Food Security in Developing Economies: An Empirical Analysis of Population Structure and Key Determinants

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Abstract

Food insecurity poses a serious and ongoing threat to many developing countries, where rapid population growth has reshaped the landscape of food production and distribution. This study examines the non-linear analysis of urban and rural populations on food security. Besides these effects, it also explores the key determinants of food security, with a special focus on the role of trade openness, foreign direct investment, education, and institutional quality dynamics. The empirical results are estimated using the Panel Quantile Regression approach of 47 developing countries from 2002 to 2023. This approach reveals an inverted U-shaped relationship between both urban and rural populations on food security. The linearized marginal effect shows that the urban population is more vulnerable to food security compared to the rural population in developing countries. Moreover, education enhances food security, while foreign direct investment and trade openness cause food insecurity in developing countries. This study recommends that developing countries should promote sustainable urban development and strengthen rural agriculture systems.

Keywords: Food Security, Urban Population, Rural Population, Developing Countries.

Introduction

Food insecurity is a critical issue that remains unresolved in many developing countries. Despite the significant advancement in the agriculture sector, millions of people still suffer from chronic food shortages, issues, and malnutrition (Hassoun et al., 2024). The FAO (2024) report highlighted that roughly 2.2 billion people faced severe food insecurity. Climate change, wars, economic instabilities, and an inefficient food distribution system contribute significantly to the chronic food insecurity crisis, and the role of population growth cannot be overlooked (Hussain et al., 2025; Marwa et al., 2025). As the global population has expanded from 2.5 billion to over 8 billion today, more than 90% of this growth occurred in Asia, Africa, and parts of the Latin American region (Teperek, 2024).

Due to the widespread and persistent issue of food insecurity, it is an attractive research topic to examine its various dimensions across developing countries. Unfortunately, developing countries have been listed at the top in dealing with the problem of food shortage because millions of the population face food insecurity (Hassen & Bilali, 2024). These countries have also undergone political instability, which impacts agricultural activities. In spite of these challenges, some

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countries have improved food production (Ozdemir, 2024). However, food insecurity remains a significant challenge in all developing countries (Abdullahi et al., 2024).

Measuring food insecurity is crucial to understanding and addressing the challenges related to hunger and malnutrition. This study measures food security using a comprehensive food security index developed by four key dimensions: availability, accessibility, stability, and utilization. The food availability dimension presents the supply side, denoting the physical existence of the food. It encompasses food produced domestically, imported, or received through aid and is influenced by agricultural production level and trade dynamics (Cheng & Yu, 2024). The food access dimension confirms people's ability to obtain reasonable resources to acquire food in adequate quantities, quality, and diversity to meet nutritional requirements. It encompasses economic factors, including income to purchase food and physical access, sufficient income to buy food, and availability of food (Nontu et al., 2024). Food Utilization refers to the biological and practical ways in which food is available to the household or community. It encompasses the storage, preparation, processing, and consumption processes that determine how effectively the body can metabolize nutrients (Onyeaka et al., 2024). Food stability is a steady condition of equitable access to adequate food resources without interruptions by every individual, household, or population. The idea of food stability comprehends the consistency of sufficient food stock to meet the individuals' or households' needs and prevent hunger until the regular food supply is restored (Abbas et al., 2025). These dimensions collectively capture the multifaceted nature of food insecurity, ensuring a more holistic assessment. By integrating these components, the index offers a robust framework to evaluate the severity and drivers of food insecurity across different regions (Zhang et al., 2024).

Population growth is a significant determinant of food security, particularly in developing countries, because these countries face different challenges in resource distribution (Guyalo, 2025; Sheira et al., 2024). The growing population raises the demand for foodstuffs, accompanied by lower agricultural harvests due to climatic variations, causing an increase in food prices and generating food insecurity situations (Ghosh et al., 2024). Several studies explored that food availability is negatively affected by the rise in population (Xia et al., 2024).

This study is significant because it examines the urban and rural populations to determine food security. This study uses the non-linear analysis of urban and rural populations and finds an inverted U-shaped relationship to assess food security. Unlike the previous literature, several studies explore the linear association between population growth and food insecurity (Abbas et al., 2025; Aroyehun, 2023; Subramaniam, 2024). Alongside the population core variables, this study also determines a few other determinants of food security, including trade openness, education, foreign direct investment, and institutional quality. This study set two objectives to examine the non-linear impact of urban and rural populations on food security.

Literature Review

This section reviews the existing literature to examine the different determinants of food security. Population size is a significant driver of food security in the literature. Initially, Malthus (1798) discussed that rapid population growth outstripped food production, leading to food shortages and hunger. However, technological advancements in the agriculture sector have increased food production. However, several studies emphasized that high population growth remains a threat to food availability and access. Hall et al. (2017) revealed the nexus between population growth and food security in 44 African countries. The study found that projected massive population growth caused food insecurity. Kousar et al. (2021) in Pakistan and Aroyehun (2023) in Nigeria linked

population growth with food insecurity. They concluded that population growth increased food insecurity. In 57 developing countries, Subramaniam (2024) and in Pakistan, Abbas et al. (2025) investigated that population growth adversely impacts food security.

Urbanization is closely linked to population growth. As urban areas expand, agricultural land is used to develop buildings and houses, which reduces the land availability for food production. This shift not only decreases agrarian output but also strains other natural resources, further complicating food security efforts. Abebe (2024) empirically reviewed how urbanization affected food security in Ethiopia. The study revealed that urbanization caused food insecurity. Dongmo and Avom (2024) examined the role of urbanization on food insecurity in 43 African countries. They found that urbanization with civil conflict factors significantly increased food insecurity.

Education is recognized as a fundamental driver of food security in the literature. It shapes not only economic access to food but also the quality and sustainability of food systems. A growing body of literature underscores education as a vital enabler of food security at both micro and macro levels. In Keynia Mutisya et al. (2016) and in Nepal, Kandel et al. (2024) discussed that education increased food security. Tsongo et al. (2024) investigated the use of education as the moderator with inclusion to determine food security in African countries. The study concluded that education with financial inclusion plays a positive role in determining food security.

In the previous literature, foreign direct investment (FDI) has emerged as a significant influencing factor in food security. Through capital inflows, improved infrastructure, and technology transfer, FDI can enhance agricultural productivity, strengthen food supply chains, and create employment opportunities that will enhance household access to food. The literature acknowledges that FDI can positively impact the availability and affordability of food. Aloui and Maktouf (2024) showed that FDI positively impacts food security in the African region. It also presented that increasing FDI improves political stability and enhances food security. Soni and RL (2024) found that FDI enhances agricultural productivity, which improves food security in BRICS countries.

Trade openness is widely determinant of food security, particularly in developing countries. By the flow of food products across borders, trade openness improves food availability, reduces the risk of local shortages, and stabilizes prices. Gnedeka and Wonyra (2023) showed that trade openness increased food security in 37 African countries. Several pieces of literature measure trade openness through globalization because they reflect the extent to which a country is integrated into the global economy. Shang et al. (2024) highlighted the role of globalization in different dimensions of food security in African countries. The study found that globalization positively influenced the availability of food security.

After securitizing the available literature, several studies found a linear negative association of population growth with food security (Abbas et al., 2025; Aroyehun, 2023; Hall et al., 2017; Kousar et al., 2021; Subramaniam, 2024). There is no previous study that non-linearly examines the role of population growth in determining food security in developing countries. This is a novel work because its research examines both the urban and rural populations to assess food security.

Theoretical Framework

This study, based on the Malthusian and neo-Malthusian theories, postulates that the human population tends to grow exponentially. At the same time, food and agricultural production can only increase at an arithmetic rate. This means that the population expansion outpaces the increase in food production, potentially leading to food shortages. The work of Burger (2021), Portes & Schauffler (1993), and Andersen (2024) supports this idea, highlighting that food scarcity arises when there is an imbalance between the number of people and the available food supply, ultimately

leading to a deterioration of food security over time (Mellos, 1988; Sengupta & Chaudhuri, 2022). Due to rapid fluctuations in population across different countries, a non-linear relationship between population growth and food security is proposed. Several studies measure the non-linearity using the quadratic effect by the motivation of Environmental Kuznets analysis (Amjad et al., 2023, 2025; Asghar et al., 2023b; Wang et al., 2025). These studies either propose a U or an inverted U-shaped curve between population growth and food security. The U-shaped curve shows that the lower level of population growth declines food security, while, after reaching a certain point, food security increases. In contrast, the inverted U-shaped curve demonstrates that low levels of population size may support food security by expanding the labor force, encouraging innovation, and improving market access. However, beyond a certain threshold, the negative consequences of overpopulation—such as resource depletion, land fragmentation, and environmental degradation—begin to dominate, leading to declines in food productivity and security.

Thus, this theoretical framework reconciles the pessimistic outlook of the Malthusian theory with the more optimistic and dynamic EKC hypothesis. While population growth initially exerts pressure on food systems, effective institutional responses, technological improvements, and economic development can alter this relationship over time. Empirically testing the shape of this relationship—whether inverted U-shaped or U-shaped—can help policymakers design more effective strategies to achieve food security in the face of growing populations.

Data and Methodology

This research utilizes panel data for 47 developing countries from 2002 to 2023, identified by the World Bank as low- and lower-middle-income economies. Urban and rural populations, expressed as percentages of the total population, are used as key regressors. The Food Security Index (FDI) serves as the regressand and is constructed using the Principal Component Analysis (PCA) method using four food dimensions. Additionally, preprimary education(PRE), foreign direct investment (FDI), trade openness (TR), and institutional quality (IQ) are included as the key determinants of food security. Additional information about the variables is highlighted in Table 1.

Table 1: Description of the factors

Symbols	Descriptions	Units	Sources
FSI	Food security	Index	(FAO, 2025)
UPOP	Urban population	%of the total population)	(WDI, 2025)
RPOP	Rural population	%of the total population	(WDI, 2025)
PRE	Preprimary school enrollment	% of gross	(WDI, 2025)
FDI	Foreign direct investment	% of GDP	(WDI, 2025)
TR	Trade openness	% of GDP	(WDI, 2025)
IQ	Institutional quality	Index	(WDI, 2025)

Following the motivation of literature review and theoretical framework, we develop the regressions as follows:

$$FSI_{it} = \alpha_1 + \alpha_2 LNUPOP_{it} + \alpha_3 LNUPOP_{it}^2 + \alpha_4 LNPRE_{it} + \alpha_5 LNFDI_{it} + \alpha_6 LNTR_{it} + \alpha_7 IQ_{it} + \varepsilon_{it} \quad (1)$$

$$FSI_{it} = \beta_1 + \beta_2 LNRPOP_{it} + \beta_3 LNRPOP_{it}^2 + \beta_4 LNPRE_{it} + \beta_5 LNFDI_{it} + \beta_6 LNTR_{it} + \beta_7 IQ_{it} + \varepsilon_{it} \quad (2)$$

Equations (1) and (2) include the subscript i to denote the 47 selected developing countries and t to represent the time period from 2003 to 2023. LN shows the natural logarithm of the variables

to address the variability of the variables. FSI_{it} presented the food security index and used as the regressand. α_2 and β_2 are linear coefficients of urban and rural population, α_3 and β_3 are their quadratic coefficients and propose the non-linear quadratic curve. While the remaining α_4, α_5, α_6 and α_7 of equation (1) and β_4, β_5, β_6 and β_7 of equation (2) demonstrates the the coefficients of education(LNPRE), Foreign Direct Investment (LNFDI), trade openness (LNTR), and Institutional Quality (IQ) respectively.

The cut-off value of the threshold of the non-linear curve is estimated as follows:

$$\frac{dFSI_{it}}{dLNUPOP_{it}} = \alpha_2 + 2\alpha_3 LNUPOP_{it} = 0$$

$$LNUPOP^*_{it} = -\frac{\alpha_2}{2\alpha_3} \quad (3)$$

$$\frac{dFSI_{it}}{dLNRPOP_{it}} = \beta_2 + 2\beta_3 LNRPOP_{it} = 0$$

$$LNRPOP^*_{it} = -\frac{\beta_2}{2\beta_3} \quad (4)$$

Equations (3) and (4) displays the threshold point of the non-linear curve. It facilitates to understand whether selected countries have achieved the threshold point or not.

This study employs the Panel Quantile Regression (PQR) method to estimate the empirical results, originally introduced by Koenker and Bassett (1978). The PQR technique is particularly effective in handling issues of outliers and unobserved heterogeneity in panel data. Unlike traditional regression models, which focus solely on the conditional mean, PQR provides a more comprehensive understanding by capturing variations across different points of the dependent variable's distribution (Rani et al., 2022a, 2022b, 2025).

Results and Discussion

Table 2 presents the statistical description of the variables. The mean score of FSI is 0.000 and its maximum value is observed in the Philippines, while the minimum in Brazil. The mean scores for the urban population (LNUPOP) and rural population (LNRPOP) are 3.88 and 3.74, respectively. Nepal has the lowest urban population and the highest rural population, whereas Argentina has the highest urban population and the lowest rural population. The average score for education (LNPRE) is 5.65, and the highest is recorded in Tajikistan, and the lowest is in Brazil. The mean value of foreign direct investment (LNFDI) is 1.16, highest in Cabo Verde and lowest in Cambodia. The average score of trade openness (LNTR) is 10.21and the maximum value is observed in Cabo Verde, and the minimum value is in Tunisia. Lastly, the central value of institutional quality (IQ) is -0.40, and the highest value is observed in Peru and the lowest in Cambodia (Amjad, 2023; Asghar & Amjad, 2022; Rafique et al., 2023).

Table 2: Descriptive analysis

Variable	Mean	Std. dev.	Min	Max
FSI	0.0000	1.0000	-4.1305	3.7388
LNUPOP	3.8871	0.4357	2.6561	4.5268
LNRPOP	3.7414	0.5055	2.0198	4.4516
LNPRE	5.6461	8.1606	0.2923	74.3259
LNFDI	1.1588	1.5724	-4.8548	17.1312
LNTR	10.2149	19.9938	3.0958	146.1061
IQ	-0.4035	0.5131	-1.4972	1.0189

Table 3 presents the results of the Wilk (W) and Francia (W') tests of normality. The p-values for both tests are less than 1%, indicating that we reject the null hypothesis of normality. This confirms

that the variables are not normally distributed, which is a prerequisite for applying the PQR approach (Abid et al., 2024a, 2024b; Aslam et al., 2024).

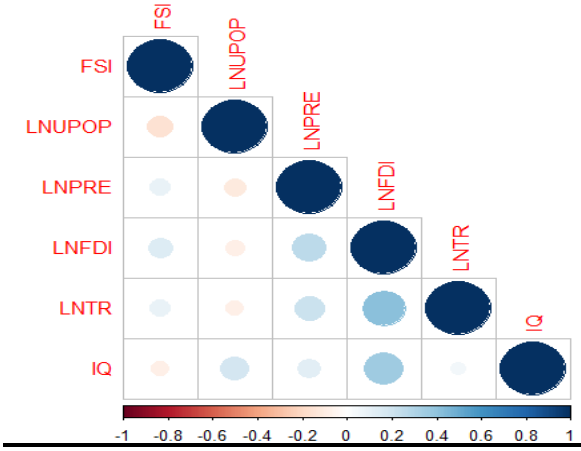
Table 3: Results of the Normality tests

Variable	W	Prob>z	W'	Prob>z
FSI	0.7328	0.0000	0.7281	0.0000
LNUPOP	0.9306	0.0000	0.9316	0.0000
LNRPOP	0.9208	0.0000	0.9215	0.0000
LNPRE	0.3547	0.0000	0.3532	0.0000
LNFDI	0.7678	0.0000	0.7644	0.0000
LNTR	0.3602	0.0000	0.3593	0.0000
IQ	0.9740	0.0000	0.9749	0.0000

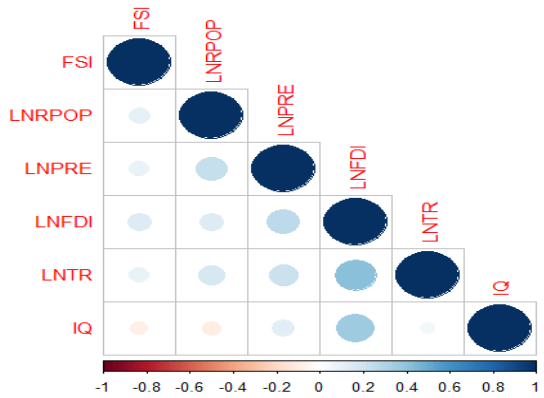
Figure 1 displays the correlation plot of both models, serving as a diagnostic tool for multicollinearity. The lower color scheme shows red and blue colors with corresponding correlation values between -1 and 1. The plot bubbles are light red and blue colors, revealing the closer values of "0", presenting a weak association. Statisticians recommended that an absolute correlation value less than 0.80 presents a weak multicollinearity issue (Asghar et al., 2023a).

Figure 1: Correlation plot

Urban Population



Rural population



The PQR approach is considered the appropriate approach to address the outliers and non-normality issues in the model. Model 1 highlights the urban population model; the level coefficient of urban population (LNUPOP) significantly increases food security at 50th and 75th quantile groups. While its quadratic coefficient negatively impacts food security. The positive coefficient of urbanization and the negative coefficient of its squared term indicate an inverted U-shaped relationship between urbanization and food security. This suggests that at lower levels, urbanization contributes positively to food security—possibly through improved infrastructure, access to markets, and better services. However, beyond a certain threshold, further urbanization begins to undermine food security. There is not any previous study that explored the inverted U-shaped relationship between urbanization and food security. However, several literatures examined the linear relationship between urbanization and food security. In Ethiopia, Abebe (2024) empirically revealed that urbanization caused food insecurity. In 43 African countries, Dongmo

and Avom (2024) found that urbanization with civil conflict factors significantly increased food insecurity.

In Model 2, the non-linear effect of the rural population on food security is under-considered. The level coefficient of the rural population (LNUPOP) is significantly positive, while the square term is negative in the 50th and 75th quantiles, indicating an inverted U-shaped relationship between the rural population and food security. This pattern suggests that at the initial stages, an increasing rural population enhances food security, likely due to greater agricultural activity and self-sustenance. However, beyond a certain point, further growth in the rural population may strain resources, reduce per capita agricultural productivity, and limit access to essential services, thereby negatively affecting food security. There is not any study that directly traces the inverted U-shaped pattern between rural population and food security. However, many studies found a linear association between population and food insecurity. In 44 African countries, Hall et al. (2017), in Pakistan Kousar et al. (2021), in Negeria Aroyehun (2023), and in Pakistan Abbas et al. (2025) found that population growth increased food insecurity.

Food insecurity in developing countries is a multifaceted issue, with rapid population growth being one of the most critical contributing factors. According to the United Nations, the population of developing regions is projected to increase by over 1.2 billion people by 2050, placing significant pressure on already strained food systems. As the population grows, the demand for food increases sharply, but agricultural production and food distribution systems often fail to keep pace. Many developing countries face limitations such as poor infrastructure, lack of access to modern farming technologies, and underinvestment in agriculture. These challenges hinder food availability and accessibility, particularly in rural areas where most of the population relies on subsistence farming. Moreover, with more mouths to feed, resources such as arable land and water become increasingly scarce, further reducing the capacity to produce enough food for everyone.

In addition to production challenges, population growth in developing countries often leads to rapid urbanization, which can exacerbate food insecurity. As people migrate from rural to urban areas, agricultural labor declines, and fertile land is converted into residential or industrial zones. This shift reduces local food production and increases dependency on food imports, which can be unaffordable for low-income populations. According to the FAO (2023), over 730 million people worldwide faced chronic hunger, with the majority residing in developing countries—especially in Sub-Saharan Africa and South Asia, where population growth rates are among the highest. These demographic pressures, combined with economic inequality, poor governance, and climate vulnerability, make it increasingly difficult for developing countries to achieve food security for all.

Table 4: Empirical results of the PQR approach

	Dependent variable: Food Security Index (FSI)					
	Model 1			Model 2		
	$\tau = 25^{th}$	$\tau = 50^{th}$	$\tau = 75^{th}$	$\tau = 25^{th}$	$\tau = 50^{th}$	$\tau = 75^{th}$
LNUPOP	1.9438 (1.8951)	5.1431** (2.0686)	7.2155* (2.6608)			
$LNUPOP^2$	-0.1716 (0.2518)	-0.5391*** (0.2748)	-0.7516** (0.3535)			
LNRPOP				1.2014 (2.1336)	12.2544* (1.5414)	13.5898* (1.4769)
$LNRPOP^2$				-0.2762 (0.3065)	-1.7364* (0.2214)	-1.9887* (0.2122)
LNPRE	0.0418 (0.0687)	0.2819* (0.0750)	0.5964* (0.0965)	-0.0270 (0.0977)	0.1766** (0.0706)	0.4933* (0.0676)
LNFDI	-0.0562 (0.0551)	-0.2540* (0.0601)	-0.3991* (0.0773)	-0.0788 (0.0815)	-0.1907* (0.0589)	-0.3733* (0.0564)
LNTR	0.1403 (0.1302)	-0.6102* (0.1422)	-1.3773* (0.1828)	0.1882 (0.2246)	-0.2683 (0.1623)	-0.7083* (0.1555)
IQ	0.0238 (0.1183)	0.0313 (0.1291)	-0.0316 (0.1661)	0.0553 (0.1737)	0.0612 (0.1255)	-0.0619 (0.1202)
cons	3.9452 (3.5129)	13.7013* (3.8345)	21.2376* (4.9321)	-0.3899 (3.3582)	22.0056* (2.4260)	24.6401* (2.3246)

Note: *, **, *** presents 1%, 5%, and 10% significance value, while () shows standard errors

The linearized marginal effect is used to determine whether an individual country lies on the left or right side of the inverted U-shaped curve. In other words, it indicates whether a country has reached the threshold point of the curve. Table 5 presents the linearized marginal effects of this study, calculated using the mean values of urban and rural populations at 50^{th} and 75^{th} quantiles. In all quantile groups, the urban population has an adverse impact on food security across countries, indicating that urban populations in developing countries are consistently facing food insecurity. In urban areas, food insecurity is increasing due to rising living costs, inadequate infrastructure, and limited access to affordable and nutritious food. As cities expand, many people settle in overcrowded areas with poor sanitation, unreliable food supply chains, and limited access to clean water. Additionally, the urban poor are highly vulnerable to economic shocks, such as inflation or job loss, which can further reduce their ability to purchase sufficient food. Weak urban planning and insufficient investment in food distribution networks exacerbate these challenges, making food insecurity a persistent issue for growing urban populations in developing countries.

When we estimate the rural population's food security, we have observed that most countries do not have rural food insecurity because their rural population shows a positive association with the food security index. Rural populations in developing countries often experience lower levels of food insecurity compared to their urban counterparts, primarily because many rural households are directly involved in agricultural activities. These communities typically rely on subsistence farming, which allows them to grow their own food and maintain a certain level of self-sufficiency. Access to locally produced staples such as grains, vegetables, and livestock reduces their dependence on market-based food systems, which are more vulnerable to price fluctuations and supply disruptions. Additionally, rural areas generally have lower living costs, which helps families allocate more resources toward food. However, while rural populations may face

challenges such as poor infrastructure and limited access to diverse diets, their ability to produce food locally often provides a buffer against the acute food insecurity frequently observed in urban slums.

Table 5: Results of Linearized Marginal Effects

		Mean value of		Urban population		Rural population	
No	Countries	LNUPOP	LNRPOP	$\tau = 50^{th}$	$\tau = 75^{th}$	$\tau = 50^{th}$	$\tau = 75^{th}$
1	Albania	3.9919	3.8064	-0.8399	-1.2152	0.9659	1.5597
2	Argentina	4.5120	2.1804	-0.2792	-0.4335	-4.6798	-4.9078
3	Armenia	4.1511	3.5971	-0.6683	-0.9759	0.2393	0.7273
4	Azerbaijan	3.9936	3.8219	-0.8380	-1.2126	1.0195	1.6211
5	Belarus	4.3288	3.1738	-0.4767	-0.7088	-1.2307	-0.9567
6	Belize	3.8187	3.9973	-1.0265	-1.4755	1.6285	2.3188
7	Benin	3.7916	4.0154	-1.0558	-1.5163	1.6916	2.3911
8	Brazil	4.4422	2.7019	-0.3544	-0.5383	-2.8689	-2.8334
9	Bulgaria	4.2919	3.2875	-0.5165	-0.7643	-0.8358	-0.5043
10	Burkina Faso	3.2491	4.3018	-1.6406	-2.3318	2.6860	3.5302
11	Cabo Verde	4.1328	3.6199	-0.6879	-1.0034	0.3184	0.8179
12	Cambodia	3.0651	4.3622	-1.8390	-2.6084	2.8955	3.7701
13	Costa Rica	4.2945	3.2444	-0.5136	-0.7603	-0.9853	-0.6755
14	Cote d'Ivoire	3.8788	3.9412	-0.9618	-1.3852	1.4340	2.0959
15	Dominica	4.2314	3.4372	-0.5816	-0.8552	-0.3160	0.0912
16	Ecuador	4.1428	3.6109	-0.6772	-0.9884	0.2871	0.7820
17	Egypt	3.7592	4.0445	-1.0907	-1.5649	1.7926	2.5067
18	Gambia, The	4.0459	3.7477	-0.7816	-1.1340	0.7621	1.3262
19	Georgia	4.0336	3.7707	-0.7949	-1.1525	0.8418	1.4175
20	Ghana	3.9547	3.8599	-0.8800	-1.2711	1.1514	1.7722
21	Guatemala	3.8972	3.9248	-0.9419	-1.3575	1.3771	2.0307
22	India	3.4630	4.2188	-1.4100	-2.0102	2.3977	3.1998
23	Indonesia	3.9358	3.8793	-0.9004	-1.2996	1.2188	1.8494
24	Iran	4.2727	3.3315	-0.5372	-0.7932	-0.6831	-0.3293
25	Jordan	4.4609	2.5224	-0.3343	-0.5103	-3.4921	-3.5473
26	Kazakhstan	4.0440	3.7598	-0.7837	-1.1369	0.8039	1.3741
27	Kyrgyz R.	3.5803	4.1605	-1.2836	-1.8339	2.1953	2.9680
28	Lesotho	3.2408	4.3071	-1.6495	-2.3442	2.7042	3.5509
29	Malaysia	4.2762	3.3156	-0.5334	-0.7879	-0.7382	-0.3925
30	Mali	3.6286	4.1240	-1.2315	-1.7613	2.0686	2.8229
31	Mexico	4.3632	3.0629	-0.4396	-0.6572	-1.6155	-1.3975
32	Morocco	4.0828	3.6998	-0.7419	-1.0786	0.5957	1.1356
33	Nepal	2.8707	4.4088	-2.0485	-2.9006	3.0573	3.9555
34	Nigeria	3.8119	3.9920	-1.0339	-1.4857	1.6102	2.2978
35	Pakistan	3.5705	4.1655	-1.2941	-1.8486	2.2125	2.9878

36	Peru	4.3403	3.1447	-0.4643	-0.6915	-1.3315	-1.0722
37	Philippines	3.8351	3.9831	-1.0089	-1.4509	1.5795	2.2626
38	Rwanda	2.8391	4.4176	-2.0826	-2.9481	3.0879	3.9906
39	Senegal	3.8025	4.0081	-1.0441	-1.5000	1.6660	2.3617
40	Serbia	4.0116	3.8008	-0.8186	-1.1856	0.9465	1.5374
41	Sri Lanka	2.9133	4.4016	-2.0026	-2.8365	3.0323	3.9268
42	Tajikistan	3.2912	4.2921	-1.5952	-2.2684	2.6521	3.4913
43	Thailand	3.7953	4.0033	-1.0518	-1.5107	1.6496	2.3429
44	Timor-Leste	3.3522	4.2671	-1.5295	-2.1768	2.5652	3.3918
45	Togo	3.6584	4.1105	-1.1993	-1.7164	2.0218	2.7693
46	Tunisia	4.2099	3.4834	-0.6048	-0.8875	-0.1558	0.2747
47	Turkiye	4.2762	3.3225	-0.5334	-0.7878	-0.7144	-0.3652

Besides the population variables, this study also used a few control variables. Preprimary education (LNPRE) positively impacts food security in most of the quantiles. In the literature, Mutisya et al. (2016) in Kenya, Kandel et al. (2024) in Nepal, and Tsongo et al. (2024) in African countries have drawn similar results. Foreign direct investment (LNFDI) inversely impacts food security, which shows food insecurity. Unlike these results, the literature found that FDI positively impacts food security. Aloui and Maktouf (2024) in the African region and in BRICS countries Soni and RL (2024) found that FDI enhances agriculture productivity, which improves food security. Trade openness (LNTR) also adversely impacts food security in most of the quantiles. These results are also contradictory results from the literature. Most of the studies found that trade openness increases food security, like Gnedeka and Wonyra (2023) in 37 African countries and Shang et al. (2024) in African countries.

Conclusion

This study investigates various dimensions of food security with a special focus on examining the non-linear analysis of population growth. This study includes 47 developing countries from 2002 to 2023. The normality test supports that our selected variables are not normality distributed and the presence of outliers. To address these issues, the Panel Quantile Regression is used. The food security index serves as the explained variable and measures using different dimensions based on food availability, accessibility, stability, and utilization. The urban and rural populations are used to measure the population size and behave non-linearly with regard to food security. The study investigates the inverted U-shaped relationship of urban and rural populations to determine food security. The findings suggest that at lower levels, increases in both urban and rural populations can initially improve food security due to better infrastructure, agricultural productivity, and economic opportunities. However, beyond a certain threshold, further population growth—particularly in urban areas—leads to a decline in food security. Moreover, additional analysis explored that urban populations face more severe food insecurity compared to rural populations, primarily due to rapid and unplanned urbanization, high living costs, dependency on food markets, and limited access to affordable and nutritious food. In contrast, rural populations, despite facing poverty and infrastructural limitations, benefit from self-sustained agricultural practices that partially shield them from acute food insecurity. In addition, this study also includes education, trade openness, foreign direct investment, and institutional quality as the key determinants of food security in developing countries.

This study recommends that developing countries should invest in sustainable urban infrastructure that ensures equitable access to food markets, clean water, sanitation, and affordable housing, especially in low-income urban areas. They should more focus on establishing urban agriculture, improving food distribution networks, and subsidizing essential food items for the urban poor can mitigate food insecurity in cities. These countries should also fomalate policies to strengthen rural food systems through investment in agricultural inputs, irrigation, training, and access to markets to sustain and improve rural food security.

References

- Abbas, S., Haider, A., Kousar, S., Lu, H., Lu, S., Liu, F., Li, H., Miao, C., Feng, W., Ahamad, M. I., Mehmood, M. S., & Zulqarnain, R. M. (2025). Climate variability, population growth, and globalization impacting food security in Pakistan. *Scientific Reports*, *15*(1), 4225.
- Abdullahi, A. M., Kalengyo, R. B., & Warsame, A. A. (2024). The unmet demand of food security in East Africa: review of the triple challenges of climate change, economic crises, and conflicts. *Discover Sustainability*, *5*(1), 1–15. https://doi.org/10.1007/S43621-024-00381-5/FIGURES/2
- Abebe, M. G. (2024). Impacts of urbanization on food security in Ethiopia. A review with empirical evidence. *Journal of Agriculture and Food Research*, *15*, 100997. https://doi.org/10.1016/J.JAFR.2024.100997
- Abid, M. Y., Batool, I., & Amjad, M. A. (2024a). Estimating the Non-linear Impact of Environmental Degradation on Climate Vulnerability in Developed and Developing Economies: A Pathway to achieve Sustainable Development. *Indus Journal of Social Sciences*, *2*(2), 126–148. https://doi.org/10.59075/IJSS
- Abid, M. Y., Batool, I., & Amjad, M. A. (2024b). Role of industrial growth on economic development: A comparative analysis of developed and developing countries. *The Critical Review of Social Sciences Studies*, *2*(2), 256–275. https://doi.org/10.59075/ZVECP766
- Aloui, Z., & Maktouf, S. (2024). The Impact of Foreign Direct Investment and Political Stability on Food Security: Evidence from Sub-Saharan African Countries. *Comparative Economic Studies*, *66*(2), 289–328. https://doi.org/10.1057/S41294-023-00222-W/TABLES/11
- Amjad, M. A. (2023). Moderating the role of social progress with greenhouse gases to determine the health vulnerability in developing countries. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-023-28867-1
- Amjad, M. A., Rani, T., & Wang, F. (2025). Nonlinear Effects of Energy Shortages on Sustainable Development and Economic Growth: Evidence From South Asian Countries. *Sustainable Development*. https://doi.org/10.1002/sd.3492
- Amjad, M. A., Rehman, H. ur, & Asghar, N. (2023). The Long-Run Dynamics of Green Technology, Ecological Footprint, and Health Vulnerability in Developed and Developing Countries. *IRASD Journal of Economics*, *5*(2), 364–376. https://doi.org/10.52131/JOE.2023.0502.0133
- Andersen, L. (2024). Zombies un-slayed: Malthusian Myopia in Lapland. *History of European Ideas*. https://doi.org/10.1080/01916599.2024.2377496
- Aroyehun, A. R. (2023). Impacts of Climate Change and Population Growth on Food Security in Nigeria. *Black Sea Journal of Agriculture*, *6*(3), 232–240. https://doi.org/10.47115/BSAGRICULTURE.1232578
- Asghar, N., & Amjad, M. A. (2022). Asymmetric impact of energy prices on tourism demand in Pakistan. *Journal of Economics and Management Sciences*, *2022*(1), 1–15. https://doi.org/10.52587/JEMS030101
- Asghar, N., Amjad, M. A., & Rehman, H. ur. (2023a). An Asymmetric Analysis of Renewable Energy in Mitigating Carbon Emissions in Pakistan. *IRASD Journal of Economics*, *5*(3), 713–724. https://doi.org/10.52131/joe.2023.0503.0156

- Asghar, N., Amjad, M. A., & Rehman, H. ur. (2023b). Analyzing the impact of access to electricity and biomass energy consumption on infant mortality rate: a global perspective. *Environmental Science and Pollution Research*, *30*(11), 29550–29565. https://doi.org/10.1007/S11356-022-24144-9/TABLES/9
- Aslam, B., Zhang, G., Amjad, M. A., Rashid, R. F., Al-Ghamdi, A. A., Iqbal, R., Manavalan, R. K., & Ali, Z. (2024). Quantifying the strategies to mitigate health vulnerability: unveiling the nexus of institutional quality with clean energy. *International Journal of Environmental Science and Technology*. https://doi.org/10.1007/s13762-024-06244-w
- Ben Hassen, T., & El Bilali, H. (2024). Three years into the pandemic: Insights of the COVID-19 impacts on food security and nutrition in low and middle-income countries. *Heliyon*, *10*(7). https://doi.org/10.1016/j.heliyon.2024.e28946
- Burger, J. R. (2021). Malthus on Population. *Encyclopedia of Evolutionary Psychological Science*, 4751–4760. https://doi.org/10.1007/978-3-319-19650-3_1267
- Cheng, J., & Yu, X. (2024). Regional differences, distributional dynamics and convergence of multidimensional food security levels in China. *PLOS ONE*, *19*(8), e0309071. https://doi.org/10.1371/JOURNAL.PONE.0309071
- Dongmo, A. D., & Avom, D. (2024). Urbanization, civil conflict, and the severity of food insecurity in Africa. *Politics and Policy*, *52*(1), 140–168. https://doi.org/10.1111/POLP.12572;PAGE:STRING:ARTICLE/CHAPTER
- FAO. (2024). *In Brief to The State of Food Security and Nutrition in the World 2024*. https://doi.org/10.4060/cd1276en
- Gnedeka, K. T., & Wonyra, K. O. (2023). New evidence in the relationship between trade openness and food security in Sub-Saharan Africa. *Agriculture and Food Security*, *12*(1), 1–17. https://doi.org/10.1186/S40066-023-00439-Z/FIGURES/3
- Guyalo, A. K. (2025). Food security and its determinants among rural households in Gambella region, Ethiopia. *Cogent Economics and Finance*, *13*(1). https://doi.org/10.1080/23322039.2025.2484651;wgroup:string:publication
- Hall, C., Dawson, T. P., Macdiarmid, J. I., Matthews, R. B., & Smith, P. (2017). The impact of population growth and climate change on food security in Africa: looking ahead to 2050. *International Journal of Agricultural Sustainability*, *15*(2), 124–135. https://doi.org/10.1080/14735903.2017.1293929
- Hussain, M. A., Li, L., Kalu, A., Wu, X., & Naumovski, N. (2025). Sustainable Food Security and Nutritional Challenges. *Sustainability, 17*(3), 874. https://doi.org/10.3390/SU17030874
- Kandel, G. P., Bavorova, M., Ullah, A., & Pradhan, P. (2024). Food security and sustainability through adaptation to climate change: Lessons learned from Nepal. *International Journal of Disaster Risk Reduction*, *101*, 104279. https://doi.org/10.1016/J.IJDRR.2024.104279
- Koenker, R., & Bassett, G. (1978). Regression Quantiles. *Econometrica*, *46*(1), 33. https://doi.org/10.2307/1913643
- Kousar, S., Ahmed, F., Pervaiz, A., & Bojnec, Š. (2021). Food Insecurity, Population Growth, Urbanization and Water Availability: The Role of Government Stability. *Sustainability, 13*(22), 12336. https://doi.org/10.3390/SU132212336
- Malthus, T. (1798). *An Essay on the Principle of Population*. http://www.esp.org
- Marwa, T., Hamira, Sukanto, Mukhlis, Atiyatna, D. P., & Hamidi, I. (2025). Food Insecurity in Asia Pacific: Climate Change and Macroeconomic Dynamic. *AGRIS On-Line Papers in Economics and Informatics*, *17*(1), 81–94. https://doi.org/10.22004/AG.ECON.355701
- Mellos, K. (1988). Neo-Malthusian Theory. *Perspectives on Ecology*, 15–42. https://doi.org/10.1007/978-1-349-19598-5_2
- Mutisya, M., Ngware, M. W., Kabiru, C. W., & Kandala, N. bakwin. (2016). The effect of education on household food security in two informal urban settlements in Kenya: a longitudinal analysis. *Food Security*, *8*(4), 743–756. https://doi.org/10.1007/S12571-016-0589-3/FIGURES/3

- Nontu, Y., Mdoda, L., Dumisa, B. M., Mujuru, N. M., Ndwandwe, N., Gidi, L. S., & Xaba, M. (2024). Empowering Rural Food Security in the Eastern Cape Province: Exploring the Role and Determinants of Family Food Gardens. *Sustainability, 16*(16), 6780. https://doi.org/10.3390/SU16166780
- Onyeaka, H., Ejiohuo, O., Taiwo, O. R., Nnaji, N. D., Odeyemi, O. A., Duan, K., Nwaiwu, O., & Odeyemi, O. (2024). The Intersection of Food Security and Mental Health in the Pursuit of Sustainable Development Goals. *Nutrients 16*(13), 2036. https://doi.org/10.3390/NU16132036
- Ozdemir, D. (2024). Reconsidering agricultural credits and agricultural production nexus from a global perspective. *Food and Energy Security*, *13*(1).
- Portes, A., & Schauffler, R. (1993). Competing perspectives on the Latin American informal sector. *Population & Development Review*, *19*(1), 33–60. https://doi.org/10.2307/2938384
- Rani, T., Amjad, M. A., Asghar, N., & Rehman, H. U. (2022a). Exploring the moderating effect of globalization, financial development and environmental degradation nexus: a roadmap to sustainable development. *Environment, Development and Sustainability*, *0123456789*. https://doi.org/10.1007/s10668-022-02676-x
- Rani, T., Amjad, M. A., Asghar, N., & Rehman, H. U. (2022b). Revisiting the environmental impact of financial development on economic growth and carbon emissions: evidence from South Asian economies. *Clean Technologies and Environmental Policy*, *24*(9), 2957–2965. https://doi.org/10.1007/S10098-022-02360-8/TABLES/5
- Rani, T., Wang, F., Ur Rehman, S. A., & Amjad, M. A. (2025). Shaping sustainable futures in BRICS-T economies: The role of digitalization with moderating effects of green technology innovation and financial inclusion. *Technology in Society*, 102879. https://doi.org/10.1016/J.TECHSOC.2025.102879
- Sengupta, R., & Chaudhuri, C. (2022). COVID-19: A Neo-Malthusian Event? : Ecological links, Challenges, and Opportunities. *Environmental Economics in Developing Countries*, 81–108. https://doi.org/10.4324/9781003253884-5
- Shang, Y., Lv, Y., Chen, Z., Bassey, R., Aderemi, T. A., & Enilolobo, O. (2024). Globalization and food security in Sub-Saharan Africa. *Frontiers in Sustainable Food Systems*, *8*, 1325172. https://doi.org/10.3389/FSUFS.2024.1325172/BIBTEX
- Soni, S., & RL, M. (2024). The dynamic nexus between agricultural productivity and renewable energy consumption in BRICS: the role of financial inclusion and foreign direct investment. *International Journal of Energy Sector Management*, *18*(6), 1885–1904. https://doi.org/10.1108/IJESM-08-2023-0028/FULL/XML
- Subramaniam, Y. (2024). Population Growth, Biofuel Production, and Food Security. *Green and Low-Carbon Economy*, *2*(4), 259–268. https://doi.org/10.47852/BONVIEWGLCE3202948
- Tsongo, G. M., Wirajing, M. A. K., Ningaye, P., & Nchofoung, T. N. (2024). Food security and financial inclusion in Africa: exploring the role of educational development. *International Review of Applied Economics*.
- Wang, F., Rani, T., & Amjad, M. A. (2025). The asymmetric impact of energy shortages on sustainable development, human development and economic growth in South Asian countries: The moderating role of globalization. *Energy Policy*, *202*, 114554. https://doi.org/10.1016/J.ENPOL.2025.114554
- WDI. (2025). *Worldwide Governance Indicators*. World Bank. https://databank.worldbank.org/source/worldwide-governance-indicators#selectedDimension_WGI_Ctry
- Xia, Q., Tian, G., Zhao, D., Zhao, Q., & Varis, O. (2024). Effects of new-type urbanization on resource pressure: Evidence from a water-energy-food system perspective in China. *Sustainable Cities and Society*, *107*, 105411. https://doi.org/10.1016/J.SCS.2024.105411
- Zhang, T., Li, Y., Lu, S., -, al, Yang, Z., Wu, G., Bai, M., Zhang, T., Sun, W., Xiao, J., & Yan, G. (2024). The impact of land use change on food security under the background of rapid urbanization - a case study of Xiamen city. *Environmental Research Communications*, *6*(10), 105006. https://doi.org/10.1088/2515-7620/AD7F2C