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Economic Impact of Climate Change on Wheat and Cotton in Major Districts of Punjab

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Abstract: The long run impact of climate change on the productivity of major crops in the districts of Punjab is analyzed for the time period of 1970 to 2010. This study used deviations from average maximum annual temperature and deviations from average rainfall are used as indicators for climate change. While other variables include sale price, fertilizer use and number of tube wells. In order to incorporate long timer periods, this study used Panel ARDL model. The results show that cotton productivity is more positively sensitive to price changes; an increase in temperature, tube wells and fertilizers while wheat productivity is more positively sensitive to the rainfall in the long run. Consequently, in the short run, wheat productivity equilibrium is faster converging. Hence deviations from average rainfall are harmful to cotton crop in the long run and cotton & wheat in the short run, while deviations in maximum temperature is only harmful for cotton crop in the short run.
Keywords: Climate Change; Agricultural productivity; Panel Co-integration; Panel ARDL; Punjab Districts.

1. Introduction

Stability in production of food within the country is necessary for long term food security and steady development process. For low development countries, consistent supply of food provides them foundation to grow and compete in international markets. For the case of Pakistan, agriculture sector contributes to 21% of gross domestic product, 18% of exports and 45% of the labor force.

Considering the many benefits of the agricultural sector, it does not come easy. There are many challenges that the agriculture sector faces, on top of this list is the effect of climate change. Karl (2009) explains the case of USA where a rise in temperature and humidity lead to foster weeds, pests and fungi, which is costing farmers extra $11 billion per year to stabilize the crop production. Today, many countries on the globe are vulnerable to the climate change and Pakistan is one among those countries exposed to it (Minister of Climate Change). Change in temperature, and unpredictable precipitation serious problem for agricultural sector. Out of the 10 countries which are most affected by the climate based disasters during 1994 – 2013 includes 5 from the Asia – Pacific Region as per Global Climate Risk Index 2015 (APP, 2015). Zahid and Rasul (2011) highlighted that overall summers are becoming warmer in Pakistan, which could adversely affect crop production. This increased temperatures will likely increase the usage of water by industrial and agricultural users.

Climate change has a vital role in food security. Food security is defined as when all people at all times have access to nutritious, sufficient and safe food to meet their food requirements and to maintain a healthy and active life (FAO, 1996). Food security involves production, accessibility and distributions. Food Security also sees that those who produce our food is able to earn decently from processing, producing, transporting and serving the food. The studies show that for food production temperature and precipitation have significant impact (Janjua *et al.*, 2010; Mahmood *et al.*, 2012), some studies found unfavorable effects of climate change on agricultural productivity (Lobell and Field, 2007; You *et al.*, 2009).

In most of the developing economies, low incomes are causing stagnant production of food, hence governments are forced to boost the agricultural output increase the sale prices. This approach usually motivates the farmers to put extra effort in production and increase in the output of agricultural products.

1.1. Agricultural Productivity

In 1961 3.5 billion world populations were cropping by using 1.37 billion hectares of the land. Later on when world population doubled to 7 billion, while land under use increased only by 12 percent which is 1.53 billion hectares. Previously world was concerned that by tripling of world population there will be a food shortage, but after tripling world population agriculture has increased globally. World started receiving more outputs from the same

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resources. At the global level the long run trend from 1900 food has been increasing in fact. Adjusted dollars in inflation, food rates reduced by one percent over the year of the 20th century, but something changed over the past decade. In 2002 real prices of food started increasing and the shock was not momentary one. In 2008, 2010, and 2012 agricultural prices of commodity sharply increased. Factors of demand side like growth of population increase in meat per capita consumption and weather created food shocks. Events like 2012 North American drought are major causes of higher prices of food in recent years. But the continuation of rising prices of commodity has brought concerns that either agriculture is facing new stress on growth. In fact, for major grains as like wheat and rice, rates of average growth yield have slow about 2 percent every year from 1970s to 1980s and about 1 percent every year from 1990 (Boserup, 2005; International Food Policy Research Institute, 2015).

For the measurement of the effect of climate, maximum temperature reported can be used. Temperature maximum is important because all functionalities of crops dependent on maximum temperature so that crops can develop their growths. In Maximum temperature many crops can have rapid growth, but their productivity can be reduced. If their higher growth period is not complemented with water and fertilizer supply (USGCRP, 2009).

Precipitation is another climatic variable which influences agricultural productivity. Annual precipitation is measured in millimeters. Precipitation plays vital role in agriculture and agricultural crop's life depend on water. In Pakistan Indus Basin receives 40 million acre feet of water from precipitation yearly. Essentially, there are two primary wellsprings of precipitations in Pakistan i.e. Monsoons and Western aggravations and around 70 percent of yearly rainstorm precipitations happens from July to September (Ahmed *et al.*, 2007).

Number of tube wells indicates water availability for farmers. Water availability is great concern for a farmer at the time of sowing the seeds until harvest season. Number of tube wells include private and government owned tube wells and it is used for irrigation purposes in agriculture. Total area irrigated in Pakistan is 18.63 million hectares and total area irrigated in Punjab region is 14.88 million hectares, total area irrigated by tube wells in Pakistan is 3.71 million hectares (19.91% of total) and a total area of Punjab region irrigated by tube wells is 2.82 million hectares (18.95% of total) (Pakistan Bureau of Statistics, 2014; Siddiqi, 2008). The previous green revolution experience that Pakistan had was contributed because of fertilizers, improved seed and increased water supply (Ahmad, 2004).

Fertilizer is basically a chemical or natural substance used on land to boost its fertility. Most important types of fertilizer are mixture of carbon, hydrogen and oxygen. Land which has been frequently cropped, usually gets infertile over the time and exhibits fall in productivity. The consumption of fertilizer in Pakistan is 4089.1 thousand nutrient tons and its 2803.9 thousand nutrient tons in the Punjab region in 2014 (National Fertilizer Development Center, 2014).

Studies by United Nations agencies on food price variation and natural hazards in Pakistan has found that wheat consumption was decreasing as a result of high food prices and falling income (FAO, 2005).

Following to introduction section, is a literature review section which will be explored through the empirical studies regarding the role of independent variables. After this is the methodology section which provides the model and the data descriptive, this is followed by the estimation of the model using the data. At the end the conclusion and policy implication will be illustrated.

1.2. Objective of the Study

Considering the fact that Agriculture is the backbone of Pakistan, hence studying the determinants of agricultural productivity is crucial. In this case, the objective of the study the productivity of the major crops (i.e. wheat and cotton) using the 30 year each, data of 12 major districts of Punjab. Primary determinants include the indicators of climate change like temperature and rainfall, secondary determinant include the sale price and control variables include the fertilizer use and the number of tube wells. Since each district includes 30 years of data, this study will use a panel ARDL approach to determine the short run and long run effects.

2. Literature Review

Wheat is one of the important staples on the globe, which consists high quality fiber and protein that consists of carbohydrates in starch form (Bayer Crop Science). Wheat is the most critical crop in Pakistan; it is sown in rabbi (winter) season and harvested in kharif (spring) season. It is grown under different climates and soils and temperate regions are more compatible for wheat production under rainfall of 30 and 90 centimeters. Total area cultivated under whet production in Pakistan is 9199.3 thousand hectares and total wheat production 25979.4 thousand tons in 2014 (Pakistan Bureau of Statistics, 2014).

Siddiqui *et al.* (2012) concluded that increase in the temperature in the short run hampers wheat productivity while it boosts productivity in the long run. While an increase in rainfall harms wheat in the short run as well as in the long run. Hanif *et al.* (2010) studied two harvesting season kharif and rabbi, and their results from rainfall in kharif season has significant positive effects on land prices, because of an increase in the productivity of the crops. Mendelsohn *et al.* (1996) use the Ricardian model to predict the farm value against changing temperatures for USA. This showed that the effect of temperature followed inverted U shape even for fertile lands.

Janjua *et al.* (2010) advocated that wheat crop is not sensitive to changes in climate in the case of Pakistan. Sultana *et al.* (2009) compared the wheat crops for ten locals of Pakistan based on climatic zones. Overall increase in temperature leads to decrease in the productivity.

(Cotton) is the most important fiber producing crops on the globe. It produces fiber for textile industries and also feeds oil industries with its seeds which are rich of oil. It is also considered as a cash crop for many underdeveloped cotton producing countries and main source of income for them. This crop is grown in tropical, sup-tropical and temperate climates. It is sensitive to temperature which requires higher than 20 degrees. Punjab cotton production mainly takes place around the Indus River, where water from the glaciers is vital for this crop (Raza, 2009). Siddiqui *et al.* (2012) showed that the change in temperature and rainfall has negative impact on cotton productivity.

Anwar *et al.* (2007) investigates that worldwide temperature variation may decrease the crop productivity by 29%. Hussain and Mudasser (2007) studied two districts of Pakistan, first Sawat 960 meters above sea level and other is Chitral 1500 meters, here the effect of increase in temperature of crops was positive in Chitral and negative in Sawat.

Kotschi and Müller-Sämann (2004) stated that organic way of cropping can be opted to dampen the effects of environmental change. Reidsma *et al.* (2010) indicated that if the farmers do not have alternative crops to rotate then the harmful effect of climate will be translated into farmer wages.

Vanhove and Van Damme (2011) concluded that if the climate change is not adapted, then by 2050 average yield of wheat will be reduced by 10%. It is expected that the temperature will rise 2 degrees Celsius and the rainfall will change about 300 mm per year, so there need to focus on crop sustainability as by 2050 there will be 240 million hungry people in sub-Sahara Africa only. Zhai and Zhuang (2009) forecasted the weather change in Southeast Asia and proved that the under developing economies in this region will experience loss in their agriculture. By 2080 the agricultural output will be reduced by 17.3%. Since these economies are dependent on crops they will experience fall in welfare and incomes.

Darwin *et al.* (1995) studied the crop productivity in Canada. They proposed that increase in temperatures in alpine and arctic regions is prone to expand the land's quantity suitable for productivity of agriculture while an increase in the temperature in dry areas lead to lessen soil wetness. Xiao *et al.* (2008) evaluated the effect of temperature between two areas which are different in terms of the altitude as compared to the sea level. The results revealed that in higher altitudes increase in temperature is beneficial to the crop productivity.

Lobell *et al.* (2005) studied the effect of temperature for the wheat crops in Mexico for the case of 1988 to 2002. In these two decades the rise in temperature lead to 25% rises in the productivity of wheat.

Zhang and Nearing (2005) showed though the controlled study in the central state of Oklahoma and showed that a decrease in the rainfall has a higher detrimental impact on crops while the increase in the increase in the temperature can be countered little bit using the proper fertilization of crops.

Wolf *et al.* (1996) studied the wheat crops in Europe and found that extreme temperatures will lead to a reduction in the productivity.

All the previously studied only checked the effect of increase in temperature or rainfall on the crops, but since the level of rainfall or temperature can be different in different regions, so its coefficient cannot be compared. Hence this study has use deviations from the mean, which will represent the effect of volatility of climate on crops.

3. Methodological Framework

3.1. Data

In order to evaluate the impact of climate change on the cotton and wheat productivity, 12 major districts of Punjab Pakistan are selected.

- **i.** Lahore
- **ii.** Multan
- **iii.** Sargodha
- **iv.** Sialkot
- **v.** Faisalabad
- **vi.** Rawalpindi
- **vii.** Bahawalpur
- **viii.** Bahawalnagar
- **ix.** Kasur
- **x.** Rahim Yar Khan
- **xi.** Mianwali
- **xii.** Jhelum

For these districts the data for the years of 1970 to 2010 is extracted from the annual reports of Punjab Bureau of Statistic (2009). Since the number of years per district is more than 20 and more than the cross sections, hence this study will use panel cointegration approach (Eberhardt, 2011; Pedroni, 2008).

3.2. Estimation Model

This study will construct the productivity model for the wheat and cotton crop as they are two of the major crops of Pakistan, covering both kharif and rabbi season.

$PW_{it} = \beta_i + \beta_1 TMAD_{it} + \beta_2 TMID_{it} + \beta_3 PRD_{it} + \beta_4 TW_{it} + \beta_5 FER_{it} + \beta_6 WPR_{it} + \varepsilon_t$ -- (Wheat Model)

$PC_{it} = \alpha_i + \alpha_1 TMAD_{it} + \alpha_2 TMID_{it} + \alpha_3 PRD_{it} + \alpha_4 TW_{it} + \alpha_5 FER_{it} + \alpha_6 CPR_{it} + \mu_t$ --
(Cotton Model)

I is number of years from 1970 to 2010 t is number of twelve districts of Punjab region

Above are the basic equations for the wheat and cotton model, but since these variables depict non stationary nature, they form equilibrium which is influenced by their past disequilibrium. In order to incorporate this dynamic, this study will use the panel ARDL model in which the long run model is same for all cross sections, but the short run model is allowed to vary across the cross sections.

$\Delta PW_{it} = \beta_i + \beta_{11i}\Delta TMAD_{it} + \beta_{12i}\Delta TMID_{it} + \beta_{13i}\Delta PRD_{it} + \beta_{14i}\Delta TW_{it} + \beta_{15i}\Delta FER_{it} + \beta_{16i}\Delta WPR_{it} - \delta(PW_{it} - \beta_1 TMAD_{it} - \beta_2 TMID_{it} - \beta_3 PRD_{it} - \beta_4 TW_{it} - \beta_5 FER_{it} - \beta_6 WPR_{it}) + \varepsilon_t'$ --
(Wheat ARDL model)

$\Delta CW_{it} = \alpha_i + \alpha_{11i}\Delta TMAD_{it} + \alpha_{12i}\Delta TMID_{it} + \alpha_{13i}\Delta PRD_{it} + \alpha_{14i}\Delta TW_{it} + \alpha_{15i}\Delta FER_{it} + \alpha_{16i}\Delta CPR_{it} - \theta(CW_{it} - \alpha_1 TMAD_{it} - \alpha_2 TMID_{it} - \alpha_3 PRD_{it} - \alpha_4 TW_{it} - \alpha_5 FER_{it} - \alpha_6 CPR_{it}) + \mu_t'$ --
(Cotton ARDL model)

Above equations is the panel ARDL specification for wheat and cotton model, the coefficients θ and δ will depict the error adjustment terms, while coefficients inside the parenthesis are long run coefficients and outside are the short run coefficients.

3.2.1. Dependent Variables

PW = Wheat productivity
PC = Cotton productivity

3.2.2. Independent variables

TMAD = Temperature maximum deviation
PRD = Log of Precipitation deviations
TW = Log of number of tube wells
FER = Log of sale of fertilizers
WPR = Log of wheat price
CPR = Log of cotton price

3.3. Descriptive Statistics

Table 1 of descriptive statistics reveals that all of the variables included in the model are non-normal, which are only allowed for estimation as per central limit theorem. While variables other than the fertilizer use have kurtosis values, not equal to 3 which means that either the variable have too many outlier (case of kurtosis > 3) or too few outliers (case of kurtosis < 3), this advocates the case of using heterogeneous intercepts in panel data model instead of pooled ordinary least squares. Here we can see that only the productivity of cotton (PC) and the deviations of maximum temperature have standard deviation higher than the mean value, which shows that these variables are over-dispersed, this means that these variables are not following a similar pattern in each district.

Table-1. Descriptive stats

Statistics	PC	PW	LWPR	LCPR	FER	LPRD2	TMAD	TW
Mean	4.08	1.66	4.67	5.37	10.17	6.03	0.00	8.70
Median	1.83	1.75	4.50	5.03	10.40	6.11	0.03	8.79
Maximum	138.33	3.47	6.86	6.59	12.37	7.21	3.64	11.43
Minimum	0.00	0.14	2.90	4.72	6.91	-3.19	-14.14	4.49
Std. Dev.	14.65	0.75	1.04	0.58	1.34	0.72	1.22	1.27
Skewness	6.85	-0.27	0.06	0.88	-0.76	-6.57	-5.45	-0.81
Kurtosis	51.23	2.20	2.09	2.37	2.95	76.18	60.72	3.61
Jarque – Bera	39483.90	17.31	16.71	41.66	46.39	88900.60	55921.66	52.72
Probability	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	1537.97	749.31	2242.34	1545.45	4942.38	2329.10	0.53	3688.92
Sum Sq. Dev.	80681.82	253.12	513.70	95.78	868.67	199.38	574.54	686.22
Observations	377.00	451.00	480.00	288.00	486.00	386.00	389.00	424.00

Table 2 provides the multicollinearity diagnostics; here 5 different criteria, are provided which can indicate the presence of the multicollinearity in the model. Here we can see that none of the Eigen value is near to 0, none of the condition index value is above 15, none of VIF is more than 10, none of tolerance value is less than 0.10 and none of the R square of auxiliary regression is higher than 0.7, all of these indicators are within the thresholds hence we can say that there is no multicollinearity (Belsley *et al.*, 1980; Belsley, 1991; Gujarati and Porter, 2004; Theil, 1971).

Table-2. Multicollinearity diagnostics

Wheat model					
Variables	**Eigen value**	**C Index**	**VIF**	**Tolerance**	$R^2_{xi,X}$
WPR	1.98	1.00	1.23	0.81	0.19
TMAD	1.19	1.29	1.04	0.96	0.04
PRD	0.84	1.53	1.05	0.95	0.05
FER	0.67	1.72	1.88	0.53	0.47
TW	0.31	2.51	1.99	0.50	0.50
Cotton Model					
CPR	1.91	1.00	1.10	0.90	0.09
TMAD	1.15	1.28	1.03	0.97	0.03
PRD	0.92	1.44	1.10	0.91	0.09
FER	0.76	1.58	2.18	0.46	0.54
TW	0.25	2.77	2.41	0.41	0.58

4. Estimation

The following section will estimate the data according to the estimation model provided in order to achieve the objectives of the study.

4.1. Unit Root Test

Gujarati and Porter (2004) specify one OLS assumption relevant to the data which has long time series component, the assumption is 'data must be fixed in repeated sampling', this in other words mean that variables must be stationary in order to use the OLS model. Table 3 below shows 4 types of panel unit root tests which includes LLC (Levin *et al.*, 2002), IPS (Im *et al.*, 2003) and Fisher based unit root tests. Here the null hypothesis is that the variable is non stationary as compared to the alternative hypothesis of variable being stationary. Table 3 below provides the p values in parenthesis which will be used to decide. From the results in table 3 we can say that variable WPR, CPR, PW, PC and TW are non-stationary while others are stationary at level. Since variables are in mixed order of integration, this implies using ARDL cointegration based model.

Table-3. Panel Unit Root Tests

Panel Unit Root Test				
	Levine, Lin & Chu	Im, Pesaran & Shin	ADF - Fisher	PP - Fisher
Variables	Statistic (P value)	Statistic (P value)	Statistic (P value)	Statistic (P value)
PW	-3.20 (0.00)*	-1.06 (0.14)	24.41 (0.44)	36.42 (0.05)*
PC	-1.27 (0.10)	-1.25 (0.10)	33.97 (0.05)*	36.12 (0.03)*
TMAD	-8.39 (0.00)*	-9.66 (0.00)*	128.5 (0.00)*	178.4 (0.00)*
PRD	-2.74 (0.00)*	-7.99 (0.00)*	102.6 (0.00)*	196.7 (0.00)*
TW	-1.00 (0.16)	0.56 (0.71)	27.32 (0.29)	39.64 (0.02)*
FER	-5.62 (0.00)*	-2.17 (0.01)*	45.56 (0.00)*	173.5 (0.00)*
WPR	4.69 (1.00)	8.99 (1.00)	0.19 (1.00)	0.15 (1.00)
CPR	10.38 (1.00)	9.87 (1.00)	0.03 (1.00)	0.00 (1.00)

* significant at 10%

4.2. Panel Cointegration Tests

Since few of the variables are non-stationary, this could lead to spurious results unless cointegration between the variables is confirmed. In table 4, Pedroni (1999;2004) and Kao (1999) residual based panel cointegration tests are provided, for these tests the null hypothesis is that there is no cointegration. Using the p values in parenthesis we can conclude that majority of tests are indicating the presence of cointegration between the variables for wheat and cotton model. This allows us to use the non-stationary variables in the estimation process.

Table-4. Panel Cointegration Tests

Pedroni Residual Panel Cointegration Test		
	Productivity of Wheat	Productivity of Cotton
Panel v-Statistic	-1.59 (0.78)	-0.71 (0.97)
Panel rho-Statistic	-1.91 (0.03)*	0.99 (0.72)
Panel PP-Statistic	-11.31 (0.00)*	-2.24 (0.00)*
Panel ADF- Statistic	-5.22 (0.00)*	-1.96 (0.01)*
Group rho-Statistic	-0.82 (0.20)	1.36 (0.91)
Group PP-Statistic	-15.02 (0.00)*	-6.02 (0.00)*
Group ADF-Statistic	-8.34 (0.00)*	-2.63 (0.00)*
Kao Residual Panel Cointegration Test		
ADF T Statistic	-4.26 (0.00)*	-2.73 (0.00)*

* significant at 10%

4.3. Long Run Estimates

Table 5 shows the long run estimation results generated from the estimation of the panel ARDL model. Here we can see that since other than the price, all of the variables in both models are supply related hence the model depicts the supply of wheat and cotton. Because of this the coefficient of the price variable is positive. Here we can see that the coefficient of price in cotton model is bigger as compared to wheat model, this means the cotton has the higher price elasticity of supply, so boosting cotton production is easier by increase cotton support price as compared to wheat using wheat support price. While studying the climate effects we can see that if there is a 1% increase in the maximum temperature above average, it increases the productivity of wheat and cotton by 0.08% and 0.10% respectively in the long run, this is because both crops required dry season at the time of harvest. While if there is a 1% increase in rainfall above average, then it increases the productivity of wheat by 0.29%, while decreases the productivity of cotton by 0.15% on average in the long run. An increase in the tube wells improves the irrigation, here if there is a 1% increase in the number of tube wells; it improves the productivity by 0.14% for wheat and 0.80% for cotton. Similarly fertilizers are also more beneficial for cotton as1% increase in fertilizer use increases its productivity by 0.47%, while it only increases productivity of wheat by 0.07% in the long run.

Table-5. Panel ARDL Long run Estimates

Long Run ARDL Estimates			
		Productivity of Wheat	Productivity of Cotton
Independent variables	Mean value	Coef. (prob.)	Coef. (prob.)
Wheat price		0.26 (0.00)*	
Cotton price			0.44 (0.00)*
Dev. in Max Temperature	0.001	0.08 (0.00)*	0.10 (0.05)*
Dev. in Precipitation	3.33	0.29 (0.00)*	-0.15 (0.02)*
Tube wells		0.14 (0.02)*	0.80 (0.01)*
Fertilizers		0.07 (0.27)	0.47 (0.01)*

* significant at 10%

4.4. Short Run Estimates

Panel ARDL provides heterogeneous short run estimates in table 6, which are different for each cross section, and also reports the mean coefficient in the overall model. Hence this model allows each district to deviate around the equilibrium differently in the short run, and also take different time to reach to homogeneous equilibrium. We can see here that the increase in the wheat and cotton price in short run increases the productivity of wheat and cotton by 0.52% and 0.97% respectively. In the short run if there is a 1% increase in the average maximum temperature, it increases the wheat productivity by 0.06% while decreases the cotton productivity by 0.12% on average. In the short run, an increase in the average rainfall is harmful for wheat crop by 0.28% and for cotton by 0.58% on average. Increase in tube wells and fertilizers do not improve the productivity of wheat, but both of them improve the productivity of cotton by 0.72% and 0.68% on average in the short run.

While analyzing the short run coefficients it is pertinent that the adjustment coefficient must be evaluated, here we can see that if there is 1% deviation from the long run equilibrium for both crops, on average across the districts, the wheat model will adjust itself 0.58% each time period, while the cotton model will adjust itself 0.29% each time period significantly. These coefficients are negative and significant showing the long run model is sustainable, while the coefficients are not near to -1 which is because of high production lag of crops.

Table-6. Panel ARDL Short run Estimates

Short Run ARDL Estimates		
Model	Productivity of wheat	Productivity of Cotton
Independent variables	Coef. (prob.)	Coef. (prob.)
ECM_{-1}	-0.58 (0.01)*	-0.29 (0.00)*
Wheat price	0.52 (0.03)*	
Cotton price		0.97 (0.06)*
Dev. in Max Temperature	0.06 (0.10)	-0.12 (0.00)*
Dev. in Precipitation	-0.28 (0.00)*	-0.58 (0.03)*
Tube wells	-0.20 (0.54)	0.72 (0.00)*
Fertilizers	-0.05 (0.66)	0.23 (0.42)
Intercept	-1.77 (0.01)*	0.68 (0.01)*
Diagnostics		
Lag order	3,3,3,3,3,3	1,1,1,1,1,1
Observations	314	177
AIC	-0.18	-0.57

* significant at 10%

Following table 7 provides the diagnostic tests for both productivity of wheat and productivity of cotton model. For both models, only Jarque Bera normality test shows the presence of non-normal residuals, since the sample size is more than 30, hence as per central limit theorem model is asymptotically normal. While other tests like autocorrelation test, hetroskedasticity test, cross sectional dependence, Ramsey mis-specification test and contemporaneous correlation test show absence of any issue in both wheat and cotton model.

Table-7. Post Regression Diagnostics

Diagnostic Tests		
Model	Productivity of Wheat	Productivity of Cotton
Autocorrelation Q stat first order	0.63 (0.42)	2.57 (0.07)
Hetroskedasticity Test Breusch Pagan Godfrey[1]	6.28	10.62
Cross Sectional Dependence Pesaran Scaled LM	1.14 (0.26)	2.12 (0.08)
Normality test Jarque Bera	83.46 (0.00)	23.79 (0.00)
Mis-Specification Test Ramsey RESET F-Test	0.16 (0.67)	0.78 (0.37)
Contemporaneous Correlation	-0.00 (0.95)	

5. Conclusion

This study is designed to evaluate the effect of fluctuations of climate of major crops for several districts of Punjab Pakistan. In this regard study used deviations of temperature and rainfall as the indicator of climate change. And control variable includes the price of the crop, use of fertilizers and tube wells.

This study used Panel ARDL to evaluate the short run and long run impact of climate change on wheat and cotton crops. Diagnostic test revealed that model is free from the problems of autocorrelation, cross sectional dependence, hetroskedasticity, multicollinearity, mis-specification and contemporaneous correlation.

The long run results show that the rise in temperature from its mean value will lead to increase the productivity of cotton and wheat. While the increase in the rainfall from the mean value, will lead to increase in productivity of wheat but decrease in productivity of cotton. An increase in the tube wells leads to increase in wheat and cotton productivity. Also in long run fertilizer is only fruitful in the case of cotton crops. Most importantly the positive coefficient of prices reveals that model is supply function, price increase have a stronger effect on increase in productivity for the case of cotton as compared to wheat.

In the short run for the case of wheat we can see that wheat price still has a persuasive effect for the sellers of wheat, the change in temperature is insignificant, rainfall fluctuations are harmful, while no effect of tube wells and fertilizer use. In the case of cotton, it can be seen that the cotton price has a higher persuasive effect on suppliers. Temperature and rainfall fluctuations are harmful and increase in irrigation through tube wells is beneficial.

Both wheat and cotton models are converging, it indicates that the constructed models can be used to apply intervention to boost the productivity using the policy options to counteract the reduction in productivity from climate or other factors. District governments can boost the output by offering sellers higher sale prices. Increase in tube well installation and proper utilization of fertilizers can counteract to decrease in the productivity.

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