Food security in South Asia under climate change and economic policies

Sun Yan
School of Economics, Xi'an University of Finance and Economics, Xi'an, China, and

Shahzad Alvi
Department of Economics, School of Social Sciences and Humanities, National University of Sciences and Technology, Islamabad, Pakistan

Received 3 October 2021
Revised 20 December 2021
23 January 2022
29 January 2022
12 February 2022
Accepted 19 February 2022

Abstract

Purpose – The first purpose of this study is to examine the impacts of climate-caused cereal productivity changes on food security, welfare and GDP in South Asian countries. The second purpose is to assess the agricultural subsidies and South Asia Free Trade Agreement (SAFTA) as policy responses to climate change.

Design/methodology/approach – The present study uses the computable general equilibrium (CGE) framework and econometric approach in an integrated manner to examine the economic impacts of climate-caused cereal productivity changes in South Asian countries. An econometric model is used to identify the impact of climate change on cereal yields and CGE approach is used to assess the future effect of climate change through simulations. In this course, the econometric findings are applied to Multiregional Global Trade Analysis Project 10 and then the model is calibrated for future projection.

Findings – The results indicate that there is a decrease in cereals production because of climate change and eventually it increases the prices of cereals, decreases the local consumption and GDP and, as a result, causes a loss in welfare. Subsidies and SAFTA have been found to have no substantial impact on increasing food security in South Asia.

Originality/value – The present study uses the concept of food demand for all cereals in an integrated way and focuses on the fiscal and trade policy responses to climate change.

Keywords Food security, Climate change, South Asia, Yields, Fiscal policy, Trade policy, GDP, Welfare, SAFTA

Paper type Research paper

1. Introduction

Extreme weather events are becoming more frequent and intense. The events such as flood, drought and storm surges threaten the land, livestock, crops and food supplies (Godde *et al.*, 2021). Climate change causes water tables to become depleted, make it more difficult for

This work is supported by the Social Science Fund Project of Shaanxi Province (2018HD06), Scientific Research Project of China (Xi'an) Institute for Silk Road Research (2019YA05) and Major theoretical and practical research projects in philosophy and social sciences of Shaanxi Province (2021ND0145).

people to get and stand in the way of attempts to boost agricultural production (Kirby *et al.*, 2017). People in fragile environments, who are already at risk of hunger, are most affected by climate change (Mahapatra *et al.*, 2021). The number of people suffering from malnutrition has risen around the world. The most affected regions are Africa and South Asia [World Health Organization (WHO) 2020]. The prevalence of stunting is 30.7% in South Asia, which is higher than the global average of 22.0% (Micha *et al.*, 2020).

Currently, one-fourth of the world's population is living in South Asia and it will grow 40% by 2050. In the future, feeding an ever-increasing population will be a major challenge [World Health Organization (WHO) 2020]. South Asia is one of the most vulnerable regions to climate change because of high rates of population growth and natural resource degradation, as well as persistently high rates of poverty and food insecurity (Barbier and Hochard, 2018; Hussain *et al.*, 2020). Over the past century, extreme climate events have increased in South Asia. In tropical areas, where the major crops are grown in South Asia, rising temperatures will have a negative impact on crop yields. The temperature tolerance in these areas is already at the threshold. While direct effects from rising temperatures are likely, indirect effects from changing soil moisture status and disease incidence are also likely (Sivakumar and Stefanski, 2010; Lal, 2021). Small rainfed farmers are affected more because of climate change because of their limited access to financial institutions and technical ability to adapt to climate change (Satishkumar *et al.*, 2013).

Socioeconomic progress has been achieved in South Asian nations over the past decade, but these countries still face difficulties, including reducing poverty and hunger, as well as ensuring food security for the people to achieve a good quality of living and healthy lifestyles. South Asian nations have the largest percentage of hungry and impoverished people, even though the region had significant economic development after 2000. The Millennium Development Goals in South Asia have not been fulfilled in a major manner. In 2015, countries adopted the sustainable development goals (SDGs) and SDGs 2 and 3 are directly related to food security. SDG 2 aims to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture", as well as help the poor and those whose situation is rapidly deteriorating [United Nation General Assembly (UNGA), 2015; Heidkamp, 2021]. The third SDG focuses on promoting good health and well-being. Furthermore, because all SDGs are linked to food and agriculture in some way, they are responsible for progress towards stable food security.

In this era of globalisation and competition, micro and macroeconomic policy measures are urgently needed to ensure the long-term sustainability of food provision by making the economy more competitive through structural change. As a result, general equilibrium economic models, also known as general equilibrium models (GEMs) are developed for this purpose. The economy, according to GEM's analysis, is made up of a complex network of several independent components, including factors of production, various industries and institutions and international economic conditions (Ianchovichina *et al.*, 2001; Calzadilla *et al.*, 2010; De-Salvo *et al.*, 2013). One of the GEMs' features is that they can adapt to global changes that occur at the country level and measure climate change in their economic sectors (Calzadilla *et al.*, 2013; Nikas *et al.*, 2019).

Few studies have developed the economic model for South Asia under climate change, including Hertel *et al.* (2010), Cai *et al.* (2016), Dissanayake *et al.* (2019) and Chalise *et al.* (2017). These studies focus on climate change along with GDP and population growth. The aim of the present study is to analyse the impact of climate change along with fiscal and trade policies on food security in South Asia. This study serves as a focal point for better understanding and assessing the impacts of climate change on agriculture production in South Asia, as well as the vulnerability that comes with it. The computable general equilibrium (CGE) framework used in the present study is different from the previous studies because it uses the real concept of food demand for all cereals in an integrated way instead of investigating the impact of climate shock separately for each cereal crop. Therefore, this study adds to the literature that provides simulations for all cereals not separately but lumped together for a meaningful analysis. Furthermore, this study contributes to the literature by concentrating on the fiscal and trade policies as compensatory responses to climate change, which are mostly ignored in the previous literature. We focused on four South Asian countries: Pakistan, India, Bangladesh and Sri Lanka. These countries have close economic structures, follow similar policies and the majority of the South Asian population is living in these countries. The agricultural sector is recognised as one of the most important in these countries, and staple food production is safeguarded owing to food security.

This study is organised as follows: Section 2 is about methodology; Section 3 is about results of cereal yields responses to temperature and precipitation; Section 4 is about future projections; Section 5 simulates the economic impact of climate change; and Section 6 discusses the results of fiscal and trade policies. Section 7 brings the study to a close and makes policy recommendations.

2. Methodology

2.1 Conceptual framework

The CGE framework in an integrated manner is used for scientific research that links the main features of society and economy with the biosphere and atmosphere into a single modeling framework. This method starts with general circulation models (GCMs). GCMs use physical, chemical and biological concepts to model the relationship of the earth system and their reactions to increasing greenhouse gas levels (IPCC, 2013). GCMs often consider the estimates of socioeconomic pathways that include population, income rise, energy consumption policies and other factors that affect greenhouse gas emissions levels. Using various socioeconomic mechanisms and assumed greenhouse gas emission trends, GCMs offer a set of predictions for potential climate change (IPCC, 2014). GCMs forecasts are then used as inputs to economic models to predict economic responses to climate change impacts and investigate the feasibility of possible strategies to combat and respond to climate change. Our CGE framework focuses on the future economic impacts of climate change by using the forecast of GCMs and taking into the policy responses to climate change. The current research developed a comprehensive CGE framework in an integrated manner by following Cai *et al.* (2016) and Alvi *et al.* (2021). Figure 1 explains the conceptual framework, which is used in the present study, which follows four steps:

(1) In the first step, an econometric model is estimated to identify the impact of climate change on yields in South Asian countries, namely, Bangladesh, India, Pakistan and Sri Lanka.

(2) Secondly, we use future temperature and precipitation projections from GCMs used in the Coupled Model Inter-comparison Project Phase 5 (CMIP5) to calculate implied future crop yield changes using the previous econometric model.

(3) Thirdly, the yield variations are fed into a multiregional Global Trade Analysis Project (GTAP) model for calibration, resulting in a decrease in grain sector factor-augmenting productivity. Using the CGE modeling approach, we also assess the macroeconomic impacts of climate change on Bangladesh, India, Pakistan and Sri Lanka.

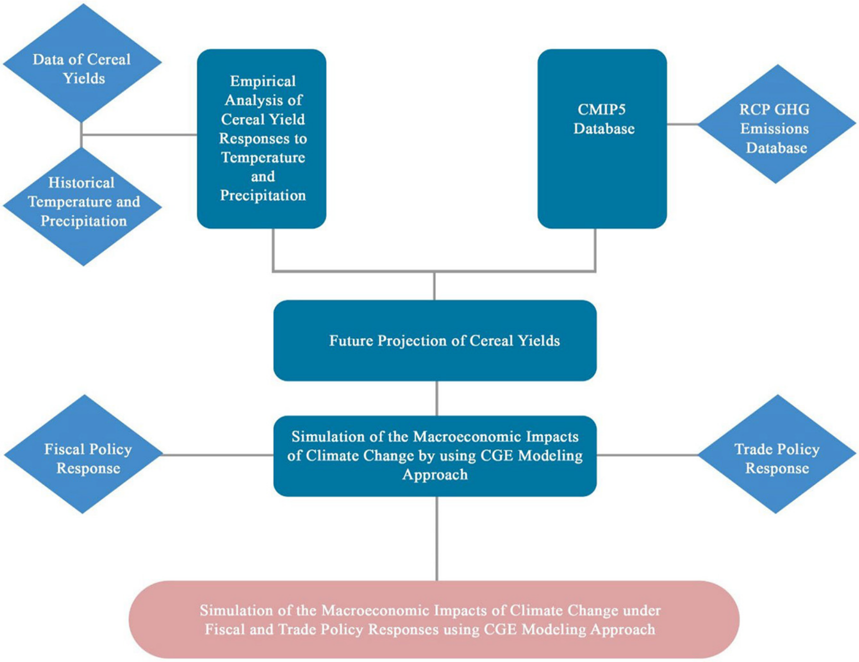

Figure 1. Conceptual framework

(4) Finally, through the CGE model, the present study also evaluates the effect of fiscal and trade policy responses to climate change.

2.2 Empirical model for cereal yields response to temperature and precipitation

To check the impact of climate change on yields, an econometric model is estimated with climatic and non-climatic variables. Yields (kg/ha) are influenced by both climatic and non-climatic factors (Di-Falco, 2014; Alvi and Jamil, 2018). We used growing degree days (GDDs) instead of average temperature because using an average temperature can hide extreme temperatures during the growing season of a crop (Schlenker and Roberts, 2009; Alvi *et al.*, 2021). The regression can be expressed as follows:

$$\begin{aligned} lny_{it} = {} & \gamma_1 GDD_{it} + \gamma_2 GDD_{it}^2 + \gamma_3 Pr_{it} + \gamma_4 \mathrm{Pr}_{it}^2 + \gamma_5 lnGFCF_{it} \\ & + \gamma_6 lnLF_{it} + \beta_t + a_i + \varepsilon_{it} \end{aligned} \tag{1}$$

where y_{it} is the crop yields, *Pr* is precipitation, *GFCF* is the gross fixed capital formation and *LF* is the labour force. A time-invariant country-fixed effect $\boldsymbol{a}_\mathrm{i}$ is used to control for regional heterogeneity. $\boldsymbol{\beta_t}$ is the time effect, which is introduced to capture the other development over the time period, such as improvement in seeds quality and farmer's practices. Subscript i is the country index and t is the year index. To capture the nonlinearity of *GDD* and precipitation, quadratic form of *GDD* and precipitation are included in the regression.

2.3 Data and variable description

The GDDs were used in this study, which is the sum of heat received by a crop over the growing period between lower and upper thresholds (Schlenker and Roberts, 2009). For each crop, the upper and lower thresholds are still being debated. The current study used 8°C as the lower threshold. Each crop has a different growing season in each of the South Asian countries. Rice crop sowing and harvesting dates in Pakistan, for example, differ from those in Bangladesh. In this study, different growing seasons are used for each crop and country. The average daily temperature during the growing season is used to calculate the GDDs for each crop. The method to calculate GDD is as follows:

$$GDD(T) = \begin{cases} 0 & if \;\; T \leq 8 \\ T - 8 & if \;\; T > 8 \end{cases} \tag{2}$$

For the period 1990 to 2015, data on climatic variables was obtained from NASA-POWER (power.larc.nasa.gov). NASA-POWER provides global coverage of satellite and model-derived agrometeorological data on a 1° latitude and 1° longitude grid. The data of climatic variables and cereal yields are made consistent with the satellite scans and images that show the areas where a specific cereal crop is growing.

The Food and Agriculture Organization (FAO, 2020) provided data on cereal yields, including wheat, rice and maize, for Bangladesh, India, Pakistan and Sri Lanka from 1990 to 2015. FAO also provides data on gross fixed capital formation and labour force in the agriculture sector.

This study uses the GTAP 10 database by focusing on four South Asian-countries, namely, Bangladesh, India, Pakistan and Sri Lanka, and three crops, namely, maize, rice and wheat, which are aggregated into one in the GTAP 10 database.

3. Results and discussion

We have started our analysis with descriptive statistics. The results of descriptive statistics are given in Table 1. It is found that the average cereal yields from 1990 to 2015 is found highest (3,509 kg per hector) in Bangladesh followed by Sri-Lanka, India and Pakistan. The average GDDs are observed highest (7,199 degrees Celsius) in Sri Lanka and lowest (4,228 degrees Celsius) in Pakistan. The descriptive statistics results show that the average

Country	Cereal yields (kg per hector)			Growing degree days (Celsius)			Precipitation (millimeters)		
	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Bangladesh	3,509	4,617	2,475	6,311	6,618	6,101	2,240	2,900	1,787
India	2,433	2,969	1,926	6,041	6,279	5,839	1,018	1,160	835
Pakistan	2,417	3,001	1,805	4,582	4,809	4,228	313	427	192
Sri Lanka	3,414	3,974	2,902	7,009	7,199	6,870	1,715	2,097	1,397
	Maize yield (kg per hector)			Rice yield (kg per hector)			Wheat yield (kg per hector)		
Bangladesh	3,671	6,984	734	3,532	4,552	2,533	2,156	3,086	1,503
India	1,986	2,610	1,376	3,075	3,691	2,609	2,675	3,177	2,121
Pakistan	2,569	4,424	1,396	3,055	3,752	2,315	2,356	2,832	1,824
Sri Lanka	1,749	3,590	969	3,480	4,055	2,993	2,515	3,154	2,071

Table 1. Descriptive statistics

precipitation in Bangladesh from 1990 to 2015 is recorded 2,240 millimeters followed by 1,715 millimeters in Sri Lanka and 1,018 millimeters in India. However, in Pakistan, average precipitation level from 1990 to 2015 is 313 millimeters, which are quite low as compared to other regional countries. Further, we have also calculated the average, maximum and minimum yields for the three major crops, maize, rice and wheat from 1990 to 2015. The average maize yield is the highest recorded in Bangladesh and the lowest average is in Sri Lanka. The average yield of rice is the highest calculated in Bangladesh and the lowest average is in Pakistan. Wheat is also one of the major staple food. The average wheat yield in India is the highest (2,675 kg) and the lowest average in Bangladesh (2,158 kg). Similarly, we have calculated the minimum and maximum values of three major crops and climatic variables (see Table 1).

We have applied the fixed-effects technique on data spanning the years 1990–2015. Maize, rice and wheat yields are dependent variables, while GDDs, precipitation, gross fixed capital formation and labour force are independent variables. Table 2 summarises the findings. The results indicate that GDDs have a significant effect on maize, rice and wheat crops at 99%, 95% and 90% confidence intervals, respectively. To account for the nonlinearity, we introduced the square of GDD. The coefficient of GDD squared is significant for maize, rice and wheat at 99%, 95% and 90% confidence intervals, respectively, indicating that a nonlinear relationship exists and that GDD increases yields but at a decreasing rate. The relationship between GDD and maize, rice and wheat yields is an inverted U-shaped relationship. Precipitation and crop yields also have a nonlinear relationship. Additionally, this indicates that increasing precipitation to a moderate level is beneficial. Crops are harmed by low or excessive precipitation. The precipitation coefficient and its square are significant for the three crops. The findings of this study corroborate with those of Schlenker and Roberts (2009) for the USA and Chen *et al.* (2016) and Zhang *et al.* (2017) for China. As the farmers are rotating their crops and people of developing countries are more concerned about the availability of overall grains (Alvi *et al.*, 2020), it is important to see the impact of climate change on overall cereal yields. We ensembled the three cereal crops (maize, rice and wheat), and the results indicate that the GDD and precipitation affect the cereal yields significantly at a 99% confidence interval. It is also found that the relationship of cereal yields with GDD and precipitation is nonlinear because the coefficients of the square of GDD and precipitation are significant at a 95% confidence interval. The results also indicate that the increase in the gross fixed capital formation and labour force in South Asia's agriculture sector increases crops' yields.

Table 2.
Impact of climate change on cereal yields

Variable	Maize	Rice	Wheat	Cereals
GDD	0.192*** (0.0024)	0.291** (0.037)	0.317** (0.013)	0.310*** (0.001)
GDD^2	−0.096*** (0.001)	−0.143** (0.025)	−0.061*** (0.001)	−0.139** (0.019)
Pr	0.044** (0.042)	0.071*** (0.008)	0.070*** (0.010)	0.093*** (0.001)
Pr^2	−0.034** (0.032)	−0.022** (0.025)	−0.049* (0.076)	−0.060** (0.002)
GFCF	0.255*** (0.001)	0.211*** (0.004)	0.295*** (0.002)	−0.276* (0.072)
LF	0.138* (0.053)	0.133** (0.037)	0.290** (0.061)	0.259* (0.081)
Adjusted *R*-square	65.25	63.91	60.38	71.85

Notes: ***, **and *denote significance at the 99, 95 and 90% confidence interval, respectively
Source: author's calculations

4. Projection of cereal yields – 2050

We forecast future cereal yields for the four South Asian countries of Bangladesh, India, Pakistan and Sri Lanka using the value of climate change impacts. The Representative Concentration Pathways (RCP) 6.0 scenario is used for this purpose; this scenario uses a high rate of greenhouse gas emissions and is a stabilisation scenario in which total radiative forcing is stabilised after 2,100 through the use of a variety of technologies and strategies for reducing greenhouse gas emissions. Global warming is expected to increase by an average of 1.3°C by the mid-century and 2.2°C by the century's end (IPCC, 2014). The future projection of cereal yields is calculated by using ten GCMs' CMIP5, Community Climate System Model (CCSM), Geophysical Fluid Dynamics Laboratory (GFDL), Goddard Institute for Space Studies (GISS), Institute Pierre Simon Laplace Climate Model 5 A (IPSL-CM5A), The Norwegian Earth System Model (NORESM), Beijing Climate Center Climate System Model (BCC-CSM), Community Earth System Model (CESM), Commonwealth Scientific and Industrial Research Organization (CSIRO), First Institute of Oceanography Earth System Model (FIO_ESM) and MIROC Earth system model (MIROC-ESM). The maximum, minimum and average values in percentage decrease in cereal yield are calculated from the ten models and the results are given in Table 3. The projection indicates that the cereal yields will be significantly decreased in four countries of South Asia because of climate change. The average impact of climate is high in Bangladesh and Pakistan, which is −16.4% and −10.7%, respectively.

5. Economic impacts of climate change

Using the CGE modeling framework, we discuss the economic impacts of climate-caused cereal productivity changes in South Asia for each country in this section. Maize, rice and wheat are combined in a multiregional GTAP model that is calibrated to the GTAP 10 database and incorporates the future decrease in cereal yields data from the previous section. According to the findings, GDP in India, Pakistan, Bangladesh and Sri Lanka could fall by up to 2.6%, 7.2%, 8.9% and 7.8% in the mid-century compared to the base year of 2015. We discovered that as a result of climate change, prices will rise, with the highest increases expected in Bangladesh and Pakistan, at 50.7% and 43.2%, respectively. The price of cereal grains has increased by 13.7% in India and 31.5% in Sri Lanka. Our simulations also show that because of climate-caused changes in cereal production in South Asia, imports could rise. At the same time, by the middle of this century, exports could be drastically reduced, with Bangladesh and Pakistan being the most affected countries. Furthermore, we discover that a decrease in cereal production raises cereal prices and has an impact on individual household consumption. In the mid-20th century, all four countries saw a decrease in cereal consumption. This could mean that these South Asian countries will face more food security issues because they are already lagging behind developed countries in average yields and have a large population that is undernourished (Cai *et al.*, 2020).

	India	Pakistan	Bangladesh	Sri Lanka
Minimum	−6.8	−9.7	−11.8	−8.8
Maximum	−11.9	−17.1	−21.8	−15.4
Average	−7.1	−10.7	−16.4	−9.5

Note: The above values are in the percentage decrease in cereal yields
Source: author's calculation

Table 3. Projection of future cereal yields – 2050

Climate change has also resulted in a loss of welfare worth US$41.8bn in India, US$27.5bn in Pakistan, US$24.7bn in Bangladesh and US$4bn in Sri Lanka (see Figure 2).

The results support the previous studies' findings, which predicted that average crop yields decreased in 2050 as a result of climate change in South Asia (Aryal *et al.*, 2020). Because of a decrease in cereal yields, the average calorie availability is expected to decline by around 15% in 2050, with cereal consumption projected to decline by as much as 24% in South Asia (Nelson *et al.*, 2009). Bangladesh, India and Pakistan are most susceptible to declining crop yields because of decreasing water resources, glacial melting, flood, droughts and unpredictable precipitation (Ahmad *et al.*, 2020; Miller and McGregor, 2020). Wang *et al.* (2017) predicted the average total economic losses for the mid-century are 9.4% for Bangladesh, 8.7% for India and 6.5% for Sri Lanka.

6. Fiscal and trade policy responses

In this study, a set of policy directions of South Asia's economies under an integrated framework is developed by keeping in view the real concept of food security. Thus, it is important to note the role of the policymakers to prepare compensatory policies to mitigate the adverse impacts of climate change on food security. There can be two options that could be considered: first, provision of subsidies at a country level, and regional agreements in form of free trade. Subsidies provide insight on food security in the presence of improving the facilitation to the farmers. The subsidies are coupled to output and create incentives for producers to expand production. These subsidies are usually provided on fertilisers, pesticides or improved seeds to influence production practices and processes. The objective of subsidies is to attain self-sufficiency in staple food items. First, we simulate the model with a very optimistic approach, in which we consider that if the South Asian countries start giving subsidies to the farmers equivalent to Europe, then how it will affect the situation. European countries subsidise farmers, undermining market access for some of the world's poorest producers. Currently, European countries are given 25% subsidies on average to their farmers. The findings suggest that output will improve in all of the South Asian countries. However, this progress is insufficient to compensate for the losses caused by climate change. Subsidies have an impact on other sectors of the economy as well as GDP. Instead of compensating, an increase in subsidies causes a drop in GDP. Subsidies allow for lower consumer prices, lower imports, improved exports and a slight increase in food availability for individual households. However, all of these improvements are insufficient

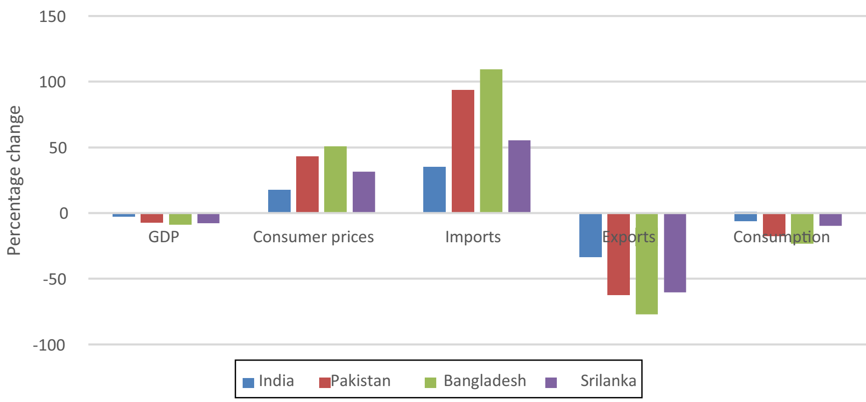

Figure 2.
Impact of climate change on GDP, consumer prices, imports, exports and consumption

and do not compensate for the climate change shock. Even our simulations show that welfare has not improved as a result of subsidies (see Figures 3–9).

Intra-regional trade constitutes less than 5% of South Asia's total trade, compared to 25% and 61.8% in the ASEAN and European Union (World Bank, 2012), respectively. According to international trade theory, allowing for more free trade in food grains between nations will drive gains in productivity and growth in food production, principally increasing market size and price stabilisation. Many studies have demonstrated that lowering trade barriers between SAARC member nations will benefit all countries in the region (Iqbal and Amjad, 2012). Nonetheless, other analyses imply that the advantages would be negligible or moderate at best, given low per capita incomes, poorly developed infrastructure, similar patterns of comparative advantage and high transaction costs (Kumar and Singh, 2009; Kemal *et al.*, 2000). This study focuses on the role of the South Asian Free Trade Agreement (SAFTA) as a compensatory policy response to climate change if it is used in the true sense of having no tariffs between South Asian countries. For cereal grains, South Asian countries currently rely on a variety of interventionist policies,

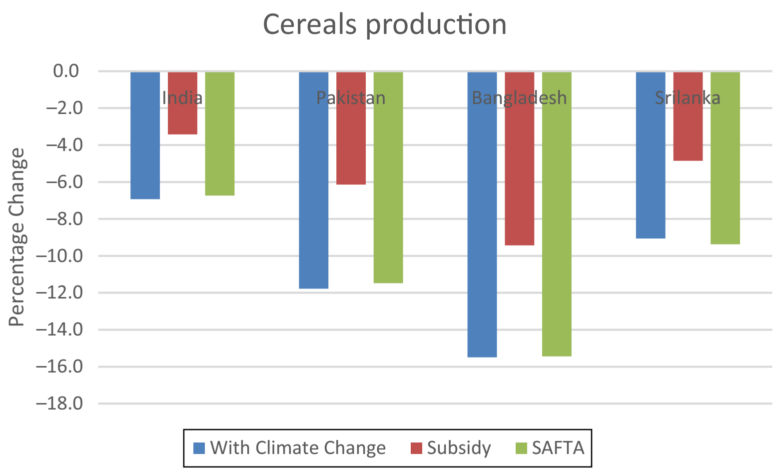

Figure 3.
Impact of compensatory policies on cereals production

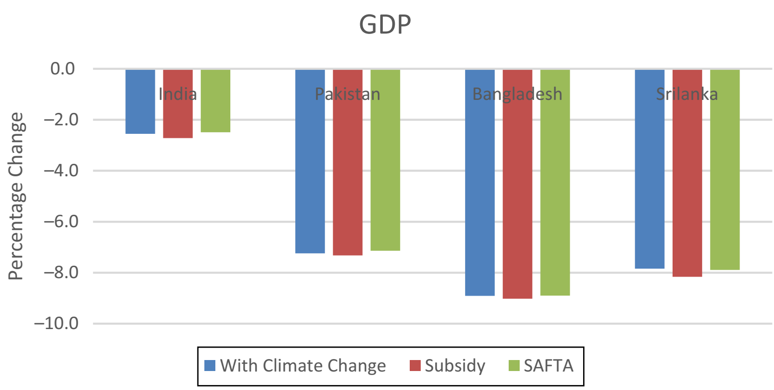

Figure 4.
Impact of compensatory policies on GDP

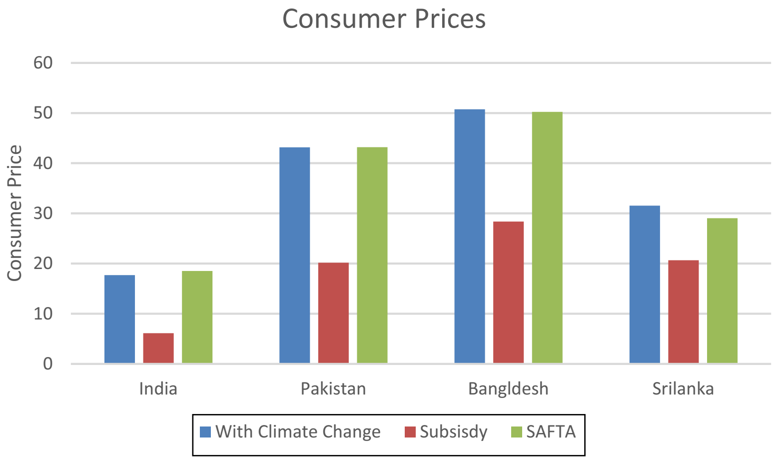

Figure 5.
Impact of compensatory policies on consumer prices

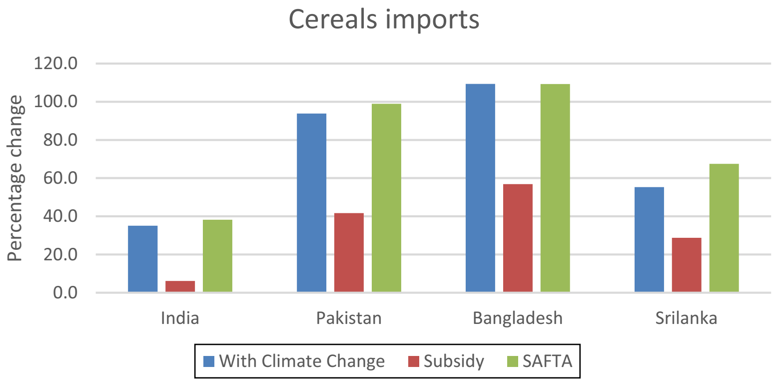

Figure 6.
Impact of compensatory policies on cereals imports

which have resulted in forced domestic adjustments rather than trade solutions. In this context, it is expected that strong yield growth will protect the situation and that any disruption caused by climate change will result in a rapid deterioration of the regional food balance (Laborde *et al.*, 2012). We run the model by taking into account future regional trade developments in South Asia, where SAFTA is a hot topic. SAFTA has been applied and implemented to see what will happen to the economic variables, and the results are shown in Figures 3–9. It is indicated that SAFTA is not very effective at compensating for climate change. It has a chance of failing to improve food security in South Asia. SAFTA will provide little benefit to Bangladesh. Previous studies by Laborde *et al.* (2012) and Bandara and Cai (2014) support the results of our simulations. Both studies found that South Asia is the region most negatively impacted by climate change on agricultural yields. SAFTA's implementation and increased agricultural subsidies have failed to significantly improve agricultural yields.

Simulations based on the integrated framework reveal a threatening situation in terms of food security for South Asian countries by the middle of this century, in spite of the fact that these countries already have a large number of undernourished people. In this situation,

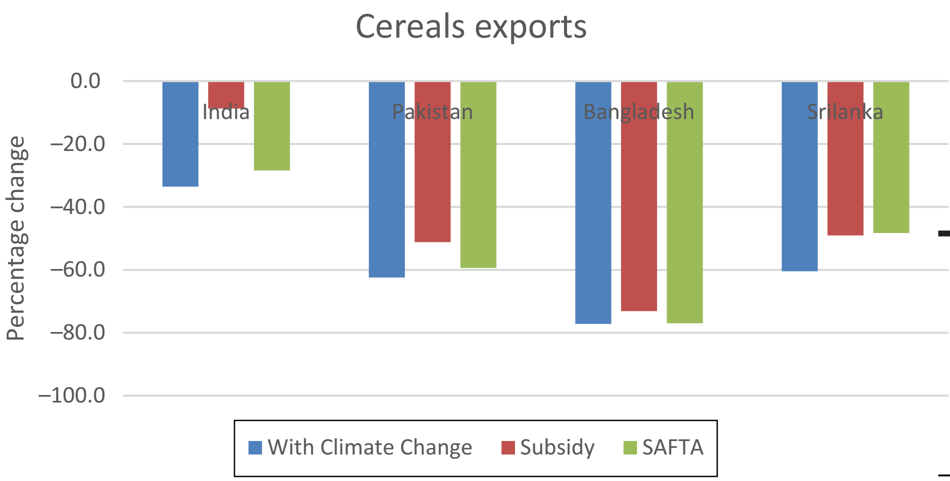

Figure 7.
Impact of compensatory policies on cereals exports

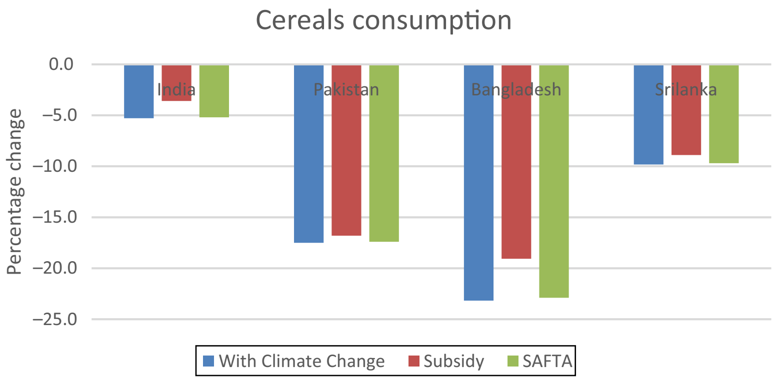

Figure 8.
Impact of compensatory policies on cereal consumption

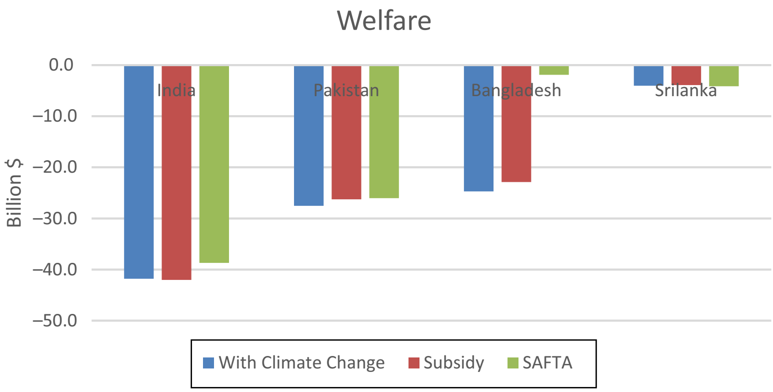

Figure 9.
Impact of compensatory policies on welfare

South Asian countries must become more globally integrated and find a solution other than SAFTA, which is ineffective in ensuring food security. Furthermore, providing farmers with subsidies does not ensure food security, both locally and regionally. Climate change-related welfare losses can be mitigated by shifting the economy from agriculture to manufacturing, resulting in a significant increase in per capita income and, consequently, food security.

7. Conclusion

With the help of the CGE modelling framework, the current study has examined the economic consequences of climate-caused changes to cereal productivity for four South Asian countries, namely, India, Pakistan, Bangladesh, and Sri Lanka. For this purpose, first, we have estimated the econometric model to check the impact of climate change on cereal yields. Then, these findings are used to calculate the future macroeconomic effects because of climate change by using the CGE approach. According to the findings, climate change is causing a decrease in cereal production in South Asia. The prices of cereals will eventually rise, while local consumption and GDP will fall, causing a decrease in overall welfare as a result of climate change. A simulation of the impact of subsidies and SAFTA on food security in response to climate change is also included in the study, but it does not find any significant contributions. As a result, the study recommends that free trade opportunities be explored in addition to SAFTA. Instead of providing subsidies, another possible policy approach is to provide training to farmers in order for them to be better prepared for and to cope with the underlying factors that may drive the adoption of new technology in the first place.

Agriculture is the most dependent on weather and climate, especially for growing crops. Farmers are vulnerable to the impact of climate change-related problems. The people of South Asia are already struggling with the challenges of extreme weather, low incomes and hunger and poverty. Climate change adaptation strategies are now an absolute necessity for all vulnerable populations, and these populations are already disproportionately affected. To produce substantial benefits for food security and climate change adaptation and mitigation, an integrated strategy using adaptive, mitigation priorities and long-term approaches is required. The actions that yield the most benefit with respect to mitigating the consequences of climate change while also offering substantial co-benefits include increasing soil carbon sequestration in forestry and agro-forestry initiatives and tillage practices, improving nutrient management efficiency and restoring degraded lands.

Using CGE framework in an integrated manner to assess the implications of climate change for food security, this study highlights the significance of various policy interventions. First, it is critical to demonstrate that no single country can overcome the issue of food insecurity, whereas the South Asian region is jointly vulnerable, meaning, thereby, these countries have to look out of the region to formulate some sort of trade liberalisation with relatively secure countries. Trade diplomacy is a critical policy tool that should be taken on an upright agenda of foreign policy. Second, control measures are hardly available for controlling or optimising the precipitation, whereas it has an exponentially damaging impact after reaching a certain threshold. Therefore, it is critical to devise a policy for introducing small water reservoirs. These can be used as an additional source of water for various purposes, including farming. Third, the positive impact of capital formation identifies the importance of using more technologically advanced equipment and machinery for farming purposes. However, the availability of financing is a critical barrier for the farmers to deal with this dilemma. It thus identifies the need to provide financing facilities to the farmers. Last but not the least, appropriate training of farming community to deal with climate change should be on the priority agenda of the respective governments.

References

Ahmad, M.D., Stewart, J.P., Peña-Arancibia, J.L. and Kirby, J.M. (2020), "Punjab water outlook: impacts of climate change and dam sedimentation on water for irrigated agriculture", March 2020. Technical Report, Sustainable Development Investment Portfolio project, CSIRO, Australia, p. 50.

Alvi, S. and Jamil, F. (2018), "Impact of climate change and technology adoption on cereal yields in South Asian countries", *European Journal of Sustainable Development*, Vol. 7 No. 3, pp. 237-237, doi: 10.14207/ejsd.2018.v7n3p237.

Alvi, S., Jamil, F., Roson, R. and Sartori, M. (2020), "Do farmers adapt to climate change? A macro perspective", *Agriculture*, Vol. 10 No. 6, p. 212.

Alvi, S., Roson, R., Sartori, M. and Jamil, F. (2021), "An integrated assessment model for food security under climate change for South Asia", *Heliyon*, Vol. 7 No. 4, p. e06707, doi: 10.1016/j.heliyon.2021.e06707.

Aryal, J.P., Rahut, D.B., Sapkota, T.B., Khurana, R. and Khatri-Chhetri, A. (2020), "Climate change mitigation options among farmers in South Asia", *Environment, Development and Sustainability*, Vol. 22 No. 4, pp. 3267-3289, doi: 10.1007/s10668-019-00345-0.

Bandara, J.S. and Cai, Y. (2014), "The impact of climate change on food crop productivity, food prices and food security in South Asia", *Economic Analysis and Policy*, Vol. 44 No. 4, pp. 451-465, doi: 10.1016/j.eap.2014.09.005.

Barbier, E.B. and Hochard, J.P. (2018), "Land degradation and poverty", *Nature Sustainability*, Vol. 1 No. 11, pp. 623-631, doi: 10.1038/s41893-018-0155-4.

Cai, Y., Bandara, J.S. and Newth, D. (2016), "A framework for integrated assessment of food production economics in South Asia under climate change", *Environmental Modelling and Software*, Vol. 75, pp. 459-497, doi: 10.1016/j.envsoft.2015.10.024.

Cai, J., Ma, E., Lin, J., Liao, L. and Han, Y. (2020), "Exploring global food security pattern from the perspective of spatio-temporal evolution", *Journal of Geographical Sciences*, Vol. 30 No. 2, pp. 179-196, doi: 10.1007/s11442-020-1722-y.

Calzadilla, A., Rehdanz, K., Betts, R., Falloon, P., Wiltshire, A. and Tol, R.S. (2013), "Climate change impacts on global agriculture", *Climatic Change*, Vol. 120 Nos 1/2, pp. 357-374, doi: 10.1007/s10584-013-0822-4.

Calzadilla, A., Rehdanz, K. and Tol, R.S. (2010), "The economic impact of more sustainable water use in agriculture: a computable general equilibrium analysis", *Journal of Hydrology*, Vol. 384 Nos 3/4, pp. 292-305, doi: 10.1016/j.jhydrol.2009.12.012.

Chalise, S., Naranpanawa, A., Bandara, J.S. and Sarker, T. (2017), "A general equilibrium assessment of climate change–induced loss of agricultural productivity in Nepal", *Economic Modelling*, Vol. 62, pp. 43-50, doi: 10.1016/j.econmod.2017.01.014.

Chen, S., Chen, X. and Xu, J. (2016), "Impacts of climate change on agriculture: evidence from China", *Journal of Environmental Economics and Management*, Vol. 76, pp. 105-124, doi: 10.1016/j.jeem.2015.01.005.

De-Salvo, M., Begalli, D. and Signorello, G. (2013), "Measuring the effect of climate change on agriculture: a literature review of analytical models", *Journal of Development and Agricultural Economics*, Vol. 5 No. 12, pp. 499-509.

Di-Falco, S. (2014), "Adaptation to climate change in Sub-Saharan agriculture: assessing the evidence and rethinking the drivers", *European Review of Agricultural Economics*, Vol. 41 No. 3, pp. 405-430.

Dissanayake, S., Mahadevan, R. and Asafu-Adjaye, J. (2019), "Is there a role for trade liberalization in mitigating the impacts of climate change on agriculture?", *Economic Analysis and Policy*, Vol. 62, pp. 307-324.

FAO (2020), *Food and Agriculture Data*, Food and Agriculture Organization of United Nation, available at: www.fao.org/faostat/en/#data (accessed 20 June 2020).

Godde, C.M., Mason-D'Croz, D., Mayberry, D.E., Thornton, P.K. and Herrero, M. (2021), "Impacts of climate change on the livestock food supply chain; a review of the evidence", *Global Food Security*, Vol. 28, p. 100488, doi: 10.1016/j.gfs.2020.100488.

Heidkamp, R.A., Piwoz, E., Gillespie, S., Keats, E.C., D'Alimonte, M.R., Menon, P., Das, J.K., Flory, A., Clift, J.W., Ruel, M.T. and Vosti, S. (2021), "Mobilising evidence, data, and resources to achieve global maternal and child undernutrition targets and the sustainable development goals: an agenda for action", *The Lancet*, Vol. 397 No. 10282, pp. 1400-1418, doi: 10.1016/S0140-6736(21)00568-7.

Hertel, T.W., Burke, M.B. and Lobell, D.B. (2010), "The poverty implications of climate-induced crop yield changes by 2030", *Global Environmental Change*, Vol. 20 No. 4, pp. 577-585, doi: 10.1016/j.gloenvcha.2010.07.001.

Hussain, M., Butt, A.R., Uzma, F., Ahmed, R., Irshad, S., Rehman, A. and Yousaf, B. (2020), "A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan", *Environmental Monitoring and Assessment*, Vol. 192 No. 1, pp. 1-20.

Ianchovichina, E., Darwin, R. and Shoemaker, R. (2001), "Resource use and technological progress in agriculture: a dynamic general equilibrium analysis", *Ecological Economics*, Vol. 38 No. 2, pp. 275-291.

IPCC (2013), "Climate change 2013 of the physical science basis", Working group I, fifth assessment report of intergovernmental panel for climate change, Summary for policy makers, IPCC, Switzerland.

IPCC (2014), Climate change: synthesis report, Contribution of Working Groups I, II and III to the fifth assessment report.

Iqbal, M. and Amjad, R. (2012), "Food security in South Asia: strategies and programmes for regional collaboration", *Regional Integration and Economic Development in South Asia*, University Library of Munich, Germany.

Kemal, M.A., Qadir, U. and Mohsin, H. (2000), "Impact of trade reforms on poverty", *The Pakistan Development Review*, Vol. 39 No. (4 Part II), pp. 1127-1137.

Kirby, M., Mainuddin, M., Khaliq, T. and Cheema, M.J.M. (2017), "Agricultural production, water use and food availability in Pakistan: historical trends, and projections to 2050", *Agricultural Water Management*, Vol. 179, pp. 34-46.

Kumar, R. and Singh, M. (2009), "India's role in South Asia trade and investment integration", ADB Working Paper Series on Regional Economic Integration (No. 32), Asian Development Bank.

Laborde, D., Lakatos, C., Nelson, G., Robertson, R., Thomas, M., Yu, W. and Jansen, H.G. (2012), *Climate Change and Agriculture in South Asia: Alternative Trade Policy Options*, World Bank, Washington, DC, available at: https://openknowledge.worldbank.org/handle/10986/26792

Lal, R. (2021), "Climate change and agriculture", *Climate Change* (third edition), Elsevier, Amsterdam, pp. 661-686.

Mahapatra, B., Walia, M., Rao, C.A.R., Raju, B.M.K. and Saggurti, N. (2021), "Vulnerability of agriculture to climate change increases the risk of child malnutrition: evidence from a large-scale observational study in India", *PloS One*, Vol. 16 No. 6, p. e0253637, doi: 10.1371/journal.pone.0253637.

Micha, R., Mannar, V., Afshin, A., Allemandi, L., Baker, P., Battersby, J., Bhutta, Z., Chen, K., Corvalan, C., Di Cesare, M. and Dolan, C. (2020), 2020 Global nutrition report: action on equity to end malnutrition.

Miller, F.P. and McGregor, A. (2020), "Rescaling political ecology? World regional approaches to climate change in the asia pacific", *Progress in Human Geography*, Vol. 44 No. 4, pp. 663-682, doi: 10.1177/0309132519849292.

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D. . . . and Shaw, M. (2009), "Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales", *Frontiers in Ecology and the Environment*, Vol. 7 No. 1, pp. 4-11.

Nikas, A., Doukas, H. and Papandreou, A. (2019), "A detailed overview and consistent classification of climate-economy models", in Doukas, H., Flamos, A. and Lieu, J. (Eds), *Understanding Risks and Uncertainties in Energy and Climate Policy*, Springer, Cham, available at: https://doi.org/10.1007/978-3-030-03152-7_1

Satishkumar, N., Tevari, P. and Singh, A. (2013), "A study on constraints faced by farmers in adapting to climate change in rainfed agriculture", *Journal of Human Ecology*, Vol. 44 No. 1, pp. 23-28.

Schlenker, W. and Roberts, M.J. (2009), "Nonlinear temperature effects indicate severe damages to US crop yields under climate change", *Proceedings of the National Academy of Sciences*, Vol. 106 No. 37, pp. 15594-15598.

Sivakumar, M.V. and Stefanski, R. (2010), "Climate change in South Asia", *Climate Change and Food Security in South Asia*, Springer, Dordrecht, pp. 13-30.

United Nation General Assembly (UNGA) (2015), Transforming our world: the 2030 agenda for sustainable development, 21 October 2015 (Vol. 16301), A/RES/70/1.

Wang, S.W., Lee, W.K. and Son, Y. (2017), "An assessment of climate change impacts and adaptation in South Asian agriculture", *International Journal of Climate Change Strategies and Management*, Vol. 9 No. 4, pp. 517-534.

World Bank (2012), "Why one South Asia", [online], available at: www.worldbank.org/en/programs/south-asia-regional-integration/trade (accessed 12 December 2021).

World Health Organization (WHO) (2020), UNICEF/WHO/The World Bank Group Joint Child Malnutrition Estimates: levels and trends in child malnutrition, key findings of the 2020 edition.

Zhang, P., Zhang, J. and Chen, M. (2017), "Economic impacts of climate change on agriculture: the importance of additional climatic variables other than temperature and precipitation", *Journal of Environmental Economics and Management*, Vol. 83, pp. 8-31.

Further reading

Lal, M. (2011), "Implications of climate change in sustained agricultural productivity in South Asia", *Regional Environmental Change*, Vol. 11 No. 1, pp. 79-94, doi: 10.1007/s10113-010-0166-9.

About the authors

Sun Yan (1979) has a doctorate degree and she is an Associate Professor at the Xi'an University of Finance and Economics. Her research direction includes rural economy and innovation economics.

Shahzad Alvi has a doctorate degree in Economics and is currently serving as Assistant Professor at the Department of Economics, School of Social Sciences and Humanities (S3H), National University of Sciences and Technology (NUST), Islamabad, Pakistan. His research interests include development economics, environmental economics and CGE modelling. Shahzad Alvi is the corresponding author and can be contacted at: shahzad.alvi@s3h.nust.edu.pk