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VULNERABILITY OF SUGARCANE CROP PRODUCTION TO CLIMATE CHANGE IN PAKISTAN: AN EMPIRICAL INVESTIGATION

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Abstract

Climate change and its impact on agriculture productivity has gain an important consideration in recent times. Pakistan is in that part of the world, which is the one most vulnerable region to the climate change. Sugarcane is one of the cash crop of Pakistan which contributes significantly towards total agriculture crop productions. It is therefore dire need to evaluate climate change impacts on sugarcane crop production. The current evaluated the impacts of climate change on sugarcane crop production of Pakistan using ARDL (Auto Regressive Distributed Lag) bound testing approach. The empirical results guided as that climate change has significant positive effect on sugarcane crop production of Pakistan. Increase in rainfall would increase sugarcane production. One percent increase in rainfall would increase sugarcane production by 0.17 percent in long run. effect on crop production of Pakistan. Increase in mean temperature also increased sugarcane crop productions. Fertilizer use and water availability in form of ground and canal has contributed positively towards sugarcane production.
Keywords: Climate Change, Sugarcane Production, ARDL, Pakistan

1. Introduction

The quantity of sugarcane produced globally has increased four times from that of what it was in 1965 reaching over 2 billion tons globally (Mckay etal., 2016). The crop contributes significantly towards its agriculture share in GDP in major sugarcane producing economies such as Pakistan, China and Brazil. Almost from three decades mostly researchers from agriculture sector are motivated to understand the economic costs of changes in climate.To better understand changes in variables like air temperature, and atmospheric carbon dioxide (CO2) those influence sugarcane production should be under concerned (Zhao, 2015).

Sugarcane is one of the cash crop of Pakistan which plays a significant role in the up lift of socioeconomic conditions of local farming community. Pakistan is 5th largest sugarcane producer country in the worldwhile stands at 8th position in terms of sugarcane consumption respectively in the world. this crop is widely grown in Sindh, Punjab and NWFP provinces. Average per hectare productivity of sugarcane in last few years isbetween 45 to 50 ton/hectare. It is poorest among 16 sugarcane producing agriculture countries.Cropcover roughly about5% of the crop area, consuming approximately 10 percent of total water availability hence, sugarcane is consuming a hugequantity of water available through Indus basin when compared to the area (Nazir etal., 2013).

2. Climate Change and Sugarcane Production in Pakistan

The climate of Pakistan generally favors crop productivity through-out the year but extreme weather hinders sugarcane production in Pakistan. With growing debate on climate change all over the globe and having a sufficient and authentic literature about climate change happenings, climate change is supposed to effect different sectors of economy however agriculture sector is one most vulnerable sector because it is totally dependent on natural climatic conditions. Any significant deviations from the climatic means are supposed to effect agriculture production negatively. Extreme weather conditions are very much evident for last ten years where erratic rainfalls withextreme summers has been encountered. Pakistan's agriculture sector is very much exposed to climate change because of its geographical location. Sugarcane is one of the important cash crop of Pakistan and is supposed to be affected by these climatic extremes. This crop is a high water requiring crop so climate change would definitely affect this crop. The question arises that would be the effects of climate change on sugarcane production of Pakistan. Either climatic changes are good or bad for sugarcane production. We need to look in to these outcomes, so a proper long-term policy could be designed based on empirical examination.

3. Material and Methods

3.1 Data Description

The current study used total of six variables out of which climatic variables are mean temperature, mean rainfall and water availability while area under cotton crop, fertilizer used for sugarcane crop are the non-climatic variables. sugarcane production is dependent variable measured in metric tons. mean temperature is expressed in Celsius scale, mean rainfall taken in millimeters, water availability is measured in million-acre feet (MAF), while area under cotton production is in thousands hectare, fertilizer in thousand nutrients tons. The data of climatic variables is collected from Pakistan Meteorological Department,the data of sugarcaneproduction, area under sugarcane crop production were collected from different editions of Pakistan economic survey while the data of fertilizer used for cotton received from National fertilizer development center (NFDC).

3.2 Econometric Model

The study has used Auto Regressive distributive lag model first introduced by Pesaran et al. (2001). The basic assumption to use ARDL is that all variable should be stationary at same level or at 1st difference. None of the variable should be stationary at level 2.In this study,ARDL is best suitable method to meet our objectivesto check the impact on sugarcane production in the both long and short run. It will also provide coefficients of cointegration. This technique is generalized by Pesaran and Pesaran(1997), Pesran and Smith (1998), Pesaran and Shin (1999) and Pesaran *etal*., (2001) Known as Autoregressive Distributed Lag model (ARDL). The ARDL model is preferable to the other co-integration models for the reason that the model does not involve the pre-testing variables, which means the test on existence of relationship between variables in level can be applicable irrespective of whether the underlying repressors are purely I(0), purely I(1) or fractionally co-integrated Pesaran and Pesaran(1997). Janjua *et al.,* (2014) used ARDL model to check the impact of climate change on wheat crop production. Odhiambo (2009)examined the relationship between energy consumption and growth of economy using Auto Regressive Lag Distributed model.

General equation of Auto Regressive distributive lag model is

$$Y_t = \alpha_0 + \Sigma\alpha_i Y_{t-i} + \Sigma\beta_i X_{t-i} + U_t \quad (1)$$

Whereas the general correlation model of Auto Regressive distributive lag model is

$$\Delta Y_t = \alpha_0 + \Sigma\beta_j Y_{t-i} + \Sigma\beta_j X_{t-j} + \psi ECM_{t-1} + U_t \quad (2)$$

In the equation ψ show the speed of adjustment parameter and ψ must be negative for significant of error correction model (ECM). The relationship between dependent and independent variables are as follow, Sugarcane Production = f (AVGMT$_{emp}$, AVGR$_{ainfall}$, , A$_{rea}$ under Sugarcane crop, F$_{ertilizer}$ Used, Water Avaliability (3)

Log transformation has been applied which gave us the proficient and suitable results as compared to the simpler form.

$lnS_{ugarcane}=\beta_1+\beta_2 lnAvgTemp+\beta_3 lnAvgR_{ainfall}+\beta_4 A_{rea}$under sugarcane crop$+\beta_5 lnF_{ertilizer}+\beta_6$Water avalibility (4)

Auto Regressive distributive lag model for the study to find long run relationship between the variables are $lnS_{ugercane}= \alpha_0+\Sigma\alpha_1 lnSugarcane_{t-i}+\Sigma\alpha_2 lnAvgTemp_{t-i}+\Sigma\alpha_3 lnAvgRainfall_{t-i}+\Sigma\alpha_4 lnArea_{t-i}+\Sigma\alpha_5 lnFertilizer_{t-I}$ (5)

Auto Regressive distributive lag model for short run is

$\Delta lnS_{ugercane}= \beta_0+\Sigma\beta_1\Delta lnSugercane_{t-i}+\Sigma\beta_2\Delta lnAvgTemp_{t-i}+\Sigma\beta_3\Delta lnRainfall_{t-i}+\Sigma\beta_4\Delta lnArea_{t-i}+\Sigma\beta_5\Delta lnFertilizer_{t-i}+$ (6)

Where β_i (i=1, 2, 3 ……………………., 9) are all regression coefficients.

3.3 Bound Testing Model

Bound testing is to check the long-run relationship amongst the dependent and independent variables. In first step the null hypothesis of no co-integration $H_0:\delta_1=\delta_2=\delta_3=\delta_4=\delta_5=0$ amongst the variables is checked against the substitute hypothesis $H_1: \delta_1\neq \delta_2\neq \delta_3\neq \delta_4\neq \delta_5\neq 0$ of co-integration amongst the variables.F-Statistics is use to test the joint significance of lag levels of the variables in a conditional unrestricted equilibrium ECM (error correction model) Pesaran*et al*. (2001). The distribution of F-statistics is non-standard regardless of where the variables are I (0) or I (1) or partially co-integrated. Pesaran*et al*. (2001) devised two sets of critical values. One set assume that the variables are I (0), whether the other set to be assume that all the variables are at first difference.

3.4 CUSUM & CUSUMSQ Test

After the development of long-run relationship of variables, CUSUM and SUSUMQ test has been applied. This test is developed by Brown *et al*. (1975). it checks the R(sqr) for ARDL as suggested by Pesaran*et al*. (2001). Both tests are combined on the residuals of the error correction model and fabricate results in graphical form.

4. Results and Discussion

4.1 Unit Root Testing

Before applying auto regressive distributed lag bound testing approach, stationarity of the variables has been checked. The null hypothesis stated that the variables have unit root i.e. the variable is non-stationary and the alternative hypothesis is that the variables have no unit root it means that the variable is stationary.

Table 1. ADF Unit Root Test

Variables	**At Level**	**At First Difference**	**Stationarity Result**
Average.Temperature	-1.9020	-9.1897	First Difference
Average Rain Fall	-1.6844	-11.6708	First Difference
Fertilizer Used	-2.0461	-4.0977	First Difference
Area under sugarcane crop	-0.79419	-5.178	First Difference
Water Availability	-3.0631	-7.6839	At Level
Sugarcane Production	-0.5073	-7.3092	First Difference

The null hypothesis will be accepted if the value of ADF statistics is great or in between the critical values and the null hypothesis is rejected if the ADF statistics value is less than the critical value and alternative hypothesis will be accepted. The table (1) shows the results of unit root testing, show that the mean temperature, average rain, fertilizer used, area under sugarcane crop and sugarcane production are stationary at first difference while water availability is stationary at levels.

4.2 ARDL Model

To select the appropriate lags for best ARDL model we used Akaike information Criterion (AIC) and Schwarz information criterion (SIC). The lowest values of AIC and SIC directed us to use appropriate model for the study. LnPrd denote annual production of sugercane, Lnrn represent mean rainfall, LnMt denote mean maximum temperature, Lnfrt denote fertilizer used , Lnar represent area under cotton crop and lnrn represents the average rainfall.For checking long run co-integration among variables we run ARDL bound testing. Table (3) shows the results of bound testing which clearly show that the F-statistic value that is -7.4640 is greater than the upper bound value that is 3.79. So, in this case we reject the null hypothesis of having no long run co-integration against alternative hypothesis of having long-run co-integration. Therefore, it is concluded that there exists long run co-integration among the variables.

Table 2. ARDL Bound Testing

F-static	Critical Value	Lower Bound	Upper Bound	Result
-7.464077	1%	3.41	4.68	Co-Integration exists
	5%	2.62	3.79	
	10%	2.26	3.35	

Table (3) showed the results of long run elasticities of sugarcane production and independent variables i.e climatic and non-climatic variables. In Table (3), the t-statistic value for average temperature is 5.299, which is statistically significant. A one percent increase in average temperature will increase sugarcane production by 1.47 percent. Average rainfall also showed statistically significant results. It was observed that a one percent increase in average rainfall would increase sugarcane production by 0.17 percent, showing a positive effect of increase in rain fall on sugarcaneproduction. One of the important variable of the study i.e. water availability also showed significant impacts on sugarcane crop production. One percent increase in water availability would increase sugarcane production by 0.41 percent, also showing the positive affect of increasing water availability. Fertilizer use and area under the sugarcane crop production also showed significant positive effect on the production of sugarcane crop. If there is one percent increase in fertilizer use and area under sugarcane crop would increase sugarcane production by 0.11 and 1.13 percent respectively.In table 4 the error correction coefficient (– 1.61) has the expected negative sign and is highly significant. This helps reinforce the finding of a long run relationship among the variables in the model. In addition, it also indicates a very speedy convergence to long-run equilibrium of the model.

From the above mentioned empirical results it has been gathered that that the climate change has imparted significant impacts on sugarcane production. Current study doesn’t find any significant negative effects of the climatic variables as evident from the results that are reported above. Sugarcane crop is a high water requiring crop so increase in rainfall would definitely increase sugarcane production. water availability variable which includes the canal water and underground water has shown significant positive effect on sugarcane production. Timely and sufficient availability of canal water is very important to further increase sugarcane production (Deressa *et al*., 2010) showed that sugarcane production is less sensitive to average rainfall. Study also doesn’t find any negative significant effect of increasing temperature, so this study guided us in way that if the temperature increases with more rainfalls and more water in the canals, the sugarcane production would increase in the long run. (Ali *et al.,* 2017) evaluated that increase in temperature will increase sugarcane production. Non- climatic variables i.e. Fertilizer use enhances the sugarcane production in both short and long run. (Sidiqui *et al*., 2013) also deducted in his study that increase in fertilizer use would affect sugarcane production positively. Similarly area under crop production also contributed positively towards sugarcane production.

Table 3. ARDL Long Run Form

Variable	Co-efficient	Std. Error	t-Statistics	Prob.
Lnmt	1.474943	0.278304	5.299750	0.0000*
Lnfrt	0.115349	0.027594	4.180149	0.0005*
Lnar	1.138710	0.058026	19.624042	0.0000*
Lnwa	0.416514	0.097911	4.253986	0.0004*
Lnrn	0.172642	0.021020	8.213335	0.0000*

Not:* significant at 1% level of significance ** significant at 5% level of significance

Table 4. ARDL Short Run Form

Variable	Co-efficient	Std. Error	t-Statistics	Prob.
D(Lnmt)	1.444850	0.371468	3.889567	0.0009
D(Lnfrt)	0.186652	0.042846	4.356384	0.0003
D(Lnar)	1.250923	0.093447	13.386378	0.0000
D(Lnwa)	0.673984	0.195451	3.448351	0.0025
D(Lnrn)	0.092154	0.026365	3.495303	0.0023
D(Lnrn(-1))	-0.056543	0.027524	-2.054270	0.0533
CointEq(-1)	-1.618153	0.218823	-7.394790	0.0000

Not:* significant at 1% level of significance ** significant at 5% level of significance
*** significant at 10 % level of significance

4.3 Cumulative Sum and Cumulative Sum of Squares

It is to be applied to check the R (sqr) of ARDL model used by Pesaran*et al*. (2001). CUSUM and CUSUMQ have two graph with 5% critical value. If the model is in between the 5% critical values then we can say that the model is stable and goodness for fit. Figure (1) and (2) showed the results of CUSUM and CUSUMQ test respectively. It shows that model under study is stable.

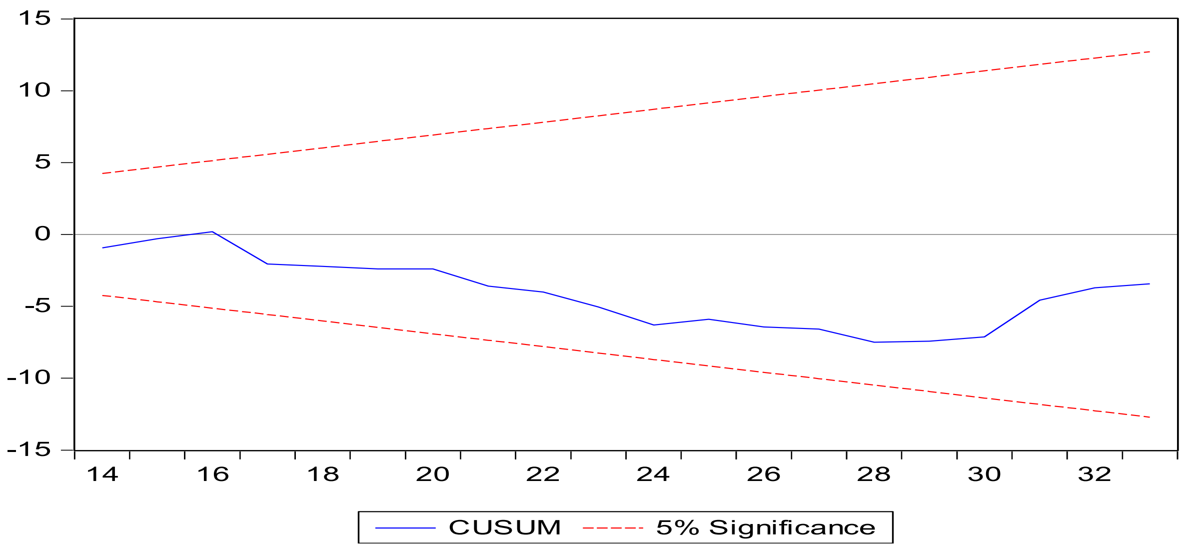

Figure 1. CUSUM Test

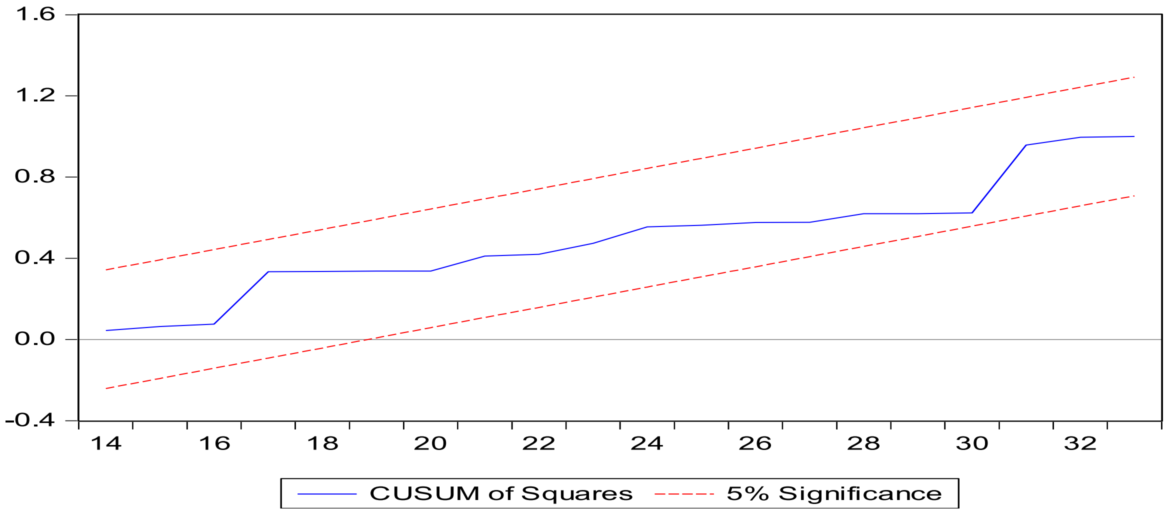

Figure 1. CUSUMQ Test

5.4 Diagnostic Tests

Serial Correlation LM Test (χ)	0.661 (0.718)
Heteroscedasticity Test (χ)	6.99 (0.726)

Serial Correlation LM test and Heteroscedasticity test reported above confirmed that there was no problem of autocorrelation and Heteroscedasticity in our model.

6. Conclusion

From empirical examination of the climate change impact on sugarcane crop production of Pakistan the study concluded that climatic changes are not threating to the sugarcane crop production of Pakistan. Almost all the climatic variables were found to have positive impacts on sugarcane crop production. Sugarcane cultivation requires a tropical or subtropical climate so increase in both the rainfall and temperature were contributing positively towards overall sugarcane production. Water that is available to the sugarcane crop throughout the crop season provided in the form of canal water, river flow and tube well water also found to be a critical factor towards increased sugarcane production. Fertilizer used also contributed towards increased sugarcane production. As rainfall and water availability was found to be the most critical factors to increase sugarcane production the study suggests a revisited water policy for Pakistan in context of current climate change events. A lot of river flow is wasted throughout the years due to no water storage which also reduces the water availability. Study considers it as the most important policy derivative for having a better crop production in future.

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