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RESEARCH ARTICLE

Dynamics of climate change, food security and agricultural imports in South Asia: An empirical investigation

S Elamathy & K M Shivakumar*

Department of Agricultural Economics, Tamil Nadu Agricultural University, Coimbatore 641 003, India

*Correspondence email - kms1@tnau.ac.in

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Abstract

The scale of global food insecurity is escalating because of conflicts, climate crisis and economic shocks and it is a multidimensional problem in South Asian countries. The objective of this study is to examine the long-term and short-term relationships between climate and non-climate factors and food security in South Asian countries. We analyzed the relationships between food security and other factors using panel ARDL model for the period 2001-2022 by computing mean group, pooled mean group and dynamic fixed effect. The dependent variable considered in study is prevalence of undernourishment which is modeled against independent variables like food production index, land area under cereal cultivation, GDP per capita, population, inflation, rainfall, temperature, cereal import dependency. Our results showed that, for an increase of land area under cereals and GDP per capita improve the food security by 0.03 % and 0.003 % respectively and if population increase pushes down the food security by 4.34 % for every unit increase. Climate variables like rainfall, temperature and cereal imports doesn't drive the food security in long run. The country specific effects are heterogeneous among South Asian countries as food security is being determined by climate factors in Afghanistan and Nepal and by non-climate factors in India. The study concluded that food insecurity can be reduced by improving GDP per capita, food production and by controlling population expansion. Since, the long run relationship is more significant than short run relationship it signifies the importance of long-term developmental policies in affirming food security condition of South Asia.

Keywords: climate change; food security; panel ARDL; trade

Introduction

The eradication of hunger, malnutrition and undernourishment, along with sufficient food access, is a persistent challenge faced by the global community. Accelerated world population growth has rendered countries off track from achieving sustainable development goals, including ending hunger and achieving food security (1). The global population is expected to reach 8.5 billion and the undernourished population is projected to decrease to 0.84 billion by 2030 (2). By the end of 2050, an increase of approximately 60 % in food production from the current level is essential to feed the growing population amid climate change (3). Climate change is the defining issue of the 21st century, with long-term shifts in weather patterns driven by both natural and human-induced causes (4).The compound effect of climate change on agriculture is witnessed in the form of harvest shrinkage, reduction in input use effectiveness and crop damage by pests and diseases. Declining yields prompt people to shift away from agriculture, leading to wildlife habitat and biodiversity loss. To achieve the SDGs, it is necessary to meet the demand shifts for agricultural products amidst an affluent population and the impacts of climate change on agriculture (5). Globally, agricultures' contribution is 4.3 % to GDP and employs 26.4 % of the total workforce. The extreme weather events of drought and flood trigger farmers' risks and threaten food security. Agricultural production patterns are already influenced by climate change (6) and climate variability is the primary reason for one-third of agricultural yield fluctuations (7).

Food security refers to the situation where all people, at all times, have physical and economic access to sufficient and nutritious food that meets their dietary needs and food preferences for an active and healthy life (8). The definition encompasses four dimensions of food security, namely food availability, food access, food utilisation and stability (9). Globally, 80 % of the population is at risk of hunger and resides in the South Asia, Southeast Asia and Sub-Saharan African regions. The highest percentage of people who cannot afford a nutritious diet are found in low-income countries (71.5 %), followed by lower-middle-income (52.6 %), upper-middle-income (21.5 %) and high-income (6.3 %). Rising commodity prices are pushing 30 million people under food insecure conditions and South Asia with highest prevalence of stunting (30.7 %) than the world average (22 %) (10). The rapid population expansion, depletion of natural resources, enduringly high rates of food security and climate change are the challenges faced by South Asian countries.

The average dietary energy supply of the chosen countries is depicted in Fig. 1. This shows that countries are circulating within the same radar regarding dietary supply. Climate change has enormous spillover effects and its impact

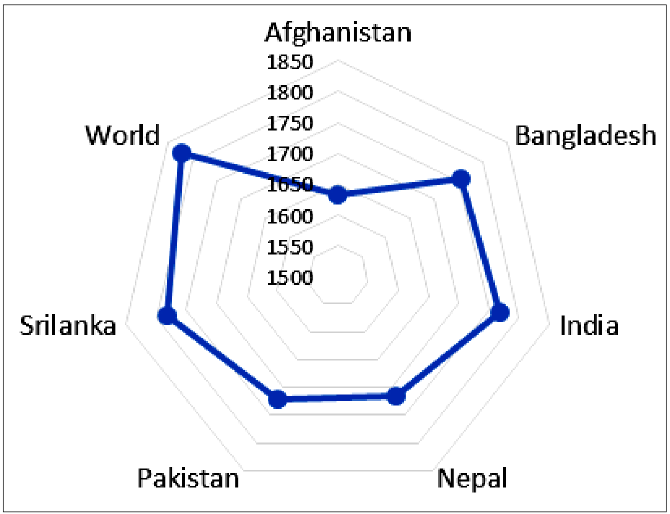

Fig. 1. Average dietary energy supply of South Asian countries.

on food security is to be concentrated on this study. The risk to world nations from climate change is shown in Fig. 2. The reliance on agriculture in South Asian countries is the highest, thus making the countries particularly prone to external factors. Considering this, the study aims to investigate the interconnections between climate change, food security and trade in selected South Asian economies from 2001 to 2022 using the panel Auto Regressive Distributed Lag (ARDL) model.

Global food security under climate change can be restored in 2050 by the adaptation of ecohydrological methods, sustainable practices, technological advances and innovations (11). The spatiotemporal food security challenges resulting from climate change suggest that socioeconomic status plays a predominant role and developing countries tend to rely on food imports during economic production shocks (12). The econometric analysis of food security level in 172 countries reveals that global food security is summed up as high-high aggregation and low-low aggregation with Western Europe, Northern America and Oceania as highly secure regions and Sub-Saharan African (SSA), South East Asia (SEA) and South Asia as least secure nations (13). The comprehensive study suggested that a transdisciplinary and collaborative approach is a prime requisite for addressing global food security, given the decreasing availability of natural resources, increasing food waste and global health challenges. For sustainable global food production, multidisciplinary food loss policies are the most necessary criterion (14).

The food security progress in India from 1990 to 2016 indicates that the performance is dismal due to low protein availability (15). Climate change has induced fluctuations in cereal productivity in South Asian countries and the formulated agricultural subsidies and SAFTA (South Asian Free Trade Agreement) agreements are not significantly affecting South Asias' food security, according to previous studies (16). In developing countries, an increase in undernourishment prevalence is decreasing the food trade openness by 0.9 %, which hinders agricultural trading and income generation opportunities (17). The surge in cereal production is decreasing undernourishment in South Asia by 0.84 %, despite the region having a substantial global hunger population (18). An examination of the triple dimensions of food security (Food availability, Food accessibility and utilisation) in association with climatic variables, such as rainfall, temperature and CO_2 emissions, in Sub-Saharan African regions reveals that rainfall and CO_2 emissions have a positive effect on the three dimensions in the long run. Still, temperature possesses detrimental effect (19).

The interplay of climate change, food security and diarrhoea prevalence in Tanzania highlights that climate change is exacerbating food security and health issues, underscoring the need for a comprehensive strategy to address these challenges (20). In Ethiopia, the long-term positive relationship between healthcare expenditure (HCE) and GDP has been elucidated, highlighting the governments' role in proceeding with efforts to augment HCE (21). The interaction among CO_2 emissions, nuclear energy consumption, urbanisation, industrial production and economic growth in different income group countries has proven that the effect varies across income groups (22). In the East African Community (EAC), food security is detrimentally impacted by temperature, but rainfall and the area under cereal crops favour food security (23). Climate change-induced productivity fluctuations in agriculture are likely to negatively affect food

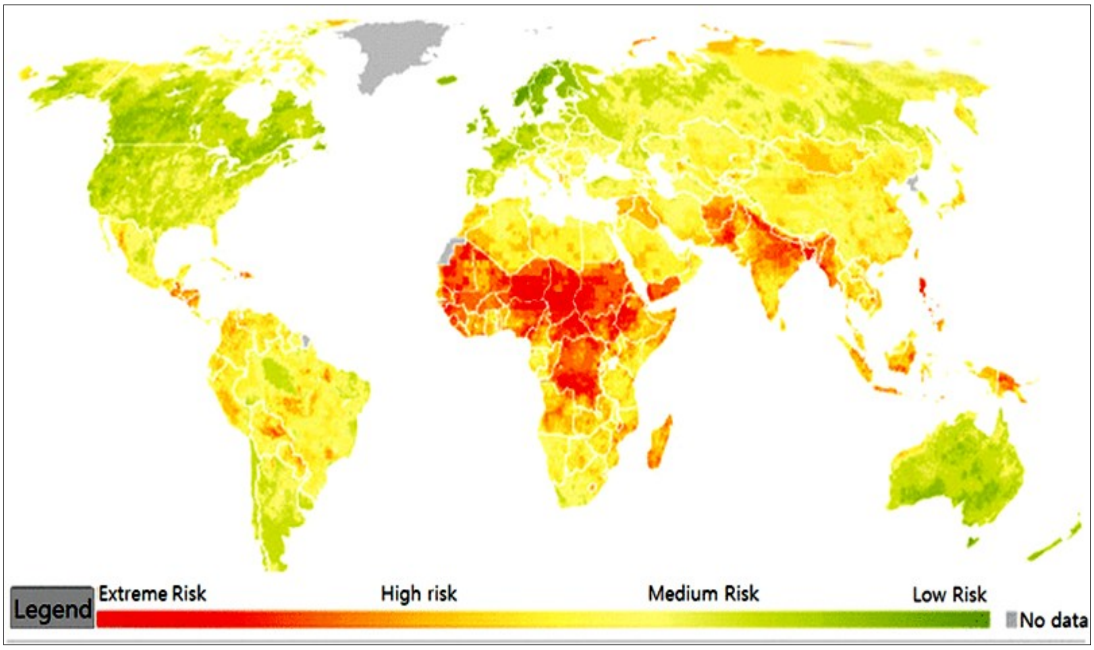

Fig. 2. Climate Risk map of world nations.

production and prices in South Asia (24). The climatic effect on food security in Northern and Eastern African regions indicates that food security is effectively affected by climate change (25). The comprehensive importance of the effectiveness of social protection programmed along with stabilised income and food production in achieving sustainable food security is essential in Sub-Saharan African countries (26). A comprehensive review of studies highlights the importance and methodological perspective necessary to achieve the proposed research objectives.

Materials and methods

Data description

The study includes selected countries from South Asia from 2001 to 2022. Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka are the countries. The prevalence of undernourishment is a dependent variable chosen as a proxy for food security. The independent climate variables were rainfall and temperature and the non-climate variables were cereal import dependency, food production index, land area under cereal cultivation, GDP per capita, inflation and population growth. The variables are briefly described in Table 1 and descriptive statistics in Table 2.

Table 1. Description of variables and data source

Variable	Description	Source
PRU	Prevalence of undernourishment (%)	FAO stat
CID	Cereals Import Dependency (%)	
FPI	Food Production Index (2014-2016=100)	World Development Indicators
LAN	Land under cereal production (hectares)	
GDP	GDP per capita (constant 2015 US$)	
INF	Inflation, consumer prices (annual %)	
POP	Population growth (annual %)	
RF	Annual Rainfall (millimetre)	NASA power
TEM	Temperature (°C)	

Table 2. Descriptive statistics

Variables	Mean	SD	Min	Max	Obs
PRU	15.42	7.51	3.8	46	126
FPI	89.51	17.98	59.09	130.31	126
LAN	21900000	35000000	748720	102000000	126
GDP	1379.28	1001.09	338.73	338.73	126
POP	1.62	1.11	0.18	7.54	126
INF	7.09	3.91	0.62	26.41	126
RF	1140.31	959.02	10.55	5268.16	126
TEM	36.33	9.84	16.23	57.52	126
CID	9.6	17.41	-26.8	43.9	126

FPI: Food Production Index, **LAN**: Land Area under Cereal cultivation, **GDP**: Gross Domestic Product per capita, **POP**: Population, **INF**: Inflation, **RF**: Rainfall, **TEM**: Temperature, **CID**: Cereal Import Dependency

Methodology

Using non-stationary variables at a level in empirical analysis brings spurious regression results. A cross-sectional dependence test is used to eliminate this problem and ensure the long-run relationships between variables. The test is performed before the panel-unit root tests and helps choose the appropriate ones. Because the time series observations are greater than the cross-sectional observations, the Breusch-Pagan LM test is applied here. The first-generation panel unit root tests are based on the assumption of cross-sectional independence among countries, while second-generation panel unit root tests are based on the assumption of cross-sectional independence among variables. The cross-sectional dependence on the error term will be evident in South Asian economies as countries are exposed to standard external shocks.

Cross-sectional dependency test

The Breusch and Pagan LM test may be used to test for cross-sectional dependency in panels with constant n and $T \rightarrow \infty$ (27). The null hypothesis is that the test statistics are asymptotically Chi-square with n (n-1)/2 degrees of freedom. However, this test is not relevant when n reaches infinity.

Considering the heterogeneous panel data model

$$y_{it} = x'_{it}\beta_i + \mu_{it} \qquad \text{(Eqn. 1)}$$

For I=1…, N; t = 1…., T

In this equation, i represents cross-sectional units, t represents time series observations, y_{it} is a dependent variable and x_{it} is an exogenous regressor with K×1 dimension and slope parameters βi that can vary across i. μ_{it} is cross-sectionally dependent but uncorrelated with x_{it}.

Assume Ut = (u_{1t}, …., u_{nt}) ′. The n×1 vectors U_1, U_2, …., U_T are supposed to be iid N (o, Σ_u) with time. Let σ_{ij} denote the (i, j) member of the n × n matrix Σ_u. If Σ_u is non-diagonal i.e $\sigma ij \neq 0$ for $i \neq j$, the error u_{it} (i = 1, …, n; t = 1, …, T) is cross-sectionally dependent. The null hypothesis for cross-sectional dependency can be defined as:

$$H_0: \sigma_{ij} = 0 \text{ for } i \neq j$$

Or equivalently

$$H_0: p_{ij} = 0 \text{ for } i \neq j \qquad \text{(Eqn. 2)}$$

p_{ij} is the error correlation coefficients with $p_{ij} = \frac{\sigma_{ij}}{\sqrt{\sigma_i^2 \ \sigma_j^2}}$ The alternative hypothesis states the existence of atleast one non -zero correlation coefficient p_{ij}, i.e. H_a: $p_{ij} \neq 0$ for some i≠j. The OLS estimator of y_{it} or x_{it} for each i, denoted by β_i is consistent. The residuals of OLS are defined by $\hat{\mu}_{it} = y_{it} - x'_{it}\beta_i$ and used to compute sample correlation as follows:

$$\widehat{p_{ij}} = \left(\sum_{t=1}^{T} \widehat{\mu_{it}}^2\right)^{-1/2}\left(\sum_{t=1}^{T} \widehat{\mu_{jt}}^2\right)^{-1/2}\sum_{t=1}^{T}\widehat{\mu_{it}}\,\widehat{\mu_{jt}} \qquad \text{(Eqn. 3)}$$

The LM test can be used to check for cross-sectional dependency in heterogeneous panels in the fixed n scenario and as $T \rightarrow \infty$ (27). Here, it is provided by

$$LM_{BP} = T\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\widehat{p_{ij}}^2$$

This is asymptotically distributed under the null as a X^2 with n (n-1)/ 2 degrees of freedom. The Breusch-Pagan LM test is not applicable for $N \rightarrow \infty$.

Panel unit root test

To determine the stationary of variables after establishing cross-sectional dependence, the study used the Pesaran Cross-Sectional Augmented Dickey-Fuller (CADF) test (28). The existence of cross-sectional dependency can be eliminated by augmenting the usual Dickey-Fuller regression with cross-sectional averages of lagged levels and first differences of individual series (28). The panel second-generation unit root test is effective in identifying cross-sectional dependency and interdependence among nations.

The Pesaran CADF equation is

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i \bar{y}_{t-1} + \varphi_i \Delta\bar{y}_t + \epsilon_{it} \quad \text{(Eqn. 4)}$$

Where the unit root test hypothesis will be tested based on the OLS results derived from Eq. (4) with t-ratio by ti (N, T)

The Pesaran CADF test is

$$CADF = t_i(N,T) = \frac{\Delta y_i m_w y_{i-1}}{\delta_j\,(y'_{i,-1}\,\bar{m}_w y_{i-1})^{1/2}}$$

Where,

$$\Delta y_i = (\Delta y_{i,1}, \Delta y_{i,2}, \ldots\ldots\ldots\ldots, \Delta y_{i,T} \quad \text{(Eqn. 5)}$$

$$\Delta y_{i,-1} = (y_{i,0}, y_{i,1} \ldots\ldots\ldots\ldots, y_{i,T-1}), \tau\, T = (1,1, \ldots\ldots, 1)' \quad \text{(Eqn. 6)}$$

$$M_W = I_T - \bar{w}(\bar{w}, \bar{w}\bar{w})^{-1}\bar{w}'\bar{w} = (\tau, \Delta_\sigma, \bar{y}_{T-1}) \quad \text{(Eqn. 7)}$$

$$\sigma_i^2 = \frac{\Delta y_i\, 'm_{i,w}\Delta y_i}{T-4} \quad m_{i,w} = I_T - (G_i\,(G_i'G_i)^{-1}G_i' \text{ and } G_i = (\bar{w}, y_{i-1}) \quad \text{(Eqn. 8)}$$

Panel autoregressive distributed lag model (P-ARDL)

To analyse the long-term association between variables, we used a panel autoregressive distributed lag model with three estimators: Mean Group (MG), Pooled Mean Group (PMG) and Dynamic Fixed Effect (DFE). The ARDL (p, q) is technique for dynamic heterogeneous panel regression, where 'p' represents the lags of the dependent variable and 'q' represents the lags of the independent variables (29). For time periods t = 1, 2..., 21 and groups i = 1, 2..., 10, the panel model may be expressed as follows.

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta_{ij} X_{i,t-j} + \mu_i + \epsilon_{it} \quad \text{(Eqn. 9)}$$

Where y is the PRU_{it} dependent variable, X_{it} is the k × 1 vector of explanatory variables, Ni denotes the group specific effects, δ_{it} are the k × 1 coefficient vectors; λ_{ij} are scalar coefficients of the lagged dependent variables.

If the variables in Eq. (5) are I (1) and cointegrated, the error term used to be an I (0) process for all i. A key aspect of cointegrated variables is their sensitivity to any divergence from long-run equilibrium. This feature suggests an error correction model where deviations from equilibrium affect the short-run dynamics of system variables. Eq. (5) is commonly parameterized as an error correction equation.

$$\Delta y_{it} = \emptyset_i(y_{i,t-1} - \theta'_i X_{it}) + \sum_{j=1}^{p-1} \lambda_{ij} * y_{i,t-1} + \sum_{j=0}^{q-1} \delta'_{ij} * \Delta X_{i,t-j} + \mu_i + \epsilon_{it} \quad \text{.....(Eqn.10)}$$

Where,

$\emptyset_i = -(1 - \sum_{j=1}^{p} \lambda_{ij}), \theta_i = \frac{\sum_{j=0}^{q} \delta_{ij}}{1-\sum_k \lambda_{ij}}, \lambda_{ij} * = -\sum_{m=j+1}^{p} \lambda_{im}\ j =$ 1,2……, p-1 and

$\delta_{ij} * = \sum_{m=j+1}^{q} \delta_{im}$ j =1, 2,………..,q-1

The parameter øi represents the error-correcting speed of adjustment. If øi = 0, there will be no evidence for a long-term association. Under the previous assumption that the variables would revert to long-run equilibrium, this value should be strongly negative. The vector θi is crucial in determining the long-term connection between variables. PMG estimator incorporates average and pooling residuals (29). This test considers the intercept, short run coefficients and error variances across groups, similar to MG estimators. This approach, similar to FE estimators, assumes identical long-run coefficients across all groups.

The error correction coefficients øi, of MG estimate is

$$\hat{\emptyset} = N^{-1}\sum_{i=1}^{N} \hat{\emptyset}_i \quad \text{(Eqn.11)}$$

With the variance

$$\hat{\Delta}_{\emptyset} = \frac{1}{N(N-1)} \sum_{i=1}^{N} (\hat{\emptyset}_i - \hat{\emptyset})^2 \quad \text{(Eqn.12)}$$

Results and Discussions

Cross-sectional dependency and panel unit root test

Traditional panel unit root tests fail to account for cross-sectional dependency, potentially leading to inaccurate interpretations of the stationary features in panel data. To address this issue, this study used the Breusch and Pagan LM cross-sectional dependency test to ensure cross-sectional independence in South Asian nations (27). Table 3 presents the results of the cross-sectional dependence test, which indicates the rejection of the null hypothesis of no cross-sectional dependency between the variables at the significance level. This suggests that South Asian countries have a high level of dependence, affirming the existence of dependency among variables. The Pesaran Cross-Sectional Augmented Dickey-Fuller (PCADF) panel unit root test, which is the second generation of the panel unit root test, was applied to verify the stationarity of the variables. Table 4 shows that the PCADF results, which demonstrate that the variables attained stationarity at I (0) and I (1) i.e. two distinct orders of integration. Similar to time series analysis, the autoregressive distributed lag model is used to examine the long-term association between variables when the orders of integration differ. The Panel ARDL can be used even if the variables have distinct integration orders, such as I(0) and I(1), or a combination of both (29). Three distinct panel autoregressive distributed lag models, including the Pooled Mean Group (PMG) estimator, the Mean Group (MG) estimator and the dynamic fixed-effect model (DFE), were employed to examine the long- and short -term dynamics among the variables. The bivariate correlation analysis is listed in Table 5.

Table 3. Breusch-Pagan LM test for cross section dependency

Test	Statistic	Prob
Breusch-Pagan LM	61.98***	0.000

*** indicates significance at 1 % level

Table 4. Pesarans' cross-sectional augmented Dickey Fuller (CADF) test result

Variables	Level		First difference	
	T- Bar	P value	T -Bar	P value
PRU	-1.407	0.813	-2.566**	0.021
FPI	-3.670***	0.000	-2.324***	0.000
LAN	-2.368 **	0.024	-5.007 ***	0.000
GDP	-0.197	1.000	-2.210***	0.000
INF	-3.135 ***	0.000	-4.985***	0.000
POP	-0.366	1.000	-2.411 **	0.017
RF	-3.193 ***	0.000	-5.832***	0.000
TEM	-3.472***	0.000	-4.881***	0.000
CID	-0.158	0.471	-2.327 ***	0.000

FPI: Food production index, **LAN:** Land area under cereal cultivation, **GDP:** Gross domestic product per capita, **POP:** Population, **INF:** Inflation, **RF:** Rainfall, **TEM:** Temperature, **CID:** Cereal import dependency, *** and ** indicates 10% and 5% level of significance

Table 5. Correlation analysis

Variables	PRU	FPI	LAN	GDP	POP	INF	RF	TEM	CID
PRU	1.0000								
FPI	-0.3943	1.0000							
LAN	-0.0139	0.0060	1.0000						
GDP	-0.5881	0.2935	-0.0513	1.0000					
POP	0.7128	-0.1238	-0.1090	-0.4635	1.0000				
INF	0.0888	-0.1725	-0.0950	-0.0311	0.0280	1.0000			
RF	-0.5009	0.2136	-0.0787	0.2760	-0.496	-0.1061	1.0000		
TEM	0.6414	-0.0195	0.1266	-0.6957	0.6663	0.0347	-0.6590	1.0000	
CID	0.1368	0.0685	-0.4813	0.1781	0.1388	-0.0077	0.1796	-0.2619	1.0000

FPI: Food production index, **LAN:** Land area under cereal cultivation, **GDP:** Gross domestic product per capita**, POP:** Population, **INF:** Inflation, **RF:** Rainfall, **TEM:** Temperature, **CID:** Cereal import dependency

Panel ARDL estimation

The long- and short-run coefficients of the pooled mean group, mean group and dynamic fixed-effect estimators are presented in Table 6. The PMG allows for the homogeneity of long-run results across cross-sections, whereas the short-run estimates and error variance differ across cross-sectional groups. The PMG estimates are robust according to the Hausman test and are interpreted for policy implications and statistically significant conclusions. In the long term, the land area under cereal cultivation, GDP per capita and population growth exhibits significant impact on food security. The highest magnitude of influence is exerted by population growth, which states that an increasing population pushes more people into food insecure conditions, as traditional food resources are insufficient to sustain food security (30, 31). The burgeoning population places additional pressure on land under cultivation, thus limiting agricultural production (32). Food security tends to improve with an increase in land area under cereal cultivation, GDP per capita and a decrease in the inflation rate. Cereal production and yield increases can decrease the extent of undernourishment, as cereals play a major role in South Asian countries, which ensures food security and contributes to the nations' GDP (18, 16). The significance of the effect of land area under cereal cultivation on food security is consistent with previous studies, which indicate that hat food security largely is governed by cereal crops (25). Rainfall and the effect of temperature on food security in South Asia are mitigated by investments in climate-resilient technologies (33). In the short run, only GDP per capita exhibits the significant influence on food security.

Pooled mean group estimation: Individual country effects

The heterogeneity of parameters allowed in the short run enables us regional estimations. The ECT (Error Correction Term) represents the speed of adjustment and connects between long- and short-run dynamics. The country-specific short-run coefficients are listed in Table 7. Afghanistan, India, Nepal and Sri Lanka converge toward an equilibrium situation, with long-run impacts resulting in levels of 23 %, 17 % and 38 %. Despite the increase in food production, the undernourishment situation persists in Afghanistan and Nepal; however, the behaviour is different in India, as the rise in food production suppresses the undernourishment status. The prevalence of undernourishment

Table 6. Panel ARDL results

Variables	Mean group		Pooled mean group		Dynamic fixed effects	
	Long run	Short run	Long run	Short run	Long run	Short run
FPI	2.6255**(1.3895)	-0.0081(0.0967)	-0.1305(0.3535)	-0.0083(0.0663)	0.6072**(0.3171)	-0.0236*(0.0183)
LAN	-0.0000(0.0000)	0.0000**(0.0001)	-0.0341**(0.0017)	0.0343(1.1206)	0.0000*(0.0000)	0.0021*(0.0002)
GDP	-0.2085*(0.1146)	-0.0217*(0.0145)	-0.0035***(0.0005)	-0.0157**(0.0063)	0.0172**(0.0072)	-0.0032*(0.0018)
POP	-10.7784(15.0766)	1.7311(2.0659)	4.3407***(0.6317)	-1.5733(1.5425)	-3.1596(3.6106)	0.1178(0.1544)
INF	-0.9926(0.7950)	-0.0150(0.0676)	-0.1806***(0.0589)	-0.0341(0.0276)	-0.8838*(0.5155)	0.0347*(0.0262)
RF	-0.0258(0.0226)	-0.0004(0.0010)	0.0006(0.0007)	0.0008(0.0011)	-0.0059*(0.0044)	0.0003*(0.0002)
TEM	-3.4387*(1.8956)	-0.0055(0.0660)	0.1638(0.1307)	0.0110(0.0260)	-1.6017*(1.1523)	0.0690*(0.0459)
CID	0.0983(0.8331)	0.0143(0.1477)	0.0538(0.5528)	0.0046(0.0787)	0.3713(0.3400)	-0.0252(0.0340)
Hausman test		MG, PMG 55.13(0.000)			PMG, DFE 0.23(1.000)	

***, **, * indicates significance level at 1%, 5% and 10 %. **( )** parenthesis shows the standard errors, **( )** indicates p value of Hausman test. **FPI:** Food production index, **LAN:** Land area under cereal cultivation, **GDP:** Gross domestic product per capita, **POP:** Population, **INF:** Inflation, **RF:** Rainfall, **TEM:** Temperature, **CID:** Cereal import dependency

Table 7. Pooled mean group: Country specific short run estimates

Variables/ country	Afghanistan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
ECT	-0.2304***(0.0299)	0.0782(0.0756)	-0.1785**(0.0840)	-0.2434***(0.0389)	0.2328*(0.1485)	-0.3852***(0.0972)
FPI	0.2071***(0.0468)	0.1051(0.0882)	-0.2636***(0.0679)	0.0959***(0.0272)	-0.0003(0.0473)	-0.0021(0.0257)
LAN	-0.0293(9.008)	-0.0878*(0.0079)	0.0504***(0.0000)	0.0005***(0.0000)	-0.0866(0.0000)	0.0106(0.0161)
GDP	-0.0301***(0.0062)	-0.0135*(0.0082)	0.0025(0.0043)	-0.0182***(0.0036)	-0.0353***(0.0094)	0.0001(0.0014)
POP	-0.3785***(0.1255)	1.9548*(1.5057)	-8.0803*(4.629)	-3.6648***(0.5706)	1.6454(1.4631)	-0.9167(0.8079)
INF	-0.0327(0.0379)	-0.0508(0.0578)	-0.1553*(0.1160)	0.0248(0.0202)	-0.02321(0.0598)	0.0323*(0.0205)
RF	0.0063***(0.0018)	0.0000(0.0001)	0.0005(0.0006)	-0.0003**(0.0001)	0.0016*(0.0009)	0.0001(0.0002)
TEM	0.1141**(0.0476)	-0.0225(0.0519)	-0.0703(0.0940)	0.0349*(0.0249)	0.0307(0.1238)	-0.2050(0.0517)
CID	0.0329(0.0589)	-0.1937**(0.0970)	-0.2618***(0.0892)	0.2498***(0.0569)	0.1279*(0.0749)	0.0169(0.0279)
Constant	1.7969(2.1046)	-3.3521(3.9249)	61.9436***(9.2493)	4.0279**(2.1268)	11.2873*(8.1109)	6.4722**(3.0907)

*, **, *** indicate 10 %, 5 % and 1 % significant levels, respectively. Standard errors are given in parentheses. **FPI:** Food production index, **LAN:** Land area under cereal cultivation, **GDP:** Gross domestic product per capita, **POP:** Population, **INF:** Inflation, **RF:** Rainfall, **TEM:** Temperature, **CID:** Cereal import dependency

has decreased to 14 % from 27 % in India due to positive growth in food production (34). Land use patterns toward cereals can exacerbate food insecurity in Bangladesh, as the cultivation of rice and wheat is shifting toward self-sufficient production (35). The diversified consumer basket in India, Afghanistan and Nepal proves that cereal cultivation is insufficient to ensure food security (36). Higher GDP levels are associated with higher food security (37). Food affordability is increasing in Afghanistan, Sri Lanka, Nepal and Pakistan, with rising GDP per capita. Consequently, population growth does not significantly impact food security enhancement in Afghanistan, India and Nepal. However, in Bangladesh, the food insecure situation persists under population expansion (38). South Asia serves as a hotspot for food security due to its population increase. Climate variable rainfall affects food security indirectly in Afghanistan, Nepal and Pakistan. Rainfall variation matters in ensuring food security because it determines the per capita food availability (39). Temperature affects food security in Afghanistan and Nepal. An increase in cereal imports ensures that people in Bangladesh and India are protected from insecure food conditions. In Nepal and Pakistan, food insecurity prevails despite an increase in cereal imports because of internal conflicts.

Conclusion

The research study aims to explore the driving factors of food security South Asian countries. To examine the factors, a panel ARDL model based on Mean group, Dynamic Fixed Effects and pooled mean group estimation is accomplished, along with pre-estimation tests of panel unit root and cross-sectional dependency. The PMG estimator is chosen as the appropriate model based on the Hausman test. This model gives the short and long run relationship along with country specific estimates. The results showed that food security is influenced not only by climatic effects but also by macroeconomic and trade factors of the country. Food security is influenced mostly in the long run, which highlights the effectiveness of long-term developmental policies in protecting the food security of South Asian countries.

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Authors' contributions

SE has conducted the data collection and analysis, as well as drafted the original manuscript. KMS contributed to the conceptualisation, methodology, supervision, validation and editing of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Greibe Andersen J, Kallestrup P, Karekezi C, Yonga G, Kraef C. Climate change and health risks in Mukuru informal settlement in Nairobi, Kenya-knowledge, attitudes and practices among residents. BMC Public Health. 2023;23(1):393. https://doi.org/10.1186/s12889-023-15281y
2. UNICEF. The State of Food Security and Nutrition in the World 2024. Rome (Italy): FAO; 2024.
3. WHO. The state of food security and nutrition in the world 2022: repurposing food and agricultural policies to make healthy diets more affordable [Internet]. Rome (Italy): Food & Agriculture Organisation; 2022 [cited 2025 Jul 23]. Available from: https://www.fao.org/publications/fao-flagship-publications/the-state-of-food-security-and-nutrition-in-the-world/en
4. World Meteorological Organization (WMO). State of the global climate 2022 [Internet]. Geneva (Switzerland): United Nations; 2023 [cited 2025 Jul 23]. Available from: https://wmo.int/publication-series/state-of-global-climate-2022.
5. Nelson MC, Ingram SE, Dugmore AJ, Streeter R, Peeples MA, McGovern TH, et al. Climate challenges, vulnerabilities and food security. Proc Natl Acad Sci USA. 2016;113(2):298–303. https://doi.org/10.1073/pnas.1506494113
6. Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, et al. Food security: the challenge of feeding 9 billion people. Science. 2010;327(5967):812–8. https://doi.org/10.1126/science.1185383
7. Howden SM, Soussana JF, Tubiello FN, Chhetri N, Dunlop M, Meinke H. Adapting agriculture to climate change. Proc Natl Acad Sci USA. 2007;104(50):19691–6. https://doi.org/10.1073/pnas.0701890104
8. Shaw DJ. World Food Summit, 1996. In: World food security: a history since. New York: Springer; 2007. https://doi.org/10.1057/9780230589780_35

9. Manikas I, Ali BM, Sundarakani B. A systematic literature review of indicators measuring food security. Agric Food Secur. 2023;12(1):10. https://doi.org/10.186/s40066-023-00415-7
10. Mannar V, Micha R, Allemandi L, Afshin A, Baker P, Battersby J, et al. 2020 Global nutrition report: action on equity to end malnutrition [Internet]. Bristol (UK): Development Initiatives Poverty Research; 2020 [cited 2025 Jul 23]. Available from: https://repository.mdx.ac.uk/item/89022
11. Lal R. Food security in a changing climate. Ecohydrol Hydrobiol. 2013;13(1):8–21. https://doi.org/10.1016/j.ecohyd.2013.03.006
12. Schmidhuber J, Tubiello FN. Global food security under climate change. Proc Natl Acad Sci USA. 2007;104(50):19703–8. https://doi.org/10.1073/pnas.0701976104
13. Cai J, Ma E, Lin J, Liao L, Han Y. Exploring global food security pattern from the perspective of spatio-temporal evolution. J Geogr Sci. 2020;30:179–96. https://doi.org/10.1007/s11442-020-1722-y
14. Wahbeh S, Anastasiadis F, Sundarakani B, Manikas I. Exploration of food security challenges towards more sustainable food production: A systematic literature review of the major drivers and policies. Foods. 2022;11(23):3804. https://doi.org/10.3390/foods11233804
15. Upadhyay RP, Palanivel C. Challenges in achieving food security in India. Iran J Public Health. 2011;40(4):31.
16. Yan S, Alvi S. Food security in South Asia under climate change and economic policies. Int J Clim Chang Strateg Manag. 2022;14(3):237-51. https://doi.org/10.1108/IJCCSM-10-2021-0113
17. Mary S. Hungry for free trade? Food trade and extreme hunger in developing countries. Food Secur. 2019;11(2):461–77. https://doi.org/10.1007/s12571-019-00908-z
18. Mughal M, Fontan Sers C. Cereal production, undernourishment and food insecurity in South Asia. Rev Dev Econ. 2020;24(2):524–45. https://doi.org/10.1111/rode.12659
19. Affoh R, Zheng H, Dangui K, Dissani BM. The impact of climate variability and change on food security in sub-Saharan Africa: perspective from panel data analysis. Sustainability. 2022;14(2):759. https://doi.org/10.3390/su14020759
20. Kitole FA, Mbukwa JN, Tibamanya FY, Sesabo JK. Climate change, food security and diarrhoea prevalence nexus in Tanzania. Humanit Soc Sci Commun. 2024;11(1):1–3. https://doi.org/10.1057/s41599-024-02875-z
21. Abegaz KH, Mohammed AA. Healthcare expenditure and GDP in Ethiopia from 1995 to 2014: a time-series analysis. Agric Food Secur. 2018;7:1–7. https://doi.org/10.1186/s40066-018-0199-8
22. Anwar A, Sarwar S, Amin W, Arshed N. Agricultural practices and quality of environment: evidence for a global perspective. Environ Sci Pollut Res. 2019;26:15617–30. https://doi.org/10.1007/s11356-019-04957-x
23. Mahrous W. Climate change and food security in the EAC region: a panel data analysis. Rev Econ Pol Sci. 2019;4(4):270–84. https://doi.org/10.1108/REPS-12-2018-0039
24. Bandara JS, Cai Y. The impact of climate change on food crop productivity, food prices and food security in South Asia. Econ Anal Policy. 2014;44(4):451–65. https://doi.org/10.1016/j.eap.2014.09.005
25. Fusco G. Climate change and food security in the northern and eastern African Regions: a panel data analysis. Sustain. 2022;14(19):12664. https://doi.org/10.3390/su141912664
26. Devereux S. Social protection for enhanced food security in sub-Saharan Africa. Food Policy. 2016;60:52–62. https://doi.org/10.1016/j.foodpol.2015.03.009
27. Breusch TS, Pagan AR. The Lagrange multiplier test and its applications to model specification in econometrics. Rev Econ Stud. 1980;47(1):239–53. https://doi.org/10.2307/2297111
28. Pesaran MH. A simple panel unit root test in the presence of cross-section dependence. J Appl Econom. 2007;22(2):265–312. https://doi.org/10.1002/jae.951
29. Pesaran MH, Shin Y, Smith RP. Pooled mean group estimation of dynamic heterogeneous panels. J Am Stat Assoc. 1999;94(446):621–34. https://doi.org/10.1080/01621459.1999.10474156
30. Molotoks A, Smith P, Dawson TP. Impacts of land use, population and climate change on global food security. Food Energy Secur. 2021;10(1):e261. https://doi.org/10.1002/fes3.261
31. Schmitz A, Kennedy PL. Food security: Starvation in the midst of plenty. In: Food security in an uncertain world: An international perspective. Bingley (UK): Emerald Group Publishing Limited; 2015. p. 1–13. https://doi.org/10.1108/S1574-871520150000015001
32. Gunaratne MS, Firdaus R, Rathnasooriya SI. Climate change and food security in Sri Lanka: Towards food sovereignty. Humanit Soc Sci Commun. 2021;8(1). https://doi.org/10.1057/s41599-021-00917-4
33. Rehman A, Batool Z, Ma H, Alvarado R, Oláh J. Climate change and food security in South Asia: the importance of renewable energy and agricultural credit. Humanit Soc Sci Commun. 2024;11(1). https://doi.org/10.1057/s41599-024-02847-3
34. Sharma A, Monlai S, Shi Z, Manpoong C, Raghavan M, Linggi BW, et al. Current status of food security in India. Indian J Pure Appl Biosci. 2020;8(1):293–302. https://doi.org/10.18782/2582-2845.7980
35. Timsina J, Wolf J, Guilpart N, Van Bussel LG, Grassini P, Van Wart J, et al. Can Bangladesh produce enough cereals to meet future demand?. Agric Syst. 2018;163:36–44. https://doi.org/10.1016/j.agsy.2016.11.003
36. Reddy AA. Food security indicators in India compared to similar countries. Curr Sci. 2016;632–40. https://doi.org/10.18520/cs/v111/i4/632-640
37. Swietlik K. Economic growth versus the issue of food security in selected regions and countries worldwide. Probl Agric Econ. 2018;3(356). https://doi.org/10.30858/zer/94481
38. Miladinov G. Impacts of population growth and economic development on food security in low-income and middle-income countries. Front Hum Dyn. 2023;5:1121662. https://doi.org/10.3389/fhumd.2023.1121662
39. Kinda SR, Badolo F. Does rainfall variability matter for food security in developing countries? Cogent Econ Finance. 2019;7(1):1640098. https://doi.org/10.1080/23322039.2019.1640098

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