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Climate Change and Rice Productivity: Evidence from Pakistan

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The impacts of climate change on various domains of economy have been the focus of recent literature. Amongst them, agriculture is the most important one which is greatly affected by a slight change in climate. The current study analysed the climate change and agricultural productivity taking rice as a sample of agriculture output in case of Pakistan. Quantitative analysis for the period of 1981 to 2018 was conducted and the data was taken from World Development Indicators (WDI). An Autoregressive Distributive Lag model was employed to extract the long run estimates of the model. Climate change was measured through CO2 emission. Results of the study revealed that CO2 emission reduces rice productivity in long run. Amongst the other control variables like fertilizers offtake, water availability and area under cultivation, all have a positive contribution in the rice production. Diagnostic tests confirm that the model is best fitted, and stability of the coefficient is verified by CUSUM and CUSUMQ. On the basis of the findings of this study there is an urge for making strong decisions to curb the effects of climate change by switching the economy to efficient energy usage and recycling of wastes to reduce CO_2 emissions.

Keywords: *ARDL, Climate Change, CO_2 Emission, Rice Productivity*

Introduction

Developing countries are mostly traditional economies where agriculture is the main source of earning for the majority of population and has a significant contribution at an aggregate level of economy. The farmers with the inputs in hands grow their crops for their families and national economies (Banerjee and Adenaeuer, 2014). Although, the role of agriculture is important, its output depends on the weather and climate of that particular region (Gornall et al., 2010). With change in climatic conditions, the agricultural productivity is adversely affected (Howden et al., 2007).

It is expected that the development made by underdeveloped nations in the field of technology may decrease the climatic effects on agriculture. Literature provides the evidence for change in food production with the change in temperature (Zhao et al., 2017). Developing nations are prone to climate change and more effected by these changes as compared to the developed world (Rauf et al., 2018; Ali et al., 2017). Pakistan, being a developing nation, is based on agriculture for their economic growth. The climate of Pakistan is ideal for various agricultural productivity, e.g. cotton, wheat, rice (Dharmasiri, 2012). Amongst them rice is the second important staple food crop after wheat and its value added in GDP of Pakistan is 0.6% and in agriculture the value added of rice is 3% (Economic Survey of Pakistan, 2017).

The importers of Pakistan rice are middle eastern countries like UAE, Saudi Arabia, Qatar and along with them Afghanistan and Iran are also the major importers of Pakistani rice (Mohamed et al., 2002). As the temperature increase it affects the rice production (Saseendran et al., (2000); Vaghefi.et.al, (2010); Shakoor et al., (2015); Chandio et al., (2018)). The unfavourable environmental effects lead the current government of Pakistan to tickle the issue seriously. The Prime Minister has established the "Executive's Committee on Climate Change" to give direction on the issues of environmental change (Janjua et al., 2014). The Government Forestry Board (FFB) has likewise been established to restore woods and timberland spread in the nation. The administration has presented atmosphere spending coding and consumption following framework. This activity has turned into a strong channel for the environmental change fund mainstreaming and will encourage transparency in investment. The checking of the use will offer certainty to the worldwide advancement accomplices in consumption under various subsidising streams to guarantee that the funds are spent on the intentional programs (Chandio et al., 2018). Similarly, the Ministry for Climate Change has taken some notable measures which are; (i) to make sure that the meetings are regularly held, (ii) the ministry should ensure that the Doha Amendment to Kyoto Protocol has approved, (iii) to ensure that climatic issues of Pakistan are addressed according to the requirements of international conventions and (iv) monitoring of whether the international agreements are implemented or not.

From this discussion it can rightly be said that climate change is a real issue which has serious implications for global economies and for Pakistan too. Most of the literature used panel data for underlying hypothesis (e.g. Vaghefi.et.al, 2010; Ahmad and Schmitz, 2011; Ahmad et.al., 2014; Raza and Anwar 2015). There is no common consensus in the literature on the exact impacts of climate change on rice productivity. The current study while using a more coherent methodology and latest available data set will be a meaningful contribution to the literature. This specific attempt will back the literature in understanding the complexities of climate change for rice production in developing countries like Pakistan. Furthermore, this analysis provides some valuable insights into the government of Pakistan in tackling CO_2 emissions that is the real threat for agriculture of Pakistan in general and to the rice production in particular.

Data

Data for selected variables is taken from various issues of economic survey of Pakistan. This study uses CO_2 emission as a proxy to measure climate change, along with some other important variables like fertilizers offtake, water availability and area under cultivation of rice. The dependent variable of this study is rice productivity.

Materials

Our study is a time series in its nature and this type of data has the problem of unit root and regression analysis becoming spurious if the data has a unit root. To check the unit root property of the data, the Augmented Dicky Fuller (ADF) test is employed. ADF is preferred over the Dicky Fuller (DF) test because of the inclusion of the lag effects of ADF. To analyse the hypothesis of whether global warming has any significant impact on rice productivity this study employed ARDL approach. Previous literature used Johansen and Juselius (1990) or Engle Granger (1987) methodologies to analyse this relationship. ARDL is preferred over the other two because Johansen and Juselius needs to be applied where the total observations are greater than 60 and needs same order of integration. Same is the case for application of Engle Granger which also needs same order of integration of the variables to be applied. On the other hand, ARDL is a small sample technique or gives best results even in small sample size and can be applied whether the order of integration of the variables is mixed or same. Furthermore, data engendering in a general to specific framework is best made by ARDL taking satisfactory lags (Laurenceson and Chai, 2003).

Model

The functional form of the model is;

$$RP = f(CO2) \text{ --------1}$$

RP in above equation stands for Rice Productivity, CO2 proxy the climate change, Specific econometric model is as follows;

$$RP_t = \alpha + \beta(CO2_t) + \delta\,(Z_t) + \varepsilon_t \text{ -------------2}$$

Z is used for the vector of control variables that can affect the stability of the economy e.g. fertilizers offtake, area under cultivation and water availability.

Estimation Strategy

The Auto Regressive Distributive Lag Model (ARDL) propagated by Pesaran and Pesaran (1997) and Pesaran and Shin (2001) are used for estimation purposes. In a first step of this approach, a long run cointegration is finding out. The decision of long run cointegration is made on the basis of Wald F- Statistics. If the calculated value of the Wald F-Statistics is greater than the upper bound of the tabulated value of the Wald F-Statistics at 5% level of significance, then this is a case of existence of long run cointegration. In case the calculated Wald is less than the tabulated Wald at 5% level of significance that means that there is no long run cointegration in the model and if the value of calculated Wald F-statistics lies in between the upper bound and lower bound at 5% level of significance, this is an inconclusive region. Our specific model is;

$$\Delta RPt = \alpha 0 + \sum_{i=1}^{l} \varphi 1 \Delta RP\, t - i + \sum_{j=1}^{m} \varphi 2 \Delta\, CO2t - j + \sum_{k=1}^{n} \varphi 3 \Delta\, FERt - k + \sum_{m=1}^{p} \varphi 4 \Delta\, AURt - m + \sum_{n=1}^{r} \varphi 5 \Delta\, WAt - n + + \beta 1 RPt - 1 + \beta 2 CO2t - 1 + \beta 3 FERt - 1 + \beta 4 AURt - 1 + + \beta 5 WAt - 1 + \varepsilon t \ldots\ldots 3$$

In a next step, once it is established that long run cointegration exists, the long run elasticities are estimated:

$$RPt = \alpha 0 + \beta 1 RPt - 1 + \beta 2 CO2t - 1 + \beta 3 FERt - 1 + \beta 4 AURt - 1 + \beta 5 WAt - 1 + \varepsilon t \ldots\ldots .4$$

And in a third step the short run dynamics are extracted. The short run impacts are tested through Error Correction Mechanism (ECM).

$$\Delta RPt = \alpha 0 + \sum_{i=1}^{l} \varphi 1 \Delta RP\, t - i + \sum_{j=1}^{m} \varphi 2 \Delta\, CO2t - j + \sum_{k=1}^{n} \varphi 3 \Delta\, FERt - k + \sum_{m=1}^{p} \varphi 4 \Delta\, AURt - m + \sum_{n=1}^{r} \varphi 5 \Delta\, WAt - n + vecmt - 1 + \varepsilon t \ldots .5$$

Results and Discussion

Unit Root Analysis

For ARDL it is not necessary to check the stationary of data as it can be applied in cases where the variables are integrated of order 1 or 0 or even mixed. But stationary of time series data has to be checked for unit root to avoid spurious regression. The following table suggests that in our case the selected variables are integrated of order 1 i.e. by taking first difference.

Table 1: Unit Root Analysis

Variables	Level		1st Difference		Decision
	C	C, T	C	C, T	
RP	-0.8504 (0.7925)	-0.0965 (0.0138)	-8.6191 (0.000)	-8.6308 (0.000)	I(1)
AUR	-1.7251 (0.4106)	-2.9894 (0.1914)	-7.2474 (0.000)	-7.1540 (0.000)	I(1)
CO2	-1.9261 (0.3171)	-1.0018 (0.9315)	-6.1140	-6.5926 (0.000)	I(1)
FER	-0.6467 (0.8476)	-0.2824 (0.6534)	-9.5149 (0.000)	-9.4145 (0.000)	I(1)
WA	-2.6582 (0.0909)	-0.7620 (0.9602)	-5.9578 (0.000)	-7.8864 (0.000)	I(1)

Source: Authors calculation

Lag Length Selection

There are different criteria for selection of lag length, which criteria have to be used depends on observation of the study. In less than 60 observations AIC and FPE are suitable and in the case of more than 120 observations HQ criteria are best to use (Liew, 2004). As in this study there is less than 60 observations AIC is used for lag length selection. The selection of maximum lags is the choice of a researcher and this study takes lag length 2 to finalise the total length of lags to be taken. Results are displayed in table 2 below.

Table 2: Lag Length Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-838.3151	NA	1.5314	46.85084	47.07077	46.92760
1	-710.5951	212.8666	5.1711	41.14417	42.46377*	41.60475*
2	-679.9328	42.58652*	4.1111*	40.82960*	43.24886	41.67399

Source: Authors calculation

Long Run Cointegration

The calculated Wald F-Statistics is 4.97 higher than the upper bound of tabulated Wald F-Statistics 4.58 which is the evidence of long run cointegration in our model. Taking the rest of the variables as a dependent variable one by one suggests that there is either no cointegration or the values fall in indecisive regions.

Table 3: Long Run Cointegration

Specification	Lower Bound	Upper Bound	Calculated F	Decision
F_{lnRP}[lnRP/inAUR,lnFER,lnWA, lnCo2]	3.51	4.58	4.97	Cointegration
F_{lnAUR}[lnAUR/lnRP,lnFER,lnWA,lnCo2]	3.51	4.58	3.68	Indecisive
F_{lnFER}[lnFER/lnAUR,lnRP,lnWA,lnCO2]	3.51	4.58	.89	No Cointegration
F_{lnWA}[lnWA/lnAUR,lnRP,lnFER,lnCO2]	3.51	4.58	4.27	Indecisive
F_{lnCO2}/lnCo2/,lnAUR,lnRP,lnFER,lnWA]	3.51	4.58	3.88	Indecisive

Source: Authors calculation

Long Run Estimates

Results of the long run impacts of climate change on rice productivity along with other control variables are displayed in the table below. The results suggest that CO_2 emission has a great impact on rice productivity. Emission of CO_2 reduces the productivity of rice by 3.72%. These findings are consistent with Mohandrass et al. (1995), Mohamed et al. (2002), Peng et al. (2004), Janjua et. al (2014) and Chandio et. al, (2018).

Pakistan is amongst the low CO_2 emitters in the world but amongst the top countries that are facing the consequences of climate change. In 2008, the total contribution of Pakistan in greenhouse gas emission were 310 million tons only (Economic Survey of Pakistan 2018-19). There is a need to switch the economy to least-carbon fossil fuels and a strong measure has to be taken to save the agriculture of Pakistan from the negative effects of climate change especially CO_2 emission.

Water availability, fertilizers and the area under cultivation have positive impacts on rice productivity. Water is essential for rice cultivation and its supply in adequate quantity is one of the most important factors in rice production (Akinbile, 2010; Mondonedo, 2008; Rosegrant *et al.*, 2002). The current way of irrigation of rice needs a huge sum of water for its production. Therefore, through better water management, rice cultivation can be further be improved. Rice production in Pakistan is positively influenced by area under cultivation. An increase in the area under cultivation by 1% is expected to increase rice production by more than unity. This finding is consistent with Hussain (2012) and Chandio et al., (2018).

The farmers of Pakistan sow the rice through conventional ways and there is no advanced technology for cropping that can further increase the productivity of agriculture. These conventional methods increase the cost of labour and there is a need of adopting sophisticated technologies in rice production so that not only the area under cultivation increases but also the share of rice in agriculture output be increased e.g.

The introduction of dry rice is need in the system which will not only reduce the cost of production but also increase the efficiency and reward with high yields. Fertilizers are confirmed to exert a positive impact on rice production in Pakistan at a significance level of 5%. An increase in the fertilizer consumption by 1% is expected to raise rice production by 0.32% in the long-run. Fertilizers have very much effect on crop productivity like improving the land fertility and also enhancing plant growth. In the long-run fertilizers would enhance the available land fertility affecting lead the crop productivity. In rural areas of Pakistan, most of the farmers use both natural and chemical fertilizers to improve the land fertility. This empirical evidence supports the findings of Janjua et al., (2014) and Chandio et al., (2018) on the relationship between fertilizer consumption and food grain production in Pakistan.

Table 4: Long Run Estimates

Regressors	**Coefficient**	**Standard Error**	**T-Ratio**	**Probability**
$lnCO_2$	-3.7274	1.2854	-2.8997	[.016]
lnWA	25.3860	13.6687	1.8572	[.076]
lnFER	.32083	.17048	1.8819	[.043]
lnAUR	2.6205	.30916	8.4762	[.000]
A	-236.9794	91.5132	-2.5896	[.016]
T	11.1005	3.3460	3.3176	[.003]
$R^2 = .90$	F-Stat. 20.98(0.000)			
Adj. $R^2 = .86$	DW= 1.91			
Test Statistic (LM Version)		**Chi -Square**		**Value**
Serial Correlation (LM Test)		Chi -Square		.9204(.148)
Functional Form (Ramsey RESET)		Chi -Square		.0029(.112)
Normality (JB Test)		Chi -Square		.2120(.276)
Heteroscedasticity (White Test)		Chi -Square		.9728(.324)

Source: Authors calculation

Short Run Estimates

Table 6 presents the short run estimates for our hypothesis. The short run results are not very much different from their long run counter parts for area under cultivation and water availability. The results of CO_2 emissions in the short run suggest that it contributes positively to the rice productivity. Fertilizer intake has an insignificant role when it comes to the short run. The speed of adjustment towards the long run is shown by the ECM which suggests a high speed of adjustment to equalise the disequilibria between the short and long run. The values of R^2 and Adjusted R^2 suggest the fitness of the model. The higher is the value best fitted is the model. In our case the values of R^2 and Adjusted R^2 are .96 and .95 respectively, which shows that 95% variation is explained by the explanatory variables or indication of strongly fitted model.

Table 5: Short Run Estimates

Regressor	Coefficient	Standard Error	T-Ratio	Probability
dLNRP1	.3534	.1681	2.1024	.045
dLNCO2	5.1561	1.1346	4.5444	.000
dLNWA	4.0490	1.5690	2.8100	.042
dLNFER	-.1748	.1581	-1.5018	.145
dLNAUR	2.7646	.2639	10.4741	.000
dA	-42.8689	16.0943		.000
dT	2.1357	5.3865	3.7382	.001
$ECM_{(-1)}$	-.8140	.2812		.000
R^2 = .96	F-St. 83 (0.000)			
Adj. R^2 =.95	DW= 1.63			

Source: Authors calculation

Diagnostic Tests

The diagnostic test results are displayed in table 7 where the results for serial correlation, heteroscedasticity, misspecification of the model and normality are displayed, and it is evident from the table 7 below that our model has not such problems[1].

Table 6: Diagnostic Tests

[1]*For the diagnostic tests this study follows the methodology used by Oteng & Frimpong, (2006), "Bounds testing Approach to Cointegration: An Examination of Foreign Direct Investment Trade and Growth Relationship", AJPS.3(11): 2079-2085*

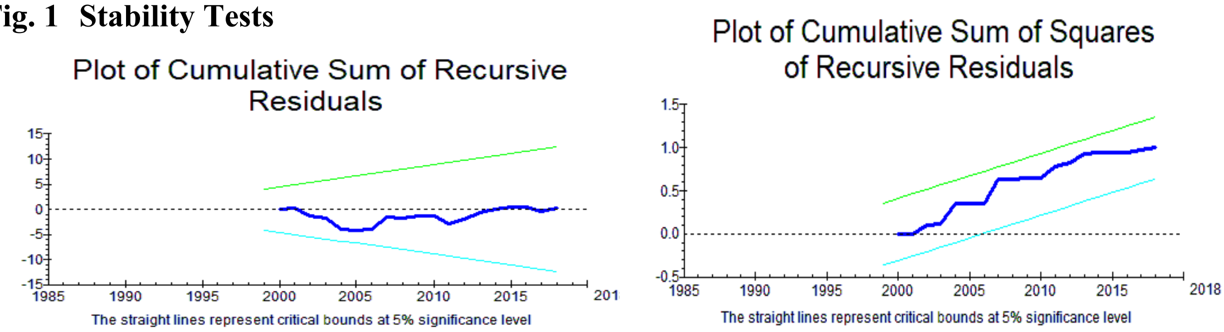
Test Statistic (LM Version)	Chi -Square	Value
Serial Correlation (LM Test)	Chi -Square	.1504(.698)
Functional Form (Ramsey RESET)	Chi -Square	.7994(.371)
Normality (JB Test)	Chi -Square	.6007(.122)
Heteroscadasticity (White Test)	Chi -Square	.4985(.480)

Source: Authors calculation

Stability Test

CUSUM and CUSUMQ tests are used to test the stability of coefficients. The figure below suggests that the coefficients were stable in our model as it does not go beyond the critical regions.

Fig. 1 Stability Tests



Conclusions and Policy Recommendations:

Taking Pakistan as a sample case, this study took the period from 1981 to 2018 to analyse the impacts of climate change on rice productivity. The selected model was estimated by using more relevant technique, ARDL commonly known as Bound test of Cointegration. Data was scrutinized through the application of the ADF test for Unit root. Results revealed that there exists strong long run cointegration in the model. Climate change is a proxy by CO_2 emissions which have negative impacts on rice productivity in Pakistan. The rest of the other variables like area under cultivation, fertilizers offtake and water availability contribute significantly in rice production. The ECM suggests a high speed of adjustment that equilibrate the disequilibria exist for short to long run. It is recommended that the policy makers must look for bipartite elucidations that minimize CO_2 emissions. Furthermore, the government is needed to use the water astutely and proficiently and increase the area under rice crop cultivation to increase fertilizers offtake to increase the yields of rice crops.

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Authors Contribution

All author contributes equally in the manuscript preparation. Author one proposed the main ideas and framework. Author second help in data analysis. The third author review the article in all aspects. The authors have no conflict of interest.