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Climate Change and Food Security in Selected Developing Countries: Panel Data Analysis

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Abstract: *Climate change is causing more global warming today, which has an impact on every sector of the economy. In order to avoid financial damage as a result of climate change, it is necessary to validate the policies for policymakers and government authorities. The aim of this study is to measure the impact of climate change on food security in selected developing economies. The results indicate that climatic variations have a positive long-run impact on food security in selected developing countries due to extended growing seasons and fertilization effects. On the other hand, energy consumption and rapid urbanization are deteriorating the food security situation significantly over time due to the costlier energy and unplanned urban sprawl in most of the region. The study suggests that we need to learn from developed nations by using sustainable urbanization planning and liberalizing energy prices for agricultural consumption to fight hunger and food insecurity in these economies.*

Introduction

The issue of food insecurity is important to analyze because it has serious consequences for human development, economic development, health, individual productivity, and learning capabilities (Upton, Cissé, & Barrett, 2016). Therefore, the I. FAO (2014) has emphasized the issue of food insecurity as a top priority of political, economic, and global resource planning and also stressed the creation of a suitable environment to enhance the food security situation by making sufficient investments and formulating better policies. According to the Food and Agriculture Organisation of the United Nations (FAO, 2009), food security is the condition in which everyone, at all times, has physical, social, and economic access to enough food that is safe and nutritious to meet their dietary needs and food preferences in order to lead an active and healthy life. According to recent assessments of global food and nutritional security, the majority of those who are undernourished reside in emerging nations, where access to food is the primary problem with food security, notably in the world's most underdeveloped regions like Africa and some regions of South Asia (Dithmer & Abdulai, 2017).

One of the primary issues of the twenty-first century is reducing the risk of climate change to food and nutritional security (Campbell et al., 2016). According to some estimates, the severe effects of its use will be shown in the form of stunting in children, which is expected to grow by 62% in Southern Asia by the year 2050 in comparison to a future in which there will be no changes in climate (Lloyd, Kovats, & Chalabi, 2011). It is a fact that climatic variations affect every component of food security over time (Noiret, 2016; Vermeulen, Campbell, & Ingram, 2012). The continuous upswing in the average temperature of the earth has threatened millions of people around the globe with a higher risk of floods, hunger, and water and food shortages (Escobar et al., 2009). All of the above shows that food insecurity is a key issue for the whole world in present times.

With the help of several academic studies, the relationship between population and food is well known (Bongaarts, 2011; Pimentel, Harman, Pacenza, Pecarsky, & Pimentel, 1994). Yet, there is no methodical econometric investigation of how urbanization affects food insecurity (Szabo, 2016). Extreme weather conditions and a reduction in agricultural land have a direct impact on the agricultural industry and the distribution of food because rising food demand as a result of rapid urbanization, a reduction in agricultural land, and poor harvests as a result of climatic variations raises the price of food products, which in turn has increased food insecurity, particularly in developing countries (Frenkel, 2004).

Energy consumption, which is recognized as a prerequisite for the growth and development of an economy, is thought to be an imperative factor of production in any economy, including the agriculture sector (Makun, 2015; Sultan, 2012). It is commonly used for supplying different sectors that include agriculture, manufacturing, transportation, and households, which is why it has a greater impact on the prices of other commodities (Taghizadeh-Hesary, Rasoulinezhad, & Yoshino, 2019). According to some ecological economists, energy is the most significant and crucial aspect of the expansion of agriculture and an economy's general health (Stern, 1993). Therefore, one may think that energy consumption and agricultural growth have a strong association in the context of food security. It means that energy use is a crucial element for exports and economic growth (Sadorsky, 2012), which may increase the productivity of the agricultural sector and hence improve food security.

According to FAO (2010), a major fraction of undernourished people live in developing economies. The situation is worsening in the Asian region, where more than 520 million undernourished people live(FAO, 2017). South Asia is the most important region in this context as it contains more than 25% of the world's population, and nearly half of the poorest people in the world live in this region (Bandara & Cai, 2014; Hanif, Raza, Gago-de-Santos, & Abbas, 2019). According to (Godfray et al., 2010), a number of factors, including drought, famines, international conflicts, and climate change—which includes temperature variations, precipitation, greenhouse gas (GHG) emissions, and resource depletion—appear to be the root cause of the developing world's high rate of food insecurity. One of the most significant difficulties that the world will face in the future decades is going to be trying to ensure food and nutritional security for a population that is growing at an alarming rate while also dealing with increasing urbanisation and a changing climate (Change, 2007).

For developing countries, previous research and national strategies remained insufficient and unsatisfactory in reducing the dangers of food insecurity. As a result, this study examines how climate change, energy use, and an increase in urban population affect the food security of a select group of developing nations that share similar geographical, socioeconomic, and environmental characteristics. Furthermore, the study will help expose levels of food insecurity specific to developing economies and determine the impact of some socio-economic and demographic factors on food security. As a result of analyzing food insecurity, solutions can be proposed to the residents of the region by accessing one of the most basic fundamentals of life: food. This study uses selected developing countries (2004–2021) to get robust results. Moreover, these countries are highly dependent on climatic conditions and are facing the common issue of rapid urbanization. The dependability of the estimated model is evaluated throughout the course of the study by pre- and post-diagnostic tests. The data that were offered in the study have been shown to be reliable, and as a result, policymakers may use them as a key reference when formulating policy measures to monitor and reduce food insecurity in this region. The following is the structure of this paper: In part two, you'll find a review of the relevant prior research; in section three, you'll find information about the data and methods; in section four, you'll find an estimation of the results; in section five, you'll find an interpretation of the results; and finally, in section six, you'll find a summary, a conclusion, and some suggestions for future research.

The purpose of this study is to investigate the effect that climate change plays on the precariousness of food supply in developing nations. In addition, the purpose of the study is to determine the state of food security in developing countries as well as the impact that climate change has had on food security in developing nations. Apart from the Introduction in the 1st section, previous studies are reviewed in section 2, the 3rd section is about data and methodology, the 4th section is of results and discussion while the conclusion is given in the 5th section.

Literature Review

The effects of climate change are a significant contributor to food insecurity across the globe, especially in terms of food production. Keeping in view the topic of the research paper, this paper presents literature regarding climate change, energy consumption, and urbanization's impact on food security. Liu, Li, Fischer, and Sun (2004) evaluated the impact of climatic changes on agriculture in China using the Ricardian model. The study employs cross-sectional data at the county level for net revenue from agriculture, weather, and some additional geographical and economic variables for 1275 dominated counties in the agricultural sector and finds that climatic changes (more precipitation and higher temperatures) have a positive impact on Chinese agriculture. Overall, China has benefited from climatic changes in most situations.

Schmidhuber and Tubiello (2007) analyze the possible impacts of climatic changes on food security. However, the significance of various components and the general impact of climatic variation on food security differ across regions in the world, and with the passage of time, it is subject to the general socioeconomic status in the case of developing countries. The study claims that climatic changes will have a negative impact on all of the dimensions of food security.

Wang et al. (2009) analyze crop revenues by employing cross-sectional data that consists of both irrigated and rain-fed farms. Net revenues have been regressed on seasonal climatic variations and some exogenous variables based on household data. The effect of higher temperatures is adverse, whereas greater rainfall has a positive impact. Results show that global warming is projected to be dangerous for rain-fed farms, whereas it is favourable for irrigated farms. These impacts were different region-wise. Southeastern farms are slightly affected, while Northeastern and Northwestern farms are likely to face major damages.

Tambo and Abdoulaye (2012) explore the relationship between climate change and technology in Nigerian agricultural production. The study uses household data from 200 farms to determine whether small farm holders should invest and how much money should be invested to adapt technology. Empirical results illustrate that climatic variations, extension services, complementary inputs, and information are important determinants of technology adoption. It also appears that non-farm income and the wealth position of households are significant factors in adoption.

Qureshi et al. (2015) analyzed the long-term relationships among air pollution, urban population, nuclear energy consumption, industrialization, and health services in the Malaysian economy. The paper applied a two-stage least squares regression approach to the annual data for the period 1975–2012. The results of the study indicate that air pollution and factors related to the environment are strong contributors to Malaysia's health services. The fertility rate declines with urban sprawl in the country, while the impact of industrialization and the consumption of fossil fuel energy is negative on the infant mortality rate. On the other hand, Co_2 emissions have a direct impact on sanitation facilities in Malaysia. The study concludes that balancing air pollution, environmental conditions, and medical services requires sensible policymaking by the government.

Quresh and Baboo (2016) investigated the links between agricultural output and fossil fuel for the Pakistani economy from 1980 to 2013. This study employed the "Generalized Method of Moment (GMM)" and show that, in Pakistan's economy, the output of the agriculture sector is positively influenced by CO2 emissions, whereas the production is negatively influenced by energy sources. Cotton and sugarcane production is positively correlated with the use of fossil fuels, while wheat and sugarcane production is positively correlated with CO2 emissions. Due to climate change and other fluctuations, ensuring global food security is a significant concern. Therefore, to identify ards and develop potential remedies, a multidisciplinary approach is necessary(Islam et al., 2016).

Bren d'Amour et al. (2017) argue that urbanization and related demographic variations pose extraordinary issues in terms of food insecurity, malnutrition, and hunger in developing economies. As a result, the food system is facing significant pressures due to urban expansion occurring in some of the most fertile agricultural lands in developing economies in Asia and Africa. Using the "Feasible Generalised Least Square (FGLS)" method in a time series context from 1989–2015, Ali et al. (2017) analyse the effect of climatic changes (minimum temperature, maximum temperature, sunshine, relative humidity, and rainfall) on the major food crops (rice, wheat, sugarcane, and maize). The findings suggest that the highest temperature has a detrimental influence on wheat output, whilst the minimum temperature appears to have a beneficial effect on the production of all other types of crops. Except for wheat, the impact of rainfall on the yield of the selected crops is negative. Wheat is the exception. It has been stated that in order to enhance the state of food security in the country and to lessen the negative effects of climate change, the cultivation of drought- and heat-resistant types that produce large yields and are resistant to both heat and drought is necessary.

Alvi and Jamil (2018) study the impact of climatic variation and technological adoption on cereal yields for selected South Asian economies using GMM for the period 1990–2015. The empirical findings show that the change in climate reduces cereal production, whereas the adoption of technology raises cereal yields. However, the speed of technological adoption by farmers is slow and challenging in the selected South Asian region. This suggests that the use of advanced technological practices in the agricultural sector of these countries should be increased to achieve sustainable food production.

In order to evaluate the contribution of climate change to food security representation, Joyo, Ram, and Magsi (2018) investigated the effects of hazards related to climatic fluctuations on rice yield in Pakistan. The information for this study was obtained for the years 1994 to 2015. To find the appropriate research design, exploratory research methods were used. To determine the mean, standard deviation, and standard error, descriptive statistics were utilized. The unit root test revealed that water ability was already stationary and that variables were non-stationary at level but stationary at the first difference. The negative relationship between temperature, precipitation, and rice output was explained by econometric findings (Khan, 2022).

In terms of agricultural production, Bocchiola, Brunetti, Soncini, Polinelli, and Gianinetto (2019) showed that while rice and maize yields will only minimally decrease due to adaptation in land usage at higher altitudes, wheat yields will decrease by 38%. But overall, Pakistan's food security score declined. Muringai, Naidoo, Mafongoya, and Lottering (2020) investigated the effects of rising temperatures, dwindling water supplies, and rising CO2 emissions on agricultural production. Their research, along with the majority of previous studies, demonstrated a strong connection between crop failure and deteriorating meteorological conditions. As a result, its impacts necessarily have an impact on every other component of a food supply chain. Research on carbon emissions, economic expansion, and climate change is being done by Ditta et al. in 2021. According to the study's preliminary findings, emissions of carbon dioxide made in Pakistan are an important factor in the progression of climate change. Hussain and Chaudhry (2021) examined the effect of climate change on agriculture in Pakistan.

Ani, Anyika, and Mutambara (2022) looked into how Nigerian food and people's security might be affected by climate change. The data from the study are both quantitative and qualitative. The study's conclusions were based on data from primary and secondary sources collected in various areas of Nigeria during 2018 and 2019. The conclusions showed that Nigeria's food security has been adversely impacted by climate change. Continuous armed conflicts over natural resource control have also resulted, in endangering national security.

Using panel data covering the years 1995–2021, Ditta, Hashmi, Anis, and Maqbool (2023) examined how economic development can benefit the environment. Urbanization management will improve farming methods while reducing carbon emissions. Additionally, income development with the best utilization of labor and capital can lessen the rate of environmental deterioration and improve climate conditions.

The analysis of the problem of food insecurity in various nations has benefited from the findings of all of these studies as well as a few others. The majority of studies on food security were qualitative in nature or focused on household or regional analysis. Only a few of the aspects of food security have been the subject of other research that has been done nationally. However, we were unable to locate any empirical work that included a macro-level analysis of food security in relation to emerging nations.

Data and Methodology

Data Description

This study uses data from the World Bank, World Development Indicators (WDI), and the Food and Agriculture Organisation of the United Nations (FAO) to investigate the effects of climate change, energy use, and an increasing urban population on food security in a number of developing economies over the course of the period 2004 to 2021. The data were collected from the World Bank, World Development Indicators (WDI), and FAO. The selection criteria for selected countries are the availability of the data. Finally, assorted developing countries in South Asia are as follows: Bangladesh, Sri Lanka, Bhutan, Pakistan, India, Nepal and the Maldives. Despite their apparent differences, these economies have a lot in common, such as a significant reliance on climate change and rising urbanization for their food security.

Model Specification

The following is a specification of the model that can be used to construct a model for the purpose of analysing how factors such as urbanisation, energy consumption, and climate change affect the availability of food in different economies:

$$FS_{it} = F(TC_{it}, EC_{it}, UPG_{it})$$

The following is a possible representation of the econometric model used to estimate our findings after taking the natural log of the above model:

$$\ln FS_{it} = \beta_0 + \beta_1 \ln TC_{it} + \beta_2 \ln EC_{it} + \beta_3 \ln UPG_{it} + \mu_{it}$$

Here the subscripts *i* and *t* represent the cross-sectional unit and the time period, respectively, whereas FS indicates food security and is represented by the average calorie supply per capita per day, measured in kilocalories (kcal), that is available to each individual in the total population. The indicator used in the earlier research as a stand-in for national food security, according to Smith and Haddad (2001), is the most pertinent quantitative measure of food security. The fact that data are available for all nations and historical periods, as well as the fact that the availability of calories per capita is one of the most important measures of food security and is directly linked to food intake, both contribute to the fact that this study was conducted. These are the main justifications for using the average number of calories available as an explanatory variable (FAO, 2013). The availability of more calories per person has been linked to a reduction in hunger, and it has been found to have a major impact on child malnutrition and nutritional status (Dawson & Sanjuán, 2011; FAO, 2009; I. FAO, 2014; Smith & Haddad, 2001). Here (TC) shows temperature change, and (EC) and (UPG) represent energy consumption and urban population growth, respectively.

Table 1

Definition of Variables

Variables symbols	Variables Description	Unit of measurement	Data Sources
FS	Log of average calories supply per capita	Kilocalories/day	Food and Agriculture Organization of the United Nations (FAO)
TC	Log of temperature change	degree Celsius	
EC	Log of energy consumption per capita	kg of oil equivalent	World Development Indicators
UPG	Log of urban population growth	annual percentage	

Methodology

It is possible to determine if the data are stationary at level, first difference, or second difference by employing a unit root test. This is achieved by employing the Liven, Lin, and Chu (LLC) stationary test in conjunction with the Im, Pesaran, and Shin (IPS) stationary test. The Panel Auto Regressive Distributed Lag (Panel-ARDL) model has been employed for the estimation of long-run and short-run outcomes because it is consistent with the relationship between climatic fluctuations, energy consumption, urbanisation, and food security that was discussed in the section before this one. In this work, we make use of a dynamic panel regression analysis, which gives us the ability to explain the dynamic features and effectively deal with the problem of probable endogeneity that arises as a result of such a specification. This is because such a specification is expected to result in such a problem. The vast majority of economic models have a dynamic aspect, which is to be expected given that changes in government policy can have long-term repercussions that continue into the foreseeable future. As a result, the dynamic form of the model describes how independent variables affect one another through time. Most cross-sectional empirical research now uses dynamic regression approaches instead of static models for the aforementioned reasons (Headey & Ecker, 2013). Therefore, we have modelled the average calorie supply per capita per day as a proxy for food security levels as a function of its determinants, as explained in the above section.

Results and Discussion

In this part, the findings of the unit root test as well as the long-run and short-run ARDL analyses are presented. Table 2 displays the findings obtained by Liven, Lin, and Chu (LLC), as well as those obtained by Im, Pesaran, and Shin (IPS). The findings of the unit root tests indicate that the natural log of food security (lnFS) and the natural log of energy consumption (lnEC) are both stationary at first difference. On the other hand, the natural log of the change in temperature (lnTC) and the natural log of urban population growth (lnUPG) are both stationary at level. As a result, the conclusion that can be reached is that the variables that were discussed in the research have a disordered order of integration.

Table 2

Results of Panel unit root tests

Variables	Tests	At Level		At First Difference	
		Intercept	Intercept & trend	Intercept	Intercept & trend
Ln FS	LLC	-1.102 (0.135)	-1.068 (0.142)	-3.800 (0.000)	-6.747 (0.000)
	IPS	0.847 (0.801)	-0.380 (0.351)	-2.143 (0.016)	-3.527 (0.000)
Ln TC	LLC	-3.566 (0.000)	-4.186 (0.000)	-6.307 (0.000)	-5.645 (0.000)
	IPS	-2.223 (0.013)	-1.844 (0.032)	-5.223 (0.000)	-3.892 (0.000)
Ln EC	LLC	-0.346 (0.364)	-0.835 (0.201)	-6.321 (0.000)	-6.262 (0.000)
	IPS	2.518 (0.994)	-0.526 (0.299)	-4.115 (0.000)	-3.690 (0.000)
LnUPG	LLC	-3.581 (0.000)	-4.430 (0.000)	-2.465 (0.006)	-2.634 (0.004)
	IPS	-2.065 (0.019)	1.626 (0.051)	-1.753 (0.039)	-0.736 (0.023)

Note: P values have been given in the parentheses

Tables 3 and 4 show the long-run and short-run results which show that temperature change (TC) is greatly enhancing food security. More specifically, a one percent increase in temperature would raise the long-term food security position by around 0.007%. In light of these findings, it is clear that climate change, as indicated by temperature change, has little impact on food security in South Asian developing nations. The reason is that crop yields respond positively to temperature surges up to 3°C, and here, the annual changes in temperature are less than 1°Cin this region. The positive impacts of temperature change include prolonging the length of the growing seasons, reducing the growing period that is needed by the crops to mature, increasing the likelihood of two or more cropping phases during the same growing season, reducing the damage to winter crops due to low temperatures, and reducing the heating cost of crops grown in protected cultivation environments. These findings are in line with those of (Isik & Devadoss, 2006; Liu et al., 2004).

Energy Consumption (EC) in selected South Asian developing countries deteriorates food security over time. One percent more energy consumption reduces the food security situation by about 0.885% if all other factors are considered constant. A major implication of this finding is that since energy is viewed as a limiting element for food security, a rise in energy consumption would be detrimental to a nation's ability to maintain food security. The same findings were also corroborated by (Belloumi, 2009; Sebri & Abid, 2012), they arrived at the conclusion that one aspect that could be considered a barrier to the expansion of the agricultural industry was the availability of electricity.

Moreover, the coefficient of urban population growth (UPG) is -0.464, which shows a negative and significant impact of urban sprawl on food security in developing countries. It indicates that food security deteriorates by 0.364% for every percent increase in urban population growth. According to prior studies, rapid and unsystematic urbanization has destroyed urban agricultural areas as well as natural recreational areas, which are very important for the food security of a country. Excessive urbanization also led to polluted groundwater, which disturbs food utilization practices. In order to combat hunger and food insecurity, sustainable urban development should be encouraged, (Szabo, 2016). Macro-level urban growth has a considerable negative impact on a country's risk of food insecurity.

Additionally, in the short term, the results of the error correction framework demonstrate that the error correction term (ECt-1) is statistically significant and negative, indicating that the explanatory variables cause changes in the food security situation, which supports the significance of the estimated model. The relevance of the lagged error term supports the long-term connections between food security, energy use, and urbanization. Furthermore, the error correction term's negative sign shows that the estimated model converges to equilibrium as it moves from short-run to long-run estimations.

Table 3

Estimates of Panel ARDL Approach

Variables	Coefficient	Standard Error	t-statistic	Prob.
Longrun Panel ARDL Results				
LnTC	0.007***	0.004	1.687	0.091
LnEC	-0.885*	0.148	-6.619	0.000
LnUPG	-0.464*	0.114	-3.197	0.003
Shortrun Panel ARDL Results				
ΔlnTC	-0.016*	0.007	-2.154	0.041
ΔlnEC	0.571**	0.269	2.118	0.044
ΔlnUPG	-0.350	0.244	-1.433	0.164
EC_{t-1}	-0.681**	0.317	-2.385	0.025
Constant	11.610**	4.656	2.493	0.019

Conclusion & Policy Recommendations

Understanding how factors such as urbanisation, climate change, and energy use will affect food security is essential for policymakers who are tasked with developing strategies that will successfully eradicate hunger. This paper tries to support the hypotheses that climate change, energy consumption, and urban sprawl contribute to food security. In order to obtain reliable results, this study analyzes panel data from particular developing economies using an autoregressive distributed lag (ARDL) model. This study's methodology provided consistent short- and long-term effects to assess how urbanization, energy consumption, and climate change affect food security. Based on solid empirical findings, the study concludes that climatic variations as measured by temperature change have little impact on food security in the developing economies of the selected developing countries because crop yields respond positively to temperature increases up to 3ºC, and here, the annual changes in temperature are less than 1ºC.

On the other hand, the estimated results of this research paper show that energy consumption in selected developing countries deteriorates the food security situation over time. Furthermore, energy is considered a limiting factor for food security, and, therefore, an increase in energy use has a negative impact on the food security performance of the region, as confirmed by (Belloumi, 2009; Sebri & Abid, 2012). The results of this study also indicate how uncontrolled urban growth in the area has exacerbated already-existing issues. Therefore, it can be concluded that sustainable urban development should be promoted to fight the hunger and food insecurity. Moreover, no variable make significant contribution to food security in the short run, as per our analysis.

The study suggests that SAARC should play a vibrant role by working with practitioners to devise sensible policies to enhance the food security of the region by learning from developed economies how they have performed from the perspective of changing climates and rapid urbanization. Moreover, liberalized energy prices for consumption in the agricultural sector are strongly recommended to avoid any significant adverse effect on food security, while the detrimental consequences of fast urban sprawl on food security point to the need for sustainable urbanization strategies to be prioritized.

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