infrastructure (McGovern et al., 2017).

Holleman and Conti (2020) believes that income inequality eliminates the benefits of economic growth by reducing food security. When high income inequality persists in the State, the positive impact of economic growth on food security decreases. The population living in a country with a high level of income inequality very often faces acute food insecurity with a probability of 33% and average food insecurity with a probability of 42%. Nnanna and Ogbonnaya (2014) investigated income inequality and food safety and accessibility for farmers in Southeastern Nigeria. The hypothesis has been confirmed that food security is not respected if there is high income inequality in this region. Martinez et al. (2024) found that despite a 48% decrease in inequality between countries (the gini index fell from 0.15 to 0.078), inequality in food access within the country increased by 25% (the gini index increased from 0.088 to 0.111). In addition, 10% of the poor living in the countries of South, Southeast Asia, and Africa still get their daily calories from basic foods, which means that they have a limited variety of foods and, consequently, low access to food. Women with low food security in households have significant difficulties in addressing the problem of poverty and income inequality. Debebe and Zekarias (2020) the study showed that 34% of households live below the poverty line if the poverty severity index is 5.6% and the poverty gap index is 11%.

Inequality of access to agricultural production resources in rural areas has an enormous importance among women, which has a serious impact on food security and poverty (Dwomoh et al., 2023). The risks associated with food security threaten the health of the whole world population, negatively affecting social development. Income inequality negatively impacts economic growth and food security (Chen and Chen, 2023). Since the main goal of agricultural production is to ensure food security, the study by Saboori et al. (2022) was devoted to this area, and they analyzed the impact of agricultural diversification on food security across the Persian Gulf countries, which ultimately proved a causal relationship between them. Wudil et al. (2023) investigated the role of animal husbandry in food supply, and it was proved that the livestock production

index, GNP per capita and consumer spending have an important impact on food supply in the countries of Pakistan.

Through its national strategies, China has begun to implement food access through an innovative and inclusive development concept. Accordingly Zhang and Wu (2022), proposed a recently optimized model of environmental conservation indicators using the Gini index. Water, energy and food security are considered a serious problem in the country of China. The study by Xiao and He (2023) examines regional inequalities in pressure on water, energy and food (W-E-F). As a result, energy power prevails in the western and eastern regions, and the main issue is high regional inequality. Also, the main consumer of water resources is the food system. And the water footprint in the diet (DWF) explores in more detail the relationship between food and water consumption. Despite the fact that the consumption of plant products was high according to statistics, the study revealed a high level of DWF in livestock products (Song et al., 2024).

2.3. Income Inequality and Final Energy Consumption

Relationship between income inequality and energy consumption has received academic attention relatively new. Regarding the nature of the relationship between these variables, there are currently no consistent findings. Researchers look at a range of factors that fall into this category when it comes to energy consumption and energy types. Naturally, the availability and value of statistical data have an impact on this decision.

UN (2018) research revealed that disparities in energy consumption exacerbate income disparities between rural and urban areas. Because there are less energy sources available to people in South Asia and sub-Saharan Africa, the situation is considerably worse. Also, International Energy Agency (IEA, 2016) conducted research that indicates that energy inequality is more significant in nations with unequal income distribution because high rates and degrees of energy poverty make it impossible for people to live sustainably and with dignity in areas like cooking, heating, health care, and education. Rao and Pauchari (2017) studied nexus between Energy access and living standards. According to their findings, certain Asian nations were able to electrify their countries more quickly and at a lower cost than earlier attempts by developed nations. They observe that advances in access to electricity and water are consistently outpaced by the availability of clean cooking fuels and sanitary facilities globally. Developing nations and low-income middle-income nations are disproportionately affected by these two forms of deprivation. Additional research also indicates that energy use lowers poverty (Thiam, 2011; Sakanko and David, 2018; Tsaurai, 2021). In other words, having adequate access to energy broadens business growth and production opportunities, which in turn may impact job creation.

The health of women who cook and clean the house can also benefit from it. Investigating linkages between financial development, income inequality and renewable energy consumption from 39 countries in Sub-Saharan Africa, Asongu and Odhiambo (2020) found that although financial development unconditionally encourages the use of renewable energy, the underlying positive effect is offset by income inequality. Dong and Hao (2018) emphasize that China's rapidly growing fossil energy consumption and the country's widening income gap between rural and urban areas are major issues. They also provide compelling evidence of an inverted U-shaped relationship between GDP per capita and per capita electricity consumption. Their findings confirmed the dependence of income level on the impact of income inequality on electricity, with urban and rural effects on power being dependent. Gardezi and Chaudhry (2022) examined the relationship between globalization, energy consumption, and income inequality in 69 developing nations. They discovered a negative and significant correlation between the three variables, meaning that as energy consumption rises, income inequality falls. After analyzing the connection between the use of renewable energy and inequality, Topcu and Tugcu (2020) came to the conclusion that a rise in the use of renewable energy reduces income inequality. Lamia and Ghazouani (2024) discovered both positive and negative relationships between the two variables at different times when using nonparametric analysis to determine the relationship between energy consumption and income inequality in 18 African countries. The effects vary with time and show that unequal income distribution influences the use of renewable energy by favoring certain channels over others at particular periods.

To analyze influence of energy consumption on income inequality in Kazakhstan we took variable "final energy consumption." Final energy consumption (FEC) characterizes the final consumption of energy supplied to the final consumer for use for all energy purposes, both in total and by major consumers (industry, transport, households, services and agriculture) in accordance with the international standard industrial classification of types economic activity (ISIC). Final energy consumption includes fuel used for energy purposes, except for fuel consumed by energy enterprises for conversion into other types of energy (electricity, heat, gas) and operation of equipment. Thousands of tons of oil equivalent (*thousand toe*) – for total energy consumption and for energy consumption by main consumers; percentage of individual consumers' shares in final consumption. Final energy consumption is an indicator of driving forces that characterizes the trend in final energy consumption. The trend in final energy consumption (overall and by consumer) shows the progress made in reducing energy consumption and reducing the environmental impact of different end users (industry, transport, households, services and agriculture). It can be used to help monitor and evaluate the success of key policies designed to influence energy consumption and energy efficiency (Bureau of national statistics of RK, 2024). Below the graph 1 shows Final energy consumption by sectors.

There is a downward trend in the industrial sector's share of final energy consumption and an increase in the transportation, residential, commercial, and utility sectors. The housing sector made up the largest portion of the final consumption structure in 2022, accounting for 30.8% of total consumption, or 13.4 million toe. With an energy consumption volume of 12.3 million toe, the industrial sector ranks as the second largest final energy consumer, behind the residential sector. With a final consumption of 8 point 6 million toe in 2022, the transport sector is the third largest consumer of total final consumption, behind the residential and

industrial sectors. Oil and petroleum products account for 31.6% of total energy consumption in 2022, followed by coal at 22.1%. Of the total final energy consumed, heat energy accounted for 14.1%, natural gas for 15.7%, and electricity for 16.5% (Bureau of national statistics of RK, 2024).

3. METHODS

In consideration of the unevenness of the results of the reviews in the previous section, we study the relationship between the GINI INDEX and explanatory factors in the Republic of Kazakhstan in the period 1996-2022. In this case, GINI INDEX is determined by the following equation:

$$GINI_t = \beta_0 + \beta_1 \cdot FECgrowth_t + \beta_2 \cdot CDFI_t + \varepsilon_t, \quad (1)$$

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

During the study, according to the results of the ADF test, it was found that the studied variables are stationary at level I (0) or first differences I (1) (Table 2). Therefore, the ARDL methodology is used, the order of integration of variables is considered to determine the appropriateness of the ARDL model for the study, and a maximum of one lag is chosen for the outcome factor and 0 for the explanatory variables through a special test.

Based on the results of the Granger causality test using logarithms and the first difference (Table 3), the nonlinear NARDL model was estimated, and the long-term and short-term analysis of the relationship between variables was conducted. According to the linear ARDL model, it was not confirmed that all independent variables are causal to changes in the dependent variable.

So, the NARDL model was created and the results of the bounds test were shown in Table 4.

We transform the linear (1) model specification into the log-linear specification. The log-linear specification, that is, the parameters of the rank model show flexibility, gives more accurate and efficient

Table 1: Model variables and sources

Variables	Definitions	Sources
GINI	The Gini coefficient (for 10% of population groups, for 20% of population groups) - makes it possible to numerically assess the degree of inequality	Bureau of National statistics of Kazakhstan https://stat.gov.kz/
FEC growth	FEC represents the energy used by final consumers (such as households, transport, industry etc.) for all energy uses	Our World in Data https://ourworldindata.org
CDFI	CDFI=Export/import	World Data Bank Indicators (WDI) https://databank.worldbank.org/

Source: Authors. FEC: Final energy consumption, WDI: World Development Indicators, CDFI: Coefficient of dependence on food imports

Table 2: Augmented Dickey-Fuller 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
GINI	−1.911 (0.323)	−5.781*** (0.0001)	I (1)	−3.088 (0.130)	−3.041 (0.144)	>I (1)	−0.519 (0.482)	−6.781*** (0.000)	I (1)
FECgrowth	−5.796 (0.0001)	−8.378*** (0.000)	I (0)	−5.666 (0.0006)	−8.246 (0.000)	I (1)	0.238 (0.746)	−8.542*** (0.000)	I (1)
CDFI	−1.950 (0.305)	−6.762*** (0.000)	I (1)	−2.189 (0.474)	−6.618* (0.0001)	I (1)	−0.316 (0.561)	−6.923*** (0.000)	I (1)

*, **, ***Statistically significant at the 10%, 5% and 1% levels, respectively. P value is inside brackets. FEC: Final energy consumption, CDFI: Coefficient of dependence on food imports

results than the simple linear functional form. Log-transformed variables are in the same unit of measurement, thus reducing heteroscedasticity.

The first step in the non-linear autoregressive distributed lag model NARDL procedure is the determining the co-integration existence between the sampled variables. The bounds test examines long-run relationships, where the NARDL framework of the model 1 is expressed in Equation 2:

$$\Delta\ LogGINI_t = \beta_0 + \beta_1 \cdot Log\Delta\ GINI_{t-1} + \beta_2 \cdot \Delta FECgrowth_t + \beta_3 \cdot \Delta logFECgrowth_{t-1} + \beta_4 \cdot \Delta logCDFI_t + \beta_5 \cdot \Delta \log CDFI_{t-1} + \varepsilon_t \quad (2)$$

Where, operator Δ represents the differencing operation, and Log signifies the natural logarithm of the variables.

In order to test H0 and H1 indicators, the results were evaluated using the above equations to study the effect of the above variables on the poverty level in the Republic of Kazakhstan (Table 4). Based on these hypotheses, the impact of other factors on poverty is considered.

4. DATA AND FINDINGS

4.1. Data

The current study examines the impact of key economic factors on the GINI INDEX in the Republic of Kazakhstan. The study uses data for the period from 1996 to 2022, which was obtained by World Data Bank Indicators (WDI), ourworldindata.org. The identified explanatory variables in this study are growth of final economic consumption (FECgrowth), the coefficient of dependence on food imports (CDFI).

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 1996-2022 is depicted in the following graph:

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

The study used time series variables as defined in Table 1. In the study, the mean, median, standard deviation, minimum, maximum, asymmetry, and Hark-Behr statistics for each variable used in our model, and their respective characteristics are described in Table 5 below. The study validates the variables by mean, median, asymmetry, and minimum and maximum variables.

Based on descriptive statistics, the median of the GINI is 0.742 and the standard deviation is 0.283. The value of the Jarque-Bera statistic is 146.929, the probability of the link being 0.000, which is >0.05, so it can be concluded that the series is evenly distributed. The median FECgrowth 1.002% and the standard deviation is 0.163. cThe standard deviation for CDFI is not >0.025, which indicates

Table 3: Noncausality tests in the sense of granger for the vector autoregressive (1) (1996-2022)

Direction of causality	F-statistic	P
ΔlogGINI		
ΔlogFEC growth does not granger causeΔlogGINI	0.78991	0.4690
ΔlogCDFI does not granger causeΔlogGINI	2.59034	0.1026

FEC: Final energy consumption, CDFI: Coefficient of dependence on food imports

Table 4: Results of cointegration test

Model	F statistics	Critical bounds	Decision
NARDL (1, 0, 0)	29.716	3.19-5.3	Cointegration

** 10%level of significance, ***Critical bounds are reported at 1%. NARDL: Nonlinear autoregressive distributed lag

Table 5: Values of descriptive statistics of the displayed series

Values	GINI	FEC growth	CDFI
Mean	0.790	1.014	0.302
Median	0.742	1.002	0.293
Maximum	1.976	1.357	0.366
Minimum	0.442	0.793	0.267
SD	0.283	0.163	0.025
Skewness	2.868	0.368	0.872
Kurtosis	13.135	2.113	3.096
Jarque-Bera	146.929	1.440	3.305
Probability	0.000	0.487	0.192
Sum	20.549	26.374	7.850
Sum square deviation	1.996	0.661	0.015
Observations	27	27	27

SD: Standard deviation, FEC: Final energy consumption, CDFI: Coefficient of dependence on food imports

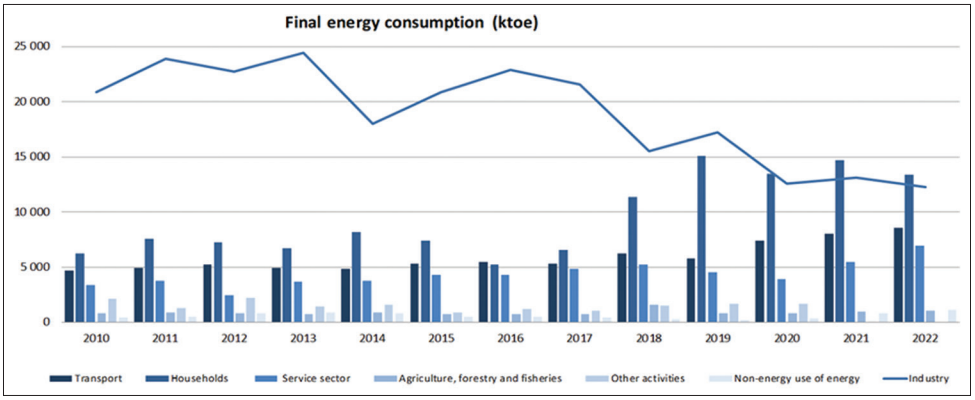
the heterogeneity of the indicator during the considered period. The Jarque-Bera statistic of 3.305 approaches a probability of 1.192, which means that the hypothesis of a null normal distribution is confirmed at the 5% significance level. In Table 5, we see that for GCF, GINI, FEC growth, CDFI, the time series asymmetry ratio is more than zero, which is to say they have right asymmetry. The correlations of all series variables do not exceed 0.9.

4.3. Unit Root Test

Before studying long-term relationships between series, it is important to determine whether they are stationary. There are many unit root tests available to determine if a series is stationary and if there are regression problems. This study used Augmented Dickey-Fuller (ADF) unit root tests to examine levels or differences of variables considered to be stationary. Some variables can be used at level I(0), while other variables are static at first difference I(1). Moreover, further cointegration methods are sensitive to the sample periods. For the purpose of this study, we can compose the ARDL.

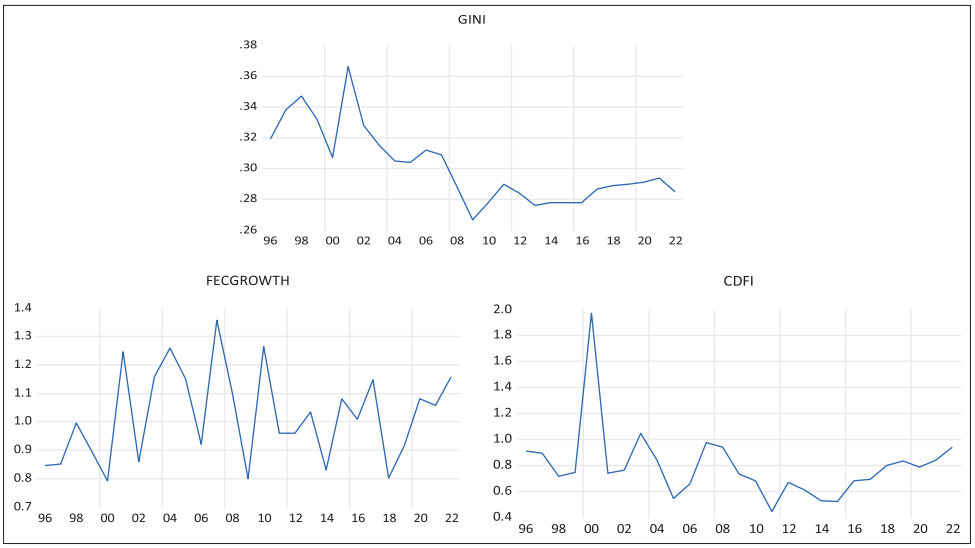
Table 3 presents the results of the unit root test of the extended Dickie Fuller (ADF) for the series at level and first difference, as the optimal lag is the first step in the measurement of the ARDL models. ADF test the non-stationary null hypothesis, which is rejected if ADF is more negative or exceed the absolute critical values of 1%, 5% and 10%. The results show that all variables except UNEMP are

Graph 1: Final energy consumption by sectors



Source: Bureau of national statistics of RK, 2024

Graph 2: Evolution of all variables for Kazakhstan (1996-2022)



Source: Authors

Table 6: Selection order criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	62.93216	NA	1.36e−06	−4.994347	−4.847090	−4.955280
1	88.81059	43.13071*	3.36e−07*	−6.400882*	−5.811855*	−6.244613*

not stationary at the level. However, these variables are stationary in the first difference, кроме случая с Trend and intercept.

So we should use those variables as the first difference to evaluate the ARDL models. The unit root results are consistent with the underlying assumptions, which require the use of the ARDL model test to confirm the existence of long-term relationships between Kazakhstan's GINI Index and the explanatory economic factors proposed in the study.

4.4. Granger Causality Test

To study the causal relationship between the selected variables and the unemployment rate, a Granger test is performed, which tests the null hypothesis that the changes in the dependent variable are not causal (Noncausality). The acceptance criterion is called the P-value. If P is <0.05, the null hypothesis is rejected. According to the Table 3, the null hypothesis is not accepted for all variable.

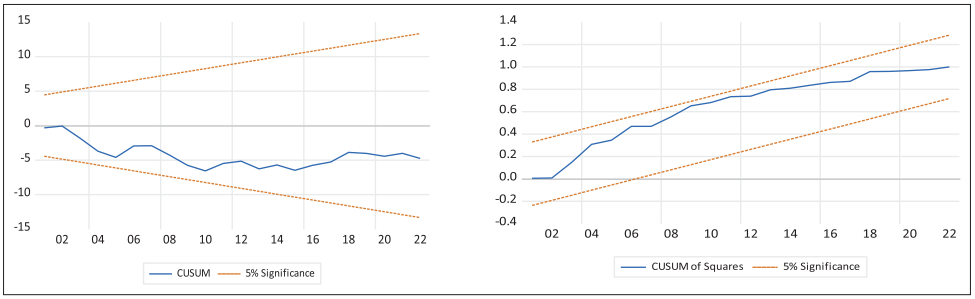
4.5. Co-Integration Test

The ARDL bounds testing procedure is used in this study to examine the long-term relationship between poverty, FEC growth, CDFI in the Republic of Kazakhstan. To investigate the long-term association of variables with, the ARDL method was chosen using a small sample size. Before a cointegration test can be performed, it is important to define a lag length criterion. The delay length criterion is determined based on LR, FPE, AIC, SC and HQ. Table 6 presents the results of the selected lag. As can be seen from Table 4, the selected lag length is 1 because it has more stars and was used throughout the study.

4.6. Results of Long- and Short Run Relationship

In the course of the study, the nonlinear NARDL (Equation 2) model was estimated using logarithms and the first difference according to the results of the ADF test, and in order to conduct a long-term and short-term analysis of the relationship between

Graph 3: CUSUM and CUSUMSQ tests



Source: Authors

variables, the obtained results are presented in the following table.

The results of the cointegration F-test for NARDL (Table 4) show that the obtained F-statistic exceeds the upper bound of 5.3 and is statistically significant at the 10% and 5% significance levels. The results show that the selected variables are cointegrated and in the Kazakhstan case there is a long-run relationship between the variables.

Given that the selected variables are cointegrated over the long term, we can move on to the next stage, which requires the estimation of long-term and short-term coefficients. Given that the NARDL model was evaluated in logarithmic form, we can estimate how a change in 1% of the explanatory variables affects the dependent variable in both the long and short term.

Table 7 shows the long-term evaluation results of the selected ARDL model. The data shows that FEC growth has a positive impact on poverty levels, which is significant at the 10% level. As a result, a 1% increase in FEC growth will lead to an increase in poverty by 0.0903%. And a 1% increase in CDFI reduces GINI by 0.079% at the 1% significance level, all other things being equal.

Both long-term estimates and short-term estimates also show that FEC growth affects GINI positively, and CDFI negatively, elasticities in this case are equal to 0.09 and −0.077, respectively. This highlights the impact of FEC growth and CDFI on poverty reduction. In addition, the dependence of the poverty level in period t on the value in period t-1 was confirmed. The negative influence of the lag variable GINI was proven in the constructed model.

4.7. Diagnostic Tests

It is extremely important to conduct a series of tests to ensure the stability of the nonlinear NARDL model. Among them are serial correlation, tests for normality and heteroscedasticity. For this model, the null hypothesis of the absence of serial correlation, homoscedasticity, or normality cannot be rejected. This suggests that the model is free from serial correlation and heteroscedasticity.

Table 8 shows the results of diagnostic studies. The LM statistic is 1.593891, has a probability value of 0.2291. As a result, we accept the null hypothesis in this analysis and conclude that there is no serial correlation in the model. Heteroscedasticity tests revealed an F-statistic of 0.8087 and a probability of 0.6273, both of which exceed a significance level of 0.05%, showing that the model

Table 7: Nonlinear autoregressive distributed lag estimation GINI index (1996-2022)

Dependent variable: ΔlogUNEMP				
Variable	**Coefficient**	**SE**	**t-statistic**	**P**
Short run				
logGINI(−1)	−1.0257***	0.1651	−6.2119	0.000
Δlog FECgrowth	0.0927**	0.0376	2.4649	0.0224
ΔlogCDFI	−0.0792***	0.0238	−3.3313	0.0032
Long run				
log FEC growth	0.0903*	0.0446	2.0263	0.0556
ΔlogCDFI	−0.0772***	0.0271	−2.8465	0.0097

*Coefficients are statistically significant at 10% level of significance, **Coefficients are statistically significant at 5%, ***Coefficients are statistically significant at 1%. Compiled by the authors. FEC: Final energy consumption, CDFI: Coefficient of dependence on food imports

Table 8: Short-run diagnostics

Test	F-statistics	P
Serial correlation	1.5939	0.2291
Heteroskedasticity	0.8087	0.6273
Jarque-Bera	0.9563	0.6199

is homoscedastic. The model accepts the null hypothesis of the normality test and concludes that the residuals are distributed normally, as evidenced by the F-statistic of 0.593734 and the probability value of 0.593734, both of which have a significance level >5%. Finally, all diagnostic tests for the serial correlation test of the Langrage multiplier, the Jarque-Bera normality test and the heteroscedasticity test were successful, which indicates the stability of the model.

4.8. Stability Tests

The CUSUM and CUSUM squares tests are used to see if the coefficients of the estimated models remain constant over time, which is an indicator of the stability of the model.

The results of the CUSUM and CUSUMSQ stability tests are shown in Graph 3. At 5%, the importance of the blue line not crossing the red lines indicates that the model is stable. This tests is also used to study the long-term dynamics of regression.

5. CONCLUSION

This study was conducted covering the period 1996-2022, which examines the relationship between poverty, growth in final electricity consumption and the coefficient of dependence of

food imports (CDFI), which is a major factor in food security, in Kazakhstan.

In the study, the ARDL bounds test was used to assess the existence of a long-term relationship between the variables. Explanatory variables were added as the coefficient of dependence of food imports and final energy consumption. The nonlinear NARDL model demonstrated that in the Republic of Kazakhstan the Gini coefficient, the growth of final energy consumption and the coefficient of dependence of food imports have a long-term relationship.

According to the model, FEC growth has a positive and significant effect on income inequality both in the long and short run. Consequently, FEC growth carries positive impact on poverty, which causes additional costs in the socio-economic system and reduces the poverty-free survival. Also, it was found that the coefficient of dependence of food imports has a negative and significant effect on the Gini coefficient in the long and short term.

It is recommended that the government work alongside other environmental protection measures to promote the growth of Kazakhstan's energy market, increase business participation through favorable pricing and quota allocation, and promote sustainable development. The financial accessibility of food to the majority of Kazakhstan's population remains inadequate due to low incomes and high food prices. Thus, adjustments in the cost and structure of the consumer basket, including its food component, are necessary.

In Kazakhstan, the economic accessibility of food is considered to be the average, reflecting the country's overall standard of living. Similarly, physical accessibility is also average, thanks to the transport infrastructure. Forecasts for food products show stable growth, suggesting no significant changes in external or internal factors in the medium and long term. To achieve this aim, we propose the revision of the organizational model for ensuring food security in Kazakhstan through the establishment of a single government body responsible for this task.

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