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Food Security in SAARC and Climate Change

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ABSTRACT

The paper tries to examine the impact of climate change indicators (e.g., CO_2 emissions, N_2O and CH_4 emissions from land use, rice and cereals, temperature change and food inflation rate) on the variability of food supply in kilo calorie per capita per day in SAARC during 2000-2021 by applying panel regression and panel cointegration and vector error correction methods. The paper found that there is significant impact of emissions from land use, rice and cereals and emissions from CO_2 respectively according to fixed effects model. The Pedroni, Kao and Johansen-Fisher panel cointegration among the variables assured long run association and there are significant short run causalities from food price inflation rate and from temperature change to variability of food supply respectively. The long run causality implies that the incremental variability of food supply is significantly positively related with incremental emissions from land use and incremental CO_2 while significantly negatively related with emission from rice and cereals. It was found from VECM that the incremental variability of food supplyin kilo calorie per capita per day showed significant negative relation with incremental temperature change and significant positive relation with incremental food price inflation rate respectively.

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Introduction

SAARC comprises 21% of world population,3% of land area,19% forest area and 5.21% of world GDP in 2021.The temperature change in SAARC varies from 1.5°C to 4.5°C under the general circulation model where the average best temperature is 2.5°C(Wikipedia). The hunger Index of South Asia is 27.4 which is the highest in the world (Global Hunger Index 2023). The poverty rate is 83.20% in 2019 under US$ 5.50 per capita per day consumption expenditure (https://www.macrotrends.net/countries/SAS/south-asia/poverty-rate). In South Asia, total number of severely food unsecured people showed 243.5 million in 2014-2016 which stipulated to 368.7 million in 2019-2021 where the male people were 79.9 million which rose to 115.8 million during the same period as against 92.4 million female people in 2014-16 and 151.7 million in 2019-2021 respectively. On the other hand, the number of people of moderately food unsecured was 510.7 million in 2014 which increased to 810.6 million in 2021in which male was accounted for 166.8 million as against female 189.4 million in 2014 which catapulted to 256.1 million in male and 303.4 million in female in 2021.The undernourished people increased from 272.70 million in 2000 to 315.80 million in 2022.The stunted under five children was accounted as 89.60 million in 2000 which declined to 53.70 million in 2021. At the same time the variability of food supply in kilo calorie per capita per day has dwindled from 43.00 to 11.00(FAO).

Therefore, the study over the food security in SAARC is highly significant in context of nexus between the food supply variability with the indicators of climate change viz CO_2 emission, N_2O and CH_4 emissions from land use and crops cultivated as well as temperature changes which causes the natural disasters.

Some Important Researches

Climate change hinders human development and livelihood in vulnerable groups in SAARC through natural calamities like temperature rise, sea level rise, water availability, drought, flood, which also have great impact on food security including malnutrition and hunger [1].

South Asia is highly vulnerable to climate change where cyclone, drought, flood, disasters are regular events, and even SAARC faces the structural deficiencies like high population growth, high poverty, high food price inflation rate, and its average farm size is uneven, along with agricultural labour force and its total factor productivity have been declining. Moreover, SAARC has low food availability where food intake in kilo calorie per man per day is below the world average. Food security policies in SAARC such as a) paradigm shift from the policy of national level self-sufficiency to regional self-reliance in staple foods; b) sharing of food production technologies and experiences; c) seed banking and exchange of genetic material; d) revising the SAARC food banking mechanism and e) devising more effective strategies for dealing with disasters respectively were recommended by [2].

Studied the problem of food security in SAARC and opined in context of policy framework that food security is a major challenge in SAARC that must face to fight against a rapid rise in population, dwindling farm productivity and a lack of employment opportunities that turned livelihood insecure where each country has to strengthen domestic production systems, to enhance investments on agricultural infrastructure such as irrigation and power and on road networks to improve rural connectivity and to improve storage, to strengthen social security systems, to introduce well-targeted distribution schemes to improve food access for the poor, increase the incomes of the poor by increasing their asset endowment and create greater non-farm employment opportunities, to improve nutritional deficiency, to set up SAARC Food Bank, to improve supply of food chain management system, strengthen agricultural research and development introducing GIS ,remote sensing and biotechnology respectively [3].

The natural disasters and extreme events, melting glaciers in the Himalayas, sea level rise, rising temperatures of such impacts of climate change affected a loss of GDP of India by 2% and the loss of Bangladesh, Maldives, Nepal, Pakistan and Sri Lanka may even more where strong interconnections between water insecurity, food insecurity, climate change and regional integration are urgently needed. Pakistan is mostly affected on food insecurity by climate change. Ground water irrigation management and investment is the key to solve food insecurity in South Asia. ADB suggested five priority areas of planning such as [i] scaling up clean energy; [ii] sustainable transport and urban development; [iii] land use and forest for carbon sequestration; [iv] climate-resilient development; and [v] strengthening policies, governance and capacities [4].

Examined integrated assessment model (IAM) for food security under climate change in South Asia from 1991 to 2015 taking variables as cereal yields, labour force and capital stock, climatic variables, the GDD and precipitation and observed that the increase in precipitation has a positive impact in South Asia(0.410) [5].The paper also found that there is a long run association between the growing degree days which is negative (-1.68), and change in climate decreases food production, increases food prices, decreases food consumption, and thus affects the welfare. It is expected that global warming will vary from 1.3°C to 2.2°C by 2100 so that cereal yields will decrease by 40.42 and 35.49 percents in the mid of this century and in Bangladesh and Pakistan, cereal yields can be dwindled by11.83 percent and 29.24% in Sri Lanka. Cereals production in Bangladesh, Pakistan, Sri-Lanka and India, will decline up to 31.49,24.19, 25.74 and 6.4 percents respectively in the mid of this century by 2050 as compared to the base year 2011. The losses to GDP of the said countries will be 6.4, 24.19, 31.49, and 25.74 per cents respectively. Prices will catapult due to climate change and the highest increase is expected in Bangladesh and Pakistan which are expected to be 97.19 and 60.25 percents, while in India, the price rise may be 21.64 per cent in comparison to 47.33 per cent in Sri-Lanka. The loss to GDP is 6.4, 24.19, 31.49 and 25.74 percents in India, Pakistan, Bangladesh, and Sri-Lanka respectively. The losses of welfare were identified as 49.224 billion US $ in India, 32.161 billion in Pakistan, 28.198 billion in Bangladesh, and 5.661 billion in Sri-Lanka respectively due to disasters of climate change.

Tested the IPCC (2014) climate change assessment models which were represented by RCP2.6, RCP4.5, RCP6.0 and RCP8.5 for projection of food security for 2050 in SSARC during 1990-2016 where the simulation process was done with the help of JULES model and found that Bangladesh is the most food secured nation followed by Sri Lanka [6]. Maldives and Afghanistan were found to fall under least food secured SAARC nations under all four scenarios of climate change. Afghanistan and Maldives belong to middle rank. In this model, authors used four indicators namely (i) cereal import dependency ratio (number), (ii) productivity decrease (Mg- C/ha/ year), (iii) vulnerability of agriculture land (number) and (iv) variance of a consumer price index (number) where $Food\ Security\ Index = (Availability) + (Access) + (Utilisation) + (Stability)$.

The impacts of climate change on productivity changes on food security, welfare and GDP in South Asian countries under the General equilibrium (CGE) framework model revealed that there is a decrease in cereals production, increases the prices of cereals, decreases the local consumption and GDP and loss of welfare from 1990 to 2015 as the future effect of climate change through simulations [7].

The Purpose of the Paper

The paper tries to examine the impact of climate change on the security of food in SAARC during 2000-2021 by applying panel regression and panel cointegration analysis where food price inflation in per cent(x_1), temperature change in °C(x_2), emissions from land use in kt/hectare(x_3), emissions from rice and cereals in kt(x_4) of 6 SAARC countries (excluding Bhutan, Maldives), and CO_2 emission in kt(x_5) during 2000-2021 have been considered as indicators of climate change and the variability of food supply in kilo calorie per capita per day (y) has been taken as the indicator of food security.

Methodology & Sources of Data

The Paper Assumes:

y=variability of food supply in kilo calorie per capita per day as indicator of food security,
x_1= food price inflation in per cent,
x_2=temperature change in °C,
x_3=emissions from land use in kt/hectare,
x_4=emissions from rice and cereals in kt,
x_5=CO_2 emissions in kt as indicators of climate change.

Both fixed effects and random effects panel regression models were applied to relate the variables in SAARC using Hausman test model. CD statistic and LM statistic have been applied to test cross section dependence problem [8-11]. Johansen-Fisher model was used for panel cointegration and vector error correction [12,13].Wald test was done for checking short run causality[14]. Unit root test was done by applying several statistic[15-18].

The data on the variability of food supply in kilo calorie per capita per day(y), food price inflation in per cent(x_1), temperature change in °C(x_2), emissions from land use in kt/hectare(x_3), emissions from rice and cereals in kt(x_4) of 6 SAARC countries (excluding Bhutan, Maldives) during 2000-2021 have been taken from FAO and data on CO_2 emission in kt(x_5) for the same period have been collected from the World Bank.

Results and Observations from the Econometric Models

Panel Regression

The Pool panel least square regression analysis in SAARC during 2000-2021 to examine the impact of climate change on food security have been done taking variability of food supply in kilo calorie per capita per day(y) as the indicator of food security and temperature change in °C(x_2), emissions from land use in kt/hectare(x_3), emissions from rice and cereals in kt(x_4), CO_2 emissions in kt(x_5) and food price inflation in per cent(x_1) as the indicators of climate change.

The Estimated Equation is as Follows:

$$y=45.7398-0.2358x_1+0.0956x_2-2.5021x_3$$
$$(13.13)^*\ (-1.20)\ \ (0.081)\ \ (-5.407)^*$$
$$+0.00162x_4-0.00135x_5+u_i$$
$$(4.251)^*\ \ (-4.292)^*$$

Where R^2=0.22, F=7.179*, DW=0.528, AIC=8.24, SC=8.37, n=132, period=22, number of countries=6, *=significant at 5% level, t values are in the first brackets.

The pool panel regression states that emission from land use and CO_2 have negative impacts on variability of food supply in kilo calorie per capita per day significantly while the coefficient of food price inflation is negative and insignificant. There is no negative impact of temperature rise and emission from rice and cereals on the variability of food supply where the latter is significant and the former is insignificant at 5% level.

The cross section random effects panel regression under EGLS following Wansbeek and Kapteyn estimator of component variances method during 2000-2021 has been conducted and the estimated equation is given below.

$$Y=45.7398-0.2358x_1+0.0956x_2-2.5021x_3+0.00162x_4-0.00135x_5+u_i$$
(12.82)* (-1.17) (0.079) (-5.538)* (4.355)* (-4.397)*

Where R^2=0.22, F=7.179*, DW=0.528, n=132, period=22, number of countries=6, SD and Rho of cross section random =0, SD and Rho of Idiosyncratic random=14.22 and 1.00, *=significant at 5% level, t values are in the first brackets.

The estimated equation states that the outcome of random effects model is the similar with pool model.

The Hausman test of random effects model revealed that $\chi2(5)$ =11.187 whose probability is 0.0478 which is rejected for acceptance of random effects model at 5% significant level.
So, the alternative panel regression is suitable for applying fixed effects model which is given below.

$$Y=43.409-0.1585x_1-0.0432x_2-5.0809x_3+0.00346x_4-0.00249x_5+u_i$$
(1.88)* (-0.780) (-0.036) (-2.003)* (2.571)* (-3.20)*

Where R^2=0.287, F=4.884*, DW=0.590, AIC=8.22, SC=8.46, n=132, period=22, number of countries=6, *=significant at 5% level, t values are in the first brackets.

The fixed effects model is better than the random effects model since the estimated equation states that the impacts from emissions from land use, emissions from rice and cereals and emissions from CO_2 are significant on the variability of the supply of food while impact from food price inflation and temperature change is insignificant on the variability of the supply of food. The negative impacts of emission from land use, and CO_2, are significant but food price inflation and temperature change are insignificant although impacts are negative. The marginal positive impact of emission from rice and cereals on the variability of the supply of food is statistically significant. The negative impacts from food price inflation, temperature change and emission from land use on the variability of the supply of food are noticeable. In all three cases of estimation, the values of R^2 are very small along with DW.

The redundant fixed effects test in loglikelihood ratio is accepted for fixed effect model of panel regression where cross section F (5, 121) =2.2374 whose probability value is 0.0548 and the value of $\chi2(5)$ =11.672 whose probability=0.0396.

The residual cross section dependence test at H0=no cross-section dependence in residual is significant at 5% level in cases of Breusch-Pagan (1979) LM statistic=44.3058(15), Pesaran (2004) scaled LM statistic=5.3504(15), Bias-corrected scaled LM statistic (15) =5.207 whose probabilities are less than 1% while Pesaran (2015) CD statistic (15) =-0.468 whose probability is 0.6391 which is insignificant where 15=degree of freedom.

Panel Cointegration and Vector Error Correction Model
The level series of variability of food supply in kilo calorie per capita per day(y), emission from land use(x_3), emissions from rice and cereals (x_4), and emissions from CO_2(x_5) contain unit root so that they are non-stationary while the level series of food price inflation rate(x_1) and temperature change (x_2) contain no unit root, so that they are stationary. The results were found out by applying the tests of Levin, Lin & Chu statistic (2002), Im, Pesaran & Sin W statistic (2003), Dicky-Fuller (1981) ADF Fisher Chi-square statistic and Phillips-Perron (1988)- PP Fisher Chi square statistic respectively which are shown in Table 1.

Table 1: Unit Root Test

Series Y	Level Series			First Difference Series		Unit Root
Method	**Value of Statistic**	**prob**	**Unit Root**	**Value of Statistic**	**Probability**	
Levin, Lin & Chu	-0.445	0.328	yes	-9.52	0.00	no
Im, Pesaran and Shin W-stat	-0.388	0.34	yes	-7.58	0.00	no
ADF - Fisher Chi-square	11.61	0.47	yes	70.24	0.00	no
PP - Fisher Chi-square	12.72	0.38	yes	65.10	0.00	no
Series X_1	**Level Series**			**First Difference Series**		
Method	**Value of Statistic**	**Prob**	**Unit Root**	**Value of Statistic**	**Probability**	
Levin, Lin & Chu	-6.43	0.00	no	14.98	0.00	no
Im, Pesaran and Shin W-stat	-6.139	0.00	no	-14.36	0.00	no
ADF - Fisher Chi-square	56.54	0.00	no	139.92	0.00	no
PP - Fisher Chi-square	56.55	0.00	no	323.45	0.00	no
Series X_2	**Level Series**			**First Difference Series**		

Method	Value of Statistic	Prob	Unit root	Value of Statistic	Probability	
Levin, Lin & Chu	-7.275	0.00	no	-14.046	0.00	No
Im, Pesaran and Shin W-stat	-6.086	0.00	no	-12.148	0.00	no
ADF - Fisher Chi-square	55.697	0.00	no	115.37	0.00	no
PP - Fisher Chi-square	55.687	0.00	no	341.17	0.00	no
Series X_3	**Level Series**			**First Difference Series**		
Method	**Value of Statistic**	**prob**	**Unit Root**	**Value of Statistic**	**Probability**	
Levin, Lin & Chu	-0.046	0.48	yes	-6.907	0.00	no
Im, Pesaran and Shin W-stat	0.362	0.64	yes	-7.447	0.00	no
ADF - Fisher Chi-square	14.84	0.24	yes	74.35	0.00	no
PP - Fisher Chi-square	12.95	0.37	yes	188.50	0.00	no
Series X_4	**Level Series**		**Unit Root**	**First Difference Series**		**Unit Root**
Method	**Value of Statistic**	**Prob**		**Value of Statistic**	**Probability**	
Levin, Lin & Chu	-0.506	0.30	yes	-7.54	0.00	no
Im, Pesaran and Shin W-stat	-0.126	0.44	yes	-7.47	0.00	no
ADF - Fisher Chi-square	12.36	0.41	yes	71.15	0.00	no
PP - Fisher Chi-square	24.40	0.017	no	394.73	0.00	no
Series X_5	**Level Series**			**First Difference Series**		
Method	**Value of Statistic**	**prob**	**Unit Root**	**Value of Statistic**	**Probability**	
Levin, Lin & Chu	-0.379	0.35	yes	-5.065	0.00	no
Im, Pesaran and Shin W-stat	2.235	0.98	yes	-4.461	0.00	no
ADF - Fisher Chi-square	3.107	0.99	yes	43.311	0.00	no
PP - Fisher Chi-square	3.052	0.99	yes	48.462	0.00	no

Source: Calculated by Author, (n=115-126, Number of Countries = 6)

The panel cointegration was done by applying three models, namely, Panel Cointegration Test respectively for SAARC during 2000-2021 [19-21].

Pedroni's method was classified into [i] no intercept, [ii]deterministic intercept and trend. The method assumed that Ho=no cointegration as alternative hypothesis of common AR coefficients and individual AR coefficients under within dimension and between dimensions, examining Panel v-statistic, Panel rho-statistic, Panel ADF-statistic, group rho-statistic, group PP-statistic, group ADF-statistic, respectively. Kao panel cointegration test was done by ADF statistic under assumption of no intercept. All the results of test statistic have been arranged in the Table-2 below where all tests consist of total 23 test statistics among which 12 statistics showed that there is cointegration among the selected variables.

Table 2: Pedroni and Kao Methods of Panel Cointegration

Pedroni Residual Cointegration Test, y, x_1, x_2, x_3, x_4, x_5				
Alternative Hypothesis: common AR coefficients. (Within dimension), No trend	**Statistic**	**Probability**	**Weighted Statistic**	**Probability**
Panel v-Statistic	-2.597162	0.9953	-2.780843	0.9973
Panel rho-Statistic	0.070785	0.5282	-0.243949	0.4036
Panel PP-Statistic	-11.99557	0.0000	-10.29315	0.0000
Panel ADF-Statistic	-4.332693	0.0000	-3.409602	0.0003
Alternative Hypothesis: individual AR coefficients. (between-dimension)	Statistic	Probability		
Group rho-Statistic	0.434722	0.6681		
Group PP-Statistic	-15.67267	0.0000		
Group ADF-Statistic	-2.223055	0.0131		
Trend Assumption: Deterministic Intercept and Trend. Alternative Hypothesis: common AR coefficients. (Within dimension)	Statistic	Probability	Weighted statistic	Probability
Panel v-Statistic	-3.687319	0.9999	-3.851233	0.9999
Panel rho-Statistic	1.092109	0.8626	0.819292	0.7937
Panel PP-Statistic	-14.31879	0.0000	-12.34180	0.0000
Panel ADF-Statistic	-4.464179	0.0000	-3.663265	0.0001
Alternative Hypothesis: individual AR coefficients. (between-dimension)	Statistic	Probability		
Group rho-Statistic	1.579723	0.9429		
Group PP-Statistic	-16.94137	0.0000		
Group ADF-Statistic	-2.091591	0.0182		
Kao (Null Hypothesis: No cointegration				
Trend Assumption: No deterministic trend)	T Statistic	Probability		
ADF	-1.609395	0.0538		

Source: Author's own

The Johansen (1988)-Fisher (1954) Panel cointegration rank test with intercept and no trend assumptions during 2000-2021 on SAARC (6 nations) revealed that there are at least three cointegrating equations among the first difference series of variability of food supply in kilo calorie per capita per day(y), food price inflation rate(x_1) temperature change (x_2), emission from land use(x_3), emissions from rice and cereals (x_4), and emissions from CO_2(x_5) respectively in Trace test and Max-Eigen test. The results are given below in Table 3.

Table 3: Panel Cointegration Test

Hypothesised no of CEs	Fisher Stat from Trace Statistic	Probability[a]	Fisher Stat from Max-Eigen Statistic	Probability[a]
None	496.6	0.0000	207.5	0.0000
At most 1	143.4	0.0000	126.3	0.0000
At most 2	46.43	0.0000	35.28	0.0004
At most 3	21.56	0.0428	15.72	0.2043
At most 4	14.61	0.2634	12.27	0.4239
At most 5	10.86	0.5409	10.86	0.5409

a= Probabilities are computed using asymptotic Chi-square distribution (following MacKinnon-Haug-Michelis (1999) p-values), n=132, cross section=6
Source: Calculated by Author

The estimated panel vector error correction equations during 2003-2021 for SAARC have been presented in a tabular form in the Table 4 below. It was found that the incremental variability of food supply in kilo calorie per capita per day(dy_t) is significantly inversely related with incremental temperature change (dx_{2t-1}) and significant positive relation with incremental food price inflation rate(dx_{1t-1}) respectively. The incremental temperature change (dx_{2t}) has significant positive relation with incremental food price inflation rate(dx_{1t-1}). The incremental food price inflation rate(dx_{1t-1}) has significant positive relation with incremental emission from land use(dx_{3t}). The incremental emission from CO_2 (dx_{5t}) is significantly positive relation with the emissions from rice and cereals (dx_{4t-1}) respectively. The other results are insignificant. Three significant cointegrating equations have been also given in first three rows.

Table 4: The Vector Error Correction Model

Error Correction:	$d(y_t)$	$d(X_{1t})$	$d(X_{2t})$	$d(X_{3t})$	$d(X_{4t})$	$d(X_{5t})$
CointEq1	-0.282337	-0.279934	0.036054	-3.16E-05	10.63586	10.65198
	[-4.46198]*	[-6.58538]*	[5.06093]*	[-0.02671]	[1.21815]	[1.11822]
CointEq2	-0.645547	-1.845370	-0.114610	-0.014677	-43.99081	-51.94212
	[-2.26025]*	[-9.61781]*	[-3.56423]*	[-2.74778]*	[-1.11624]	[-1.20805]
CointEq3	4.845761	-1.000814	-1.642824	-0.068375	-79.34884	-69.45714
	[3.60256]*	[-1.10756]	[-10.8481]	[-2.71802]*	[-0.42752]	[-0.34301]
$d(y_{t-1})$	-0.102939	0.092226	-0.011096	0.000693	-16.37393	-16.20832
	[-1.15781]	[1.54411]	[-1.10855]	[0.41704]	[-1.33468]	[-1.21097]
$d(x_{1t-1})$	0.565480	0.252113	0.049097	0.009837	26.93621	26.63560
	[3.24932]*	[2.15642]*	[2.50581]*	[3.02234]*	[1.12171]	[1.01666]
$d(x_{2t-1})$	-3.749588	0.938425	0.161437	0.015727	-17.85138	-42.02758
	[-4.51374]*	[1.68158]	[1.72612]	[1.01229]	[-0.15574]	[-0.33607]
$d(x_{3t-1})$	4.207029	-5.088800	1.350853	-0.520898	-827.5858	-705.8531
	[1.00478]	[-1.80915]	[2.86561]*	[-6.65204]*	[-1.43243]	[-1.11982]
$d(x_{4t-1})$	-8.22E-05	-0.000645	0.000218	5.26E-05	0.399695	0.971269
	[-0.03001]	[-0.35052]	[0.70744]	[1.02656]	[1.05788]	[2.35622]*
$d(x_{5t-1})$	-0.000405	0.000855	-0.000246	-4.40E-05	-0.166799	-0.654682
	[-0.16730]	[0.52641]	[-0.90427]	[-0.97375]	[-0.49990]	[-1.79843]
R-squared	0.400758	0.752688	0.732942	0.401528	0.804379	0.802592
F-statistic	8.777664	39.94555	36.02169	8.805865	53.96903	53.36181
Akaike AIC	7.841106	7.045498	3.473036	-0.117125	17.69540	17.86961
Schwarz SC	8.057122	7.261513	3.689051	0.098890	17.91142	18.08563

Source-Calculated by author, *=significant at 5% level, n=114, d=first difference, t values are in the third brackets

In the vector error correction analysis, there are three unit-roots,8 imaginary roots which are less than one and one negative root respectively, so that VECM is nonstationary and stable. In Table 5, the values of roots are given below.

Table 5: The Values of Roots

Roots	Modulus
1.000000	1.000000
1.000000	1.000000
1.000000	1.000000
-0.339321 - 0.568545i	0.662104
-0.339321 + 0.568545i	0.662104
-0.490688 - 0.218136i	0.536990
-0.490688 + 0.218136i	0.536990
-0.503597	0.503597
-0.301194 - 0.401078i	0.501579
-0.301194 + 0.401078i	0.501579
-0.099221 - 0.435295i	0.446460
-0.099221 + 0.435295i	0.446460

Source: Calculated by Author

In Figure 1, all the roots have been depicted in the unit circle where three roots lie on the circle and the rest roots lie inside the unit circle which imply that the model is stable.

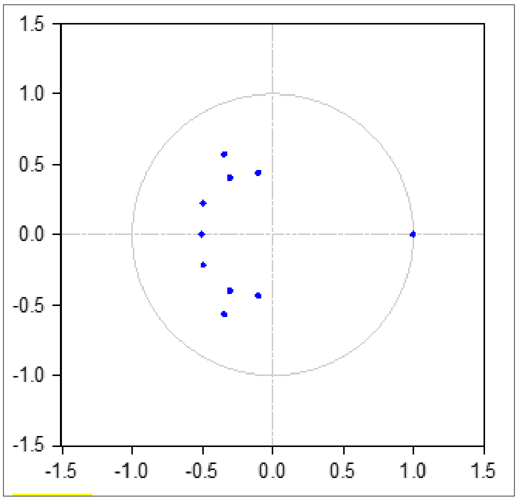


Figure 1: Unit Circle

Source: Plotted by Author

The impulse response functions revealed that the response of dx_4 to dy reached equilibrium after 1.5 years,3.5years and 4 years respectively, then converged to equilibrium. The responses of dx_2 and dx_1 to dy have the tendencies to move towards equilibrium. The response of dx_3 to dy reached equilibrium after 1.5 years, then tends to equilibrium. The response of dx_5 to dy reached equilibrium after 2 years,3 years, and 4 years respectively and then merged to equilibrium. Moreover, the responses of dx_1 to dx_2, dx_3, dx_4, dx_5 reached equilibrium several times, then converged to equilibrium. The responses of dx_2 to dx_4 and dx_5 reached equilibrium many times, then converged to equilibrium. The responses of dx_3 to dx_1, dx_4, dx_5 reached equilibrium and then moved towards equilibrium. The responses of dx_4 to dx_1, dx_2, dx_4 have been approaching towards equilibrium slowly. Lastly, the responses of dx_5 to dx_1, dx_2, and dx_5 gradually tended towards equilibrium. Therefore, the impulse responses of variability of food supply to the various indicators of climate change have great significance of economic impacts in SAARC. The impulse response functions are given below in Figure 2A and 2B below clearly.

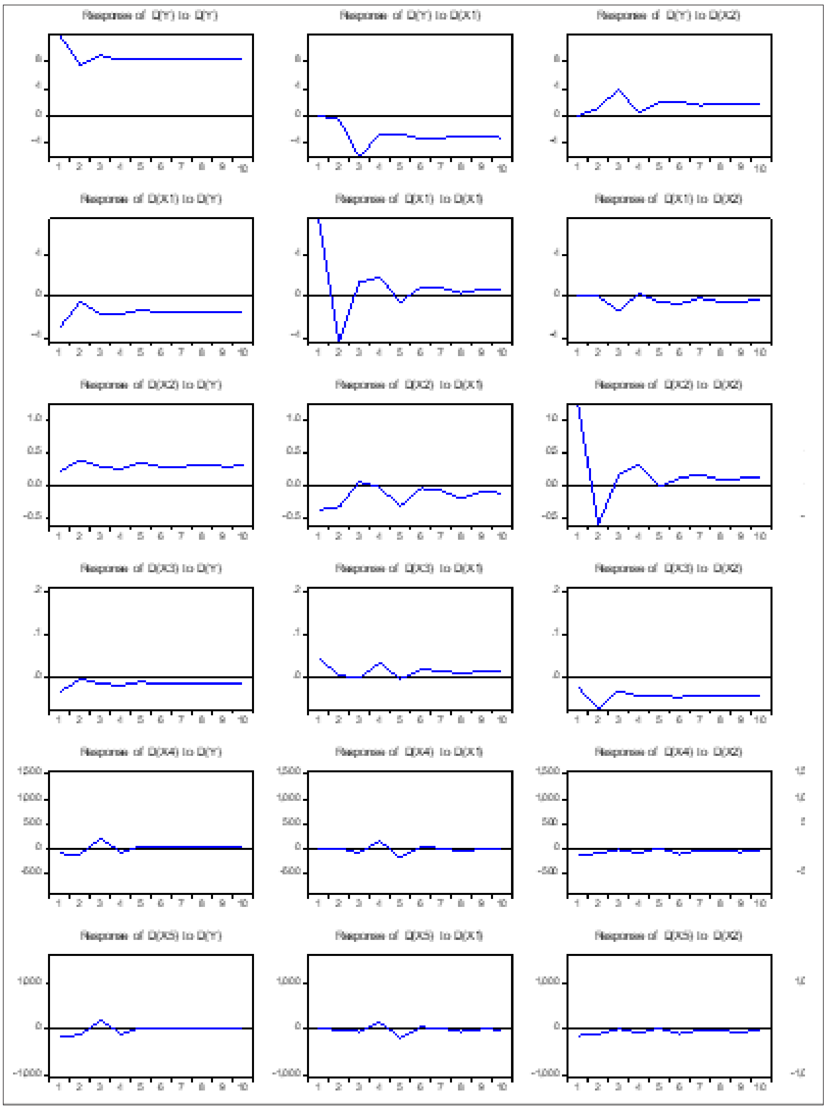


Figure 2A: Impulse Response Functions

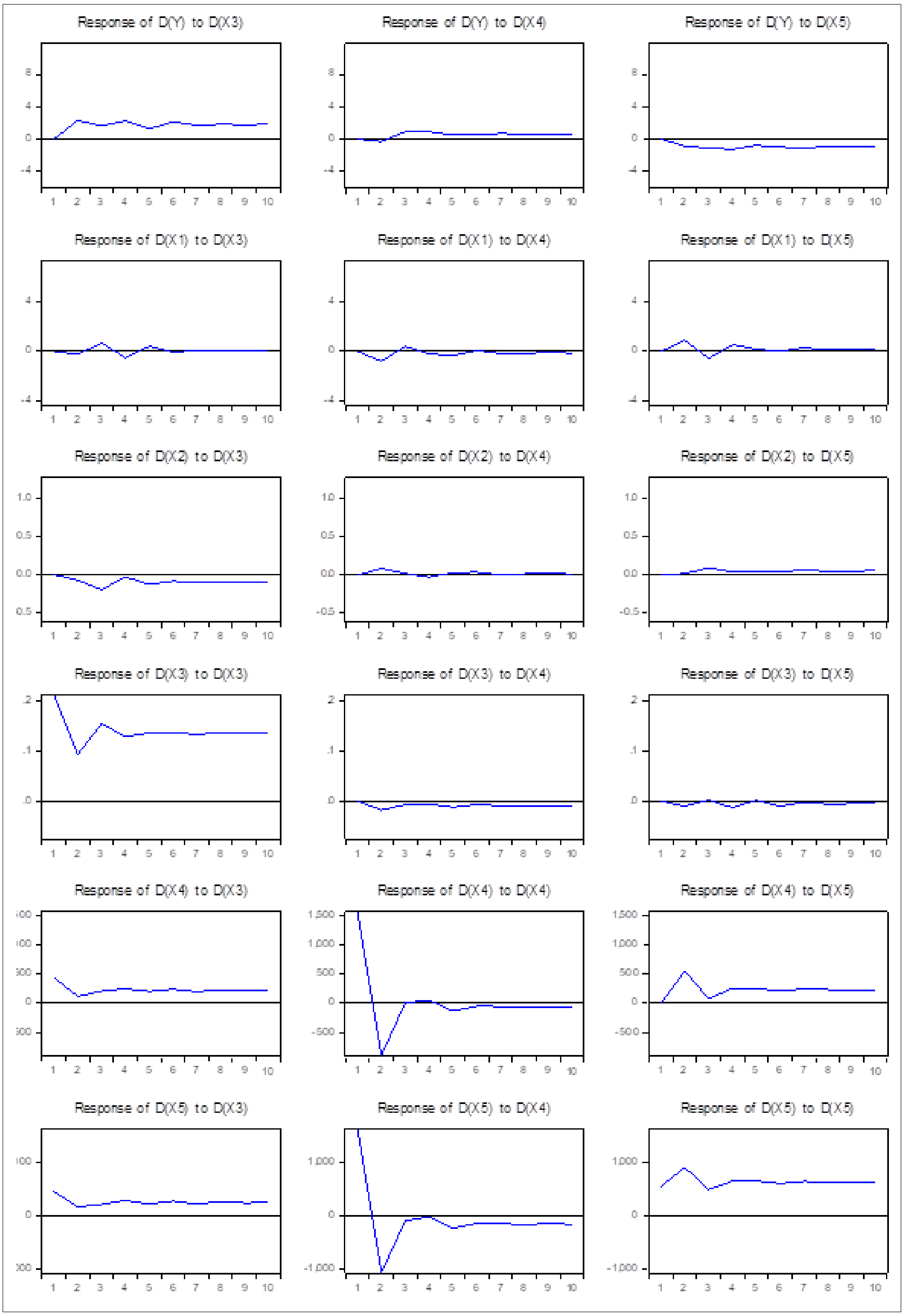


Figure 2B: Impulse Response Functions

Source: Plotted by author

There are significant short run causalities from food price inflation rate(x_1) to variability of food supply(y) and to emission from land use(x_3) respectively. The temperature change(x_2) has short run significant causality to variability of food supply(y). The emission from land use(x_3) has significant short run causality to temperature change(x_2) and the emission from rice and cereals(x_4) has significant short run causality to emissions from CO_2(x_5). All the statistic such as t statistic, F statistic and Chi-square statistic which measure the causality by Wald test (1943) from the system equations of the VECM are given below in Table 6.

Table 6: Short Run Causality

Short Run Causality From …. To …..	T Statistic (p Value)	F Statistic (p Value)	Chi-Square (p Value)	H0=No Causality
Short Run Causality from Food Price Inflation Rate(x_1) to Variability of Food Supply(y)	3.249(p=0.0016)	10.558(p=0.0016)	10.558(p=0.0012)	rejected
Short Run Causality from Temperature Change(x_2) to Variability of Food Supply(y)	-4.513(p=0.00)	20.373(p=0.00)	20.37389(p=0.00)	rejected
Short Run Causality from Emission from Land Use(x_3) to Temperature Change(x_2)	2.865(p=0.005)	8.2117(p=0.0055)	8.2117(p=0.0042)	rejected
Short Run Causality from Food Price Inflation Rate(X_1) to Emission from Land Use(X_3)	3.022(p=0.0032)	9.1345(p=0.0032)	9.1345(p=0.0025)	rejected
Short Run Causality from Emission from Rice and Cereals(X_4) to Emissions from Co_2(X_5)	2.356(p=0.0203)	5.5517(p=0.0203)	5.5517(p=0.0185)	rejected

Source: Author's Own

The estimated three panel cointegrating equations which were found from the VECM and system equations have been given below.

[1] z_{1t-1}=-0.2823dy_{t-1}+165.155dx_{3t-1}-0.192dx_{4t-1}+0.0741dx_{5t-1}+5.093
(-4.46)* (2.169)* (-6.46)* (3.009)* (0.47)

[2] z_{2t-1}= -1.8453dx_{1t-1}-31.485dx_{3t-1}+0.0335dx_{4t-1}-0.0129dx_{5t-1}-0.5135
(-9.61)* (-2.418)* (6.57)* (-3.067)* (-0.27)

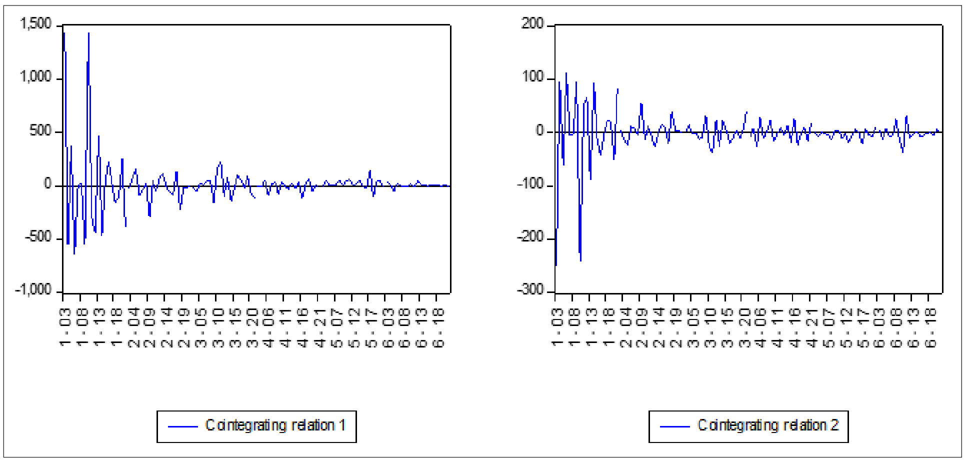
[3] z_{3t-1}=-1.6428dx_{2t-1}+6.911dx_{3t-1}-0.0064dx_{4t-1}+0.00235dx_{5t-1}+5.093
(-10.84)* (2.61)* (-6.22)* (2.75)* (0.266)

Where z=normalised variable, t values are in the first brackets. *=significant at 5% level.
The first cointegrating equation represents the long run causalities among dy_{t-1}, dx_{3t-1}, dx_{4t-1}, and dx_{5t-1} which revealed that the incremental variability of food supply has significant positive impact on incremental emissions from land use and incremental CO_2 while significantly negatively related with emission from rice and cereals. The coefficient of dy_{t-1} is negative and its t statistic is significant at 5% level which states that the cointegrating equation has been converging towards equilibrium with the speed of adjustment of 28.23% per year significantly.

The second cointegrating equation expresses long run causalities among dx_{1t-1}, dx_{3t-1}, dx_{4t-1}, and dx_{5t-1} which showed that the food price inflation rate has significant negative relation with incremental emissions from land use and from CO_2 emissions while significant positive relation with emission from rice and cereals respectively. The coefficient of dx_{1t-1} is negative and its t statistic is significant at 5% level which states that the cointegrating equation is converging towards equilibrium with the speed of adjustment of 184.28% per year significantly.

The third cointegrating equation expresses long run causalities among dx_{2t-1}, dx_{3t-1}, dx_{4t-1}, and dx_{5t-1} which showed that the temperature change has significant negative impact on incremental emissions from rice and cereals while significant positive relation with emission from land use and emissions from CO_2. The coefficient of dx_{2t-1} is negative and its t statistic is significant at 5% level which states that the cointegrating equation has been converging towards equilibrium with the speed of adjustment of 164.53% per year significantly.

The Three Cointegrating Equations have been depicted in Figure 3 below.



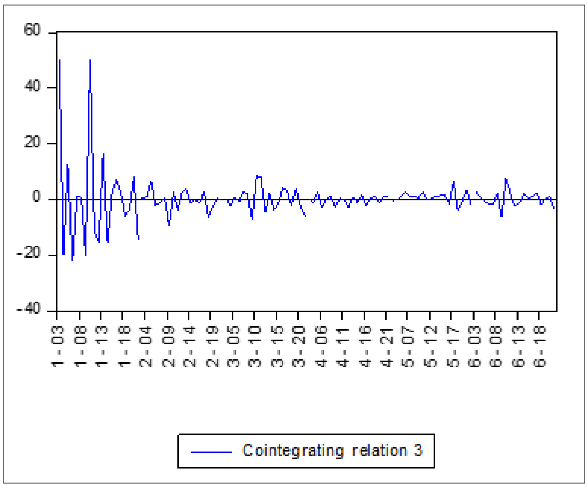


Figure 3: Cointegrating Equations

Source: Author's own

Policies to be Considered

Some of the important policies need to be discussed in context of sustainability of food security in confrontation with climate change which are as follows;[i] to enhance investment in food system,[ii] start new innovation to adaptation,[iii] use good handling of water allocation, land use pattern and post-harvest processing,[iv] promotion of sustainable agricultural technologies respectively,[v] need farm level productivity to development inclusive food value chain to nutrition education for design of food system,[vi] food system must produce healthy and safe food inequitable ways that promote environmental sustainability towards food system transformation,[vii] strengthen nutritional sensitive food distribution,[viii]require food safety management,[ix] farming genetically engineered crops,[x] transformation towards sustainable agri-based food system ,[xi] it is more fruitful to execute political economy of food system transformation,[xii] require policy reform to generate more equitable, healthier and sustainable food system,[xiii] mobilisation of internal and external financial flows for transformation of food system have good outcome, [xiv] the National Adaptation Plan under UNFCCC should be revamped,[xv]FAO report suggested to hike investment on resilience and disaster risk reduction especially data gathering and analysis to achieve agricultural sustainable goal in future.

Limitations and Future Scope of Research

Long term time series data on climate indicators if applied, may assure good results on food security indicator. Moreover, other indicators such as, impacts on nutrition, food supply in kilo calorie per capita per day, total people in severely food unsecured, moderately food unsecured, can give us detailed observations about natural disasters on food security which need long run time series data either region-wise or country-wise on those variables. It is expected that there is enough scope of empirical research in this area.

Conclusion

The paper concludes that the accepted fixed effect panel regression revealed that the negative impact of emission from land use and CO_2 on the variability of the supply of food on SAARC during 2000-2021 are significant while the marginal positive impact of emission from rice and cereals on the variability of the supply of food is statistically significant but the negative impacts of temperature change and food price inflation are insignificant at 5% level during 2000-2021. The residual cross section dependence tests are also significant. The Pedroni and Kao tests of panel cointegration showed that the variables are cointegrated according to their test statistic. The Johansen-Fisher panel cointegration rank test confirmed about at least three cointegrating equations. The long run cointegrating equation 1 states that incremental variability of food supply is significant positive relationship with incremental emissions from land use and incremental CO_2 while significantly negatively related with emission from rice and cereals which converged to equilibrium with the speed of adjustment of 28.23% per year. The second cointegrating equation implies that food price inflation rate has significant negative relation with incremental emissions from land use and from emissions from CO_2 while significant positive relation with emission from rice and cereals respectively which moved towards equilibrium at the speed of adjustment of 184.28% per year. The third cointegrating equation revealed that the temperature change has significant negative relation with incremental emissions from rice and cereals while significant positive relation with emission from land use and emissions from CO_2 which is converging towards equilibrium at the speed of adjustment 164.53% per year. There are significant short run causalities from food price inflation rate and from temperature change to variability of food supply respectively. It was found from VECM that the incremental variability of food supply kilo calorie per capita per day is significantly negative relation with incremental temperature change and significant positive relation with incremental food price inflation rate respectively. The impulse response of incremental temperature change, incremental emissions from land use, rice and cereals and CO_2 to incremental variability of food supply in SAARC during 2000-2021 have been converging towards equilibrium. The VECM model is stable and nonstationary.

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Conflicts of Interest

There is no conflict of interest in the publication of the paper.

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