Improving Productive Efficiency as An Adaptation Strategy for Climate Change: Evidence from South Asian Agriculture

K.M.K.H. Samaraweera[*], A.D.K.S.S. Somarathna, J.C. Edirisinghe
Department of Agribusiness Management, Faculty of Agriculture and Plantation Management,
Wayamba University of Sri Lanka
[*]kavindyahirushi256@gmail.com

INTRODUCTION

Climate change refers to change in climate due to natural or anthropogenic activities and this change remains for a long period of time (IPCC, 2007). The average annual surface air temperature has increased by about 1.8 ^{0}F (1.0 ^{0}C) over the last century. Due to climate change, there is increased variability in rainfall, extreme weather events and global warming. However, not all regions in the world experience the same degree of damage due to climate change. South Asia is one of the sub-regions which has been affected severely by climate change. The high incidence of poverty and high dependency on rain-fed agriculture have made South Asia highly vulnerable to climate change.

Agriculture productivity is affected by various factors such as a change in rainfall pattern, temperature hike, changes in sowing and harvesting dates, water availability, evapotranspiration and land suitability. 80% of world farmland and two-thirds of global crop production is based on rain-fed agriculture.

The impacts of climate change on food production and food security in Asia will vary by region, with many regions experiencing a decline in productivity. For example, it is forecasted that there could be a decline of about 50 percent in the most favourable and high-yielding wheat area as a result of heat stress in the Indo-Genetic Plains of South Asia (IPCC, 2014).
The incidence of extreme weather events are also expected to increase due to climate change, and in turn, negatively affect agricultural crop production in South Asia. These changes are crop-specific. Hence, this research tries to understand the agricultural production change in country and region-wise in South Asia.

Most of the South Asian countries are developing countries and are more vulnerable to climate change than developed countries as their economy relies more on labour-intensive technologies than capital-intensive technologies.

To cope the adverse effect on production, Asia must consider enhancing the total production and productivity in the region. Production and productivity can be boosted either through increased use of inputs and/or improvement in technology or by improving the efficiency of producers or firms, given a fixed level of inputs and technology (Wassie, 2014). Technical efficiency can be defined as the ratio of observed to potential output. In this scenario, this research assesses whether efficiency increases can be used to mitigate the negative impacts of climate change.

The objectives of this research are twofold: (1) to estimate the stochastic production frontier for agricultural production in South Asia and (2) to analyse whether the impacts of climate change can be mitigated by the changes in production efficiency.

METHODOLOGY

This study was conducted for South Asian region, hence data related to eight countries of South Asia *i.e.* Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka was obtained for the study. Data have been taken from the World Bank data portal, Food and Agriculture Organization and the International Labour Organization. The unbalanced panel dataset includes data on gross production values, agricultural land, employment, fertilizer and pesticide use and climate normals of temperature and rainfall for the period 1991 to 2017, covering both private and public agricultural productions of each country.

All inputs and outputs were transformed to their corresponding natural log values in estimating the Cobb Douglas production function. Inputs that are used for the analysis were agricultural land use (ha), total pesticides (tonnes), total fertilizer (tonnes), employment in agriculture (person number), climate data that include 30 year average of past data of temperature (^{0}C) and rainfall (mm). Output was the Gross Production Value (constant 2014-2016 million US$). Climate normals were obtained by averaging thirty

(30) years past data of rainfall and temperature, which is obtained from Climate change knowledge portal of World Bank.

Green, 2005 proposed an extension of Random effect (RE), called "true" random effects (TRE) model, which treats firm-specific time-invariant heterogeneity and time-varying inefficiency separately. The study used the "true" random effects (TRE) model, proposed by Green, 2005, which treats firm-specific time-invariant heterogeneity and time-varying inefficiency separately, for analysis. Eqn 1 specified the model estimated.

$$\mathit{ln}Y_{it} = \alpha + \beta_l\, \mathit{ln}L_{it} + \beta_p\, \mathit{ln}P_{it} + \beta_k\, \mathit{ln}K_{it} + \beta_f\, \mathit{ln}F_{it} + \beta_m\, \mathit{ln}M_{it} + \beta_{mm}\, (\mathit{ln}M_{it})^2 + \beta_r\, \mathit{ln}R_{it} + \beta_{rr}\, (\mathit{ln}R_{it})^2 + v_{it} - u_{it} \qquad \text{(Eqn 1)}$$

Where Y_{it}: gross production value of country i at time t, L_{it}: agricultural land use of country i at time t, P_{it} : pesticides use in i country at time t, K_{it} : total labour use of agriculture in country i at time t, F_{it} : total fertilizer use in country i at time t, M_{it} :temperature in country i at time t, R_{it} : rainfall in country i at time t, α : constant, $\beta_{i:}$ parameters to be estimated, v_{it} = two-sided normal error, u_{it} : one-sided non-negative inefficiency and *ln* = natural logarithm.

FINDINGS

Table 1 reports the estimated parameters of the Stochastic Frontier (SF). All the variables except the variable "pesticides" was found to have a positive and significant effect on production. Since the dependent variable and the covariates are logarithms and scaled by their means, the first-order coefficients are interpretable as elasticities of output evaluated at the sample mean. The average technical efficiency of agriculture production in South Asia was found to be 75%, indicating a potential to increase agriculture production by 25%, without increasing input levels.

Table 1. Estimated parameters of the stochastic frontier production function

Variable	Coeff.	Std.Err.	P>z
lnLand	0.449	0.040	0.000**
lnFertilizer	0.013	0.027	0.629**
lnPesticide	-0.018	0.009	0.038**

lnLabour	0.388	0.034	0.000**
lnTemp	44.226	7.508	0.000**
$(\ln Temp)^2$	-7.511	1.225	0.000**
lnRain	5.921	0.915	0.000**
$(\ln Rain)^2$	-0.670	0.102	0.000**
Constant	-80.920	12.238	0.000**
Lambda	3.366	0.072	0.000**
Observations	163		
No. of groups	7		

*Temp: Temperature, Rain: Rainfall, Coeff.: Coefficient, ** Significant at 5% significance level*

Using the values obtained from the stochastic production function and IPCC's (fifth assessment report, AR5) predictions of the mean annual temperature and mean annual precipitation for the year 2050, the effect of climate change on agricultural production in South Asian region was obtained. The estimated impacts are presented in Table 2.

Table 2. Predicted changes in production by country

Country	*Mean annual Temperature increase (^{0}C) in 2050	*Mean annual Precipitation increase (mm) in 2050	2017 GP with mean TE (Million US$)	2050 GP with CC (Without change in mean TE) (Million US$)	2050 GP with CC and 100% TE (Million US$)	GP change due to CC (Million US$)	GP change with both climate and TE changes (Million US$)
Bangladesh	1.69	74.03	16910.91	7999.10	10271.05	-8911.8	-6639.86
Bhutan	1.90	72.08	398.46	581.92	747.20	183.46	348.74
India	1.89	51.56	267116.20	161885.40	207865	-105231.00	-59251.20
Maldives	1.41	180.30	25.10	6.55	8.41	-18.55	-16.69
Nepal	2.08	46.24	6834.27	12061.02	15486.65	5226.74	8652.38
Pakistan	2.34	12.36	45984.60	61441.59	78892.56	15457	32907.98
Sri Lanka	1.41	170.23	3636.90	1017.62	1306.65	-2619.28	-2330.25

*CC: Climate change, GP: Gross production, TE: Technical efficiency, *World Bank climate knowledge portal*

Table 2 reports the maximum possible reduction of climate change impact on agricultural gross production. The analysis was conducted based on the assumption of no changes in technology and other factors over the study period, from 2017 to 2050. However, it is noted that the impact could be lower than the estimated value if technology advancement increased the productivity of inputs used in the agriculture sector. However, if the inefficiencies in the production system can be eliminated and full efficiency is achieved (*i.e.* 100% technical efficiency), the negative impact of climate change on production can be reduced by 28.4% on average.

CONCLUSIONS

There is a negative impact of climate change on agriculture production in Bangladesh, Maldives, India, and Sri Lanka under the 'business as usual' scenario, while there is a positive effect on production in Bhutan, Nepal and Pakistan. As predicted by the model, an increase in technical efficiency could reduce the impact of climate change on some countries, while in other countries it could further increase production. Therefore, it is prudent for all countries to work towards increasing production efficiency through the dissemination of technology, training and developments related to agriculture (Smit *et al*., 2002). Thus, for the South Asian Region, enhancement in technical efficiency was found to be a formidable adaptation strategy to reduce the impact of climate change.

REFERENCES

Greene, W. (2005). Fixed and random effects in stochastic frontier models. *Journal of productivity analysis, 23*(1), 7-32.

Change, C. (2007). The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report. *International Panel on Climate Change, 4,* 2007.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., ... & van Ypserle, J. P. (2014). *Climate change 2014: synthesis report. Contribution of Working*

Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change (p. 151). Ipcc.

Smit, B., & Skinner, M. W. (2002). Adaptation options in agriculture to climate change: a typology. *Mitigation and adaptation strategies for global change*, *7*(1), 85-114.

Wassie, S. B. (2014). *Technical efficiency of major crops in Ethiopia: Stochastic frontier model* (Master's thesis) [Accessed on 11.10.2020].