CLIMATE VARIABILITY IMPACTS ON RICE CROP PRODUCTION IN PAKISTAN

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ABSTRACT:- The climate variability has affected the agriculture production all over the globe. This concern has motivated important changes in the field of research during the last decade. Climate changes are believed to have declining effects towards crop production in Pakistan. This study carries an empirical investigation of the effects of climate change on rice crop of Pakistan by employing Vector Auto Regression (VAR) model. Annual seasonal data of the climatic variables from 1980 to 2013 has been used. Results confirmed that rising mean maximum temperature would lead to reduction in rice production while increase in mean minimum temperature would be advantageous towards rice production. Variation in mean minimum temperature brought about seven percent increase in rice productivity as shown by Variance Decomposition. Mean precipitation and mean temperature would increase rice production but simulations scenarios for 2030 confirmed that much increase in rainfall and mean temperature in long run will negatively affect rice production in future. It is therefore important to follow adequate policy action to safeguard crop productions from disastrous effects. Development of varieties resistant to high temperatures as well as droughts will definitely enhance resilience of rice crop in Pakistan.

Key Words: Rice Crop; Agriculture; Climate Change; Temperature; Precipitation; Vector Auto Regression; Pakistan.

INTRODUCTION

The climate change issue has been more frightening towards the healthier expansion of both socio-economic and agriculture activities of any country (Adejuwon, 2004). Variation in local climate will force people's decision with penalties for their economic, personal and social environment ultimately affecting their livelihood (UNFCC, 2007). The scientific literature showed that in next decade high temperatures and varying rainfall intensities will be witnessed around the globe, hence translating their effects towards low agricultural output. Climate change is affecting crop yields in many low income countries where climate is a key determinant of agriculture productivity (Apata, 2010).

Previous evidence has proved that the current global warming has turned down agriculture production, which lead to a decrease in food production (Kurukulasuriya and Mendelsohn, 2008; IISD, 2009).

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Average global temperature for previous hundred years has augmented approximately by 0.8°C whereas changes in precipitation levels are not uniform. In humid and sub humid areas, monsoon rainfalls will increase, whereas coastal and hyper arid areas will encounter decrease in winter and summer rainfalls. Sea levels will rise upto 1 to 3 mm per year. These dangerous changes have emphasized the importance of mitigation and adaptation strategies for the developing economies (IPCC, 2014).

Agriculture sector is a direct climate dependent and acts as a vital part of the economic activity in developing economies. Climate change is likely to produce significant increase in amount of hydro events and is also expected to bring changes in temperature to extreme in the current century (Cline, 2008). Increase in temperatures is supposed to produce more floods which will damage crop yields. Favorable impacts can be traced out for relatively cooler growing season while unpleasant impacts will be recorded for regions that have already encountered increasing high temperatures (Mendelsohn, 2007).

Pakistan is situated in the subtropical region where climate is temperate. Summer and winter seasons are clearly defined and these two seasons are imperative for the most advantageous crop production. Rice is the second staple food of Pakistan after wheat and has an important share in the exports. Country's economic performance primarily depends on the agriculture production, so a minor deviation in the climate variables may bring significant alteration in the overall agriculture production. Pakistan's agriculture has witnessed number of mayhems since last 50 years. Some years witnessed slow growth, while the others have recorded healthier expansion. This sector is under the threat of climate change as drop in crop yields are due to variations in climate parameters. At the end of this century, rice crop is expected to encounter 15-20% reduction due to climate change which is twice of the impact on wheat crop (Iqbal et al., 2009).

More than 90% of the total acreage of rice is in Punjab province. In Sindh province, primary rice growing districts are Larkana and Jacobabad and the ad joint district of Nasirabad of Balochistan province. In Punjab, Gujranwala, Sheikhupura and Sialkot districts are primary producer of rice. Shikarpur, Dadu, Thatta, Badin in Sindh and Okara, Gujrat, Sargodha, Lahore, Kasur and Sahiwal districts of Punjab are secondary rice growing districts (Abedullah and Mushtaq, 2007).

Major crops of Pakistan are affected by changing climate. Siddiqui et al. (2012) found the susceptibility of four major crops of Punjab, Pakistan, when they were exposed to climatic changes. Temperature rise was found important for rice production at first, but when temperature increases beyond certain level, the increase became destructive towards its production. Similarly, Mahmood et al. (2012) evaluated the effects of increasing temperature and suggested that increase in temperature by 1.5°- 3°C will enhance the production while rainfall will hurt rice crop. Ajetomobi et al. (2010) concluded that increase in temperature component has minimized net revenue of dry land rice farms in Nigeria. Kayam et al. (2000) found that drop in rainfall will reduce wheat yield in Turkey. Peng et al. (2004) observed very close connection between rice yield and average minimum temperature. Rice production is exhausted by 10% when minimum temperature is increased by 1°C.

Climate change is being countered all over the world and also portraying its physical impacts everywhere. It is therefore necessary to evaluate the impact of these changes non crop sector of Pakistan. Being the cash crop of Pakistan, the impact of climate change on its production has been assessed in this study with the objective that empirical evaluation of the impact of temperature and precipitation changes (chief climate parameter) on rice production in Pakistan.

The study also intends to inspect the role of a number of other variables on rice production and will proposes some policy measures to arrest climate change effects on rice production in Pakistan.

MATERIALS AND METHOD

Vector Auto Regression (VAR) Model

It is functioned to grab the impact of all climatic and non-climatic variables in the model. At first, VAR model was operated in macroeconomics (Janjua et al., 2010). Sims (1980) introduced the VAR model. It ostensibly looks like simultaneous equation models wherein a number of endogenous variables are simultaneously considered and each endogenous variable is elucidated by its past values, and past values of all other endogenous variables, available in the model. Generally VAR model doesn't contain exogenous variable in the model. Sims (1980) provided VAR model on the foundation of true simultaneity among the exogenous and endogenous variables.

A VAR method offers comprehensive results and also decomposes the individual effect which in reply offers the individual impact of the climate variable on rice production in the country. The impulse response function is employed to confirm for the shocks in the variables and ultimately to see their impacts on the explanatory variables. Assessments made from VAR model are easy because Ordinay Least Square (OLS) method is used (Gujarati and Porter, 2009; Janjua et al., 2010).

VAR model in the matrix form is as follows:

$$\begin{array}{cccccccccc} Z_t & - & \mu & & \Gamma_1 & \Gamma_2 & -- & \Gamma_p & & Z_{t-1} & e_t \\ Z_{t-1} & & 0 & + & I & 0 & & 0 & + & Z_{t-2} + & 0 \\ -- & & -- & & -- & -- & -- & 0 & & -- & -- \\ Z_{t-k+1} & & 0 & & 0 & -- & I & 0 & & Z_{t+k} & 0 \end{array}$$

In form of equation the above model can be written as follows:

$$Z_t = \mu + \Gamma_1 Z_{t-1} + ---- + \Gamma_k Z_{t-k} + e_t$$

or

$$\Gamma(L) Z_t = \mu + e_t$$

where,

$\Gamma(L)$ = Matrix of polynomial in lag operator.

Specification of the Model

General equation including climatic variables and non-climatic variables of the study is:

Rice production = f (mean temperature, mean min. temperature, mean max. temperature, mean precipitation, cultivated area, fertilized used, credit used, water availability).

Econometric Form of the Model

$$PD = ß_1 + ß_2\,AC + ß_3\,AVT + ß_4\,CD +$$

$ß_5$ FR + $ß_6$ MINTEM + $ß_7$ MXTEM + $ß_7$ RAIN + $ß_8$ WA + μI

where,

PD = Production of rice crop
AC = Cultivated area
AVT = Mean temperature
CD = Agricultural loan
FR = Fertilizer used
MINTEM = Mean min. temperature
MXTEM = Mean max. temperature
RAIN = Mean precipitation
WA = Water availability

Variables and Data Requirements

Rice production data was collected from different issues of Agriculture Statistics of Pakistan and Economic Survey of Pakistan. Data was expressed in thousand ton. Data regarding the climatic variables i.e mean temperature , mean maximum temperature, mean minimum temperature, mean precipitaion was collected from Pakistan Meterological Department. Cultivated area under rice crop, fertilizer used, water availability and agriculture loan are the other explainatory variables used in the study. The data of these variables was also extracted from different editions of Economic Surveys of Pakistan.

RESULTS AND DISCUSSION

Vector Auto Regression (VAR) requires the testing the stationarity of the variables. For fulfilling this requirement Augmented Dickey Fuller (ADF) test was used (Dickey and Fuller, 1981). Mean temperature, mean min. temperature, mean max. temperature and mean precipitation were stationary at level, however fertilizer used, rice production, cultivated area under rice crop, water availability and fertilizer used were stationary at 1^{st} difference as evaluated by ADF Test.

Lag Selection Criteria for VAR Model

Values of Akaike Information Criterion (AIC) and Schwarz Criterion (SC) of the model enabled to work with a VAR model of lag two. The AIC and SWC value for present model are 15.37 and 16.25, respectively, which is lower than the other lag models tested, therefore, this model was selected. Thus two lag VAR model estimated the dynamics of rice production in Pakistan.

VAR Model

The results of VAR model estimation revealed that though t-statistics of some variables are significant while some are non-significant at conventional level of significance however F-statistic value of the model is very high and also statistically significant so the model is said to a best fit and this higher value has made all the lag terms significant (Table 1). The coefficient of determination R^2 value is 0.93 and adjusted coefficient of determination R^2 value is 0.83. Both the values are lying between 0 and 1 and also both the values are very high which also shows the goodness of the fit of the overall model.

Cholskey Impulse Response Function

Impulse response function traces the effect of one time shock on one of the innovation on current and future values of endogenous variable. The impulse response functions of the mean temperature and rice production demonstrated that a unit shock in the mean temperature will die out in the period three and remains

Table 1. Results of VAR equation

Parameter	PD	AVT	MINTEM	MXTEM	RAIN	WA
PD(-1)	0.216781	0.0000729	0.000491	-0.000564	-0.000403	-0.00284
PD(-2)	-0.082455	-0.000510	-0.000477	-0.000442	0.002418	-0.002950
AVT(-1)	-201.8721	0.108040	-0.203063	0.510892	-44.29020	2.281388
AVT(-2)	-1645.077	-0.378783	-0.345236	0.001458	-31.44283	12.25208
MINTEM(-1)	317.5305	0.692477	-0.101070	1.526184	-21.54851	1.667416
MINTEM(-2)	1330.958	0.182666	0.111873	-0.008025	9.597249	-1.952683
MXTEM(-1)	-674.2208	-0.440595	0.081354	-1.119414	34.78596	0.315091
MXTEM(-2)	408.6413	0.043904	-0.234017	-0.013406	8.471804	-3.341756
RAIN(-1)	-29.48764	-0.007880	-0.002756	-0.018194	-0.205144	0.021240
RAIN(-2)	-11.53409	-0.000556	-0.001531	-0.000759	-0.261167	0.078985
WA(-1)	2.271125	-0.022950	-0.008477	-0.035141	1.423450	0.325274
WA(-2)	38.89460	-0.004012	-0.025723	-0.001506	-0.358144	0.311420
R-squared	0.934591	0.495875	0.856136	0.489795	0.514129	0.987754
Adj. R Squard	0.836477	-0.260312	0.640341	-0.275514	-0.214678	0.969385
F-statistics	9.525573	0.655757	3.967350	0.639997	0.705439	53.77319
Akaike AIC	15.37221	1.334261	0.432374	2.226120	9.034243	4.591039
Schwarz	16.25110	2.213156	1.311269	3.105016	9.913139	5.469935
C	19738.59	27.63125	42.88772	34.50515	507.0972	-213.5823

VAR model estimation results to other variables: Agricultural loan (CD); fertilizers used (FR), cultivated area (AC) are not presented

negative till period five (Table 2). After period three it again becomes positive and remains positive till the tenth period and effects rice production positively. From the impulse response function of the mean precipitation it is evidently explicable that a single standard deviation shock in the mean rainfall will become negative in period two and again becomes positive in period three and four. The impulse response functions of mean minimum temperature and the rice production made it clear that a unit shock in the mean minimum temperature will also becomes negative in second period and a single unit shock in the mean maximum temperature will die out in period two. Non-climatic variables of the study i.e., cultivated land under rice crop, fertilizer used and water availability will become negative in period eight, two and three, respectively, while one unit shock in credit availability will die out in period seven.

Variance Decomposition

The intention of variance decomposition is to break up the variations

Table 2. Impulse Response Function

Period	PD	AVT	MINTEM	MXTEM	RAIN	WA
1	458.8860	0.000000	0.000000	0.000000	0.000000	0.000000
2	193.0700	94.80015	-119.7588	-94.56199	-120.0063	4.095417
3	320.1524	-228.0404	113.0276	42.10135	55.25553	11.01197
4	219.9906	-198.3989	-268.3817	-43.36467	0.888962	-62.72556
5	581.8444	-81.63539	-97.72670	-117.8663	-115.7066	-79.62272
6	339.7266	89.31047	-205.1776	-13.24842	-78.77917	-7.406293
7	353.1206	0.307590	-6.161055	-81.02423	-36.40017	12.07972
8	177.7763	69.82375	-54.14878	90.58391	-25.21080	26.39945
9	102.9457	141.5578	62.01071	-58.71410	-78.59029	65.51808
10	-92.74458	210.5983	87.18666	-8.307131	9.415443	130.6659

Results of other variables, namely credit disbursed (CD), fertilizers used (FR), cultivated area (AC) are not reported

on the endogenous variables in to component shocks to the VAR. A variation of about seven percent in period ten showed positive effect of mean temperature (Table 3). For mean maximum temperature about 2% variation produced was in period nine while in period ten it showed about 1.7% variation in rice production, showing the negative effect of increasing maximum temperature. Variation in mean precipitation in period ten was about 2% in rice production. The highest variation due to mean precipitation was approximately 3% in period three showing positive effect of mean precipitation on rice production. Mean minimum temperature showed a variation of approximately 6% in period ten showing a positive effect on rice production as confirmed from impulse response function. Variation in water availability of approximately 1.3% in rice production, explaining the positive effect of time availability of water for rice crop. Variation in fertilizer used was approximately 5% in period ten where it has negative effect on rice production. The highest of the variation explained in rice production due to fertilizer used was about 7% in period five where fertilizer off take positively affected rice production. So it is clear that increasing application of fertilizer in long run will decrease rice production. Credit availability and area under rice cultivation showed about 22% and 15% variations in rice production, respectively.

Simulations Scenarios for Year 2030

Different simulation scenarios measured for 2030 have been analyzed. In first scenario it was assumed that temperature increased from 2°C to 4°C, in second scenario temperature increased from 4°C to 5°C from the base year was taken. The effect was measured in percentage change in rice production. In scenario three, an increase in mean precipitation from 5% to 10% was considered, while in fourth scenario, an increase from 10% to 15% in rainfall from the

Table 3. Variance Decomposition

Period	S.E.	PD	AVT	MINTEM	MXTEM	RAIN	WA
1	458.8860	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	583.2014	72.87123	2.642293	4.216746	2.629033	4.234196	0.004931
3	810.7162	53.30457	9.279343	4.125819	1.630174	2.655671	0.021002
4	922.3794	46.86807	11.79519	11.65350	1.480398	2.051694	0.478680
5	1250.042	47.18329	6.848556	6.956112	1.695083	1.973850	0.666343
6	1400.220	43.49157	5.865108	7.691174	1.359928	1.889694	0.533871
7	1457.851	45.98805	5.410570	7.096899	1.563425	1.805586	0.499362
8	1477.386	46.22787	5.491795	7.044791	1.898288	1.787271	0.518173
9	1522.463	43.98820	6.035927	6.799702	1.936271	1.949471	0.673139
10	1606.090	39.86009	7.143098	6.404720	1.742558	1.755180	1.266753

Results of other variables i.e. credit disbursed (CD), fertilizers used (FR), cultivated area (AC) are not reported

base year was considered.

In first scenario temperature increase from 2° to 4° degree till 2030 will decrease rice production by 8% approximately. In second scenario when temperature increase from 4° to 5°, percentage decrease in rice production will increase and will be about 11.5%. In rainfall scenarios when rainfall increased from 5% to 10%, rice production will decrease by only 0.3 % and when it increased from 10% to 15% decrease was about 0.59%. It is clear that too much increase in temperature and also precipitation will affect the rice production negatively.

VAR Model results and climate change scenarios showed that increase in mean precipitation will last positive effects towards rice production in Pakistan. Subash and Mohan (2010) also proposed that rainfall will increase rice production. In long run when mean precipitation will increase too much, the negative effects would be encountered on rice production. Simulations for 2030 suggested that increase in precipitation by 10% to 15% from base year will decrease rice production by approximately 0.6%; this decrease is not significantly high but further increase will decrease rice production more severely. Mean minimum temperature will effect positively the rice production; however increase in mean maximum temperature will effect rice production negatively. Jayanta (2011), portrayed negative effects of increasing maximum temperature on rice yields in Bangladesh. Impulse response and variance decomposition also showed that variation due to mean temperature towards rice production was about 7% in period ten, which highlighted the positive effects but in long run scenario increa dangerous for rice production. For 2030 it was revealed that if mean temperature increases from 4°C to 5°C, the rice production would decrease approximately 11.5% from the base year i.e., 20se in mean temperature will be highly13. Subrahmanyam et al. (2009) and Ajetomobi et al. (2010) presented the negative effects of increasing mean temperature on rice production. The non-climatic variables will also affect the rice production as analysis provided us that too much increase in fertilizer application would also disturb rice production, while timely availability of the water will significantly add towards rice crop production.

It is thus concluded that this evolving risk of climatic change will stress the production of rice in Pakistan. Rainfall and mean temperature increase would be beneficial for healthier rice production but will produce negative effects if these climatic variables are increased too much in future decades as evident from the simulation scenarios. Increase in mean maximum temperature will impair rice production while increase in minimum temperature will raise rice production. Varieties which are tolerant to high temperature and drought should be developed so that losses could be avoided. The temperature component may shorten the growth periods; therefore the cultivating time should be adjusted accordingly. A Climate Smart rice production system should be maintained which is backed by comprehensive extension system.

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