Climate change impacts on cereal crops production in Pakistan

Evidence from cointegration analysis

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Abstract

Purpose – This paper aims to examine the effects of CO_2 emissions, energy consumption, cultivated area and the labour force on the production of cereal crops in Pakistan from the period 1971-2014.

Design/methodology/approach – The study used the Johansen cointegration test, the autoregressive distributed lag (ARDL) approach and Granger causality test to estimate the long-run cointegration and direction of the relationship between the dependent and independent variables.

Findings – The outcomes of the Johansen cointegration test confirmed the existence of a long-term cointegrating relationship between the production of cereal crops, CO_2 emissions, energy consumption, cultivated area and the labour force. The results of the long-run coefficients of CO_2 emissions, energy consumption, cultivated area and labour force have a positive impact on cereal crops production. The long-run relationships reveal that a 1 per cent increase in CO_2 emissions, energy consumption, cultivated area and labour force will increase cereal crops production by 0.20, 0.11, 0.56 and 0.74 per cent, respectively. Moreover, the findings show that there is a bidirectional causality running from CO_2 emissions and cultivated area to cereal crops production. Moreover, there is a unidirectional causality running from energy consumption to cereal crops production.

Originality/value – The present study also fills the literature gap for applying the ARDL procedure to examine this relevant issue for Pakistan.

Keywords Pakistan, Cointegration, Energy consumption, CO_2 emissions, Cereal production

Paper type Research paper

1. Introduction

The agricultural sector plays a significant role for the path of national economic development. Agriculture exists worldwide and allows farmers to grow and improve their crops with available inputs (Banerjee and Adenaeuer, 2014). This sector plays a significant role and contributes to the

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economic prosperity of advanced countries, and its role in developing countries has its own role and importance. However, most crops are dependent on the prevailing climate in a specific region or area (Gornall *et al.*, 2010). Weather and climate are key factors that influence agricultural productivity. Global climate change has become a serious threat to activities in the agriculture sector and has become critical for the sustainable development of any nation (Howden *et al.*, 2007). Therefore, the main climate change impact is on the production of the agricultural sector because of the changes in temperatures, rain patterns, floods and famines, and it has negative effects on the land and water resources (Ali *et al.*, 2017). Developing countries (such as in Africa and Asia) have progressed in their technology, and this progress is considered to have decreased the effects of climate change on production from the agricultural sector. Studies have shown that there are substantial effects from changing rainfall patterns and from increasing temperatures on food production (Zhao *et al.*, 2017). Climate change is considered to be a global issue, but developing countries are more widely affected; the reason is their higher vulnerability to climate change and their lower ability to mitigate climate change effects (Ali *et al.*, 2017; Rauf *et al.*, 2018). Developing countries, including Pakistan, are mostly agriculture-based nations, so they incur major effects on their economies due to their direct exposure to nature. The climate of Pakistan is suitable for the production of various crops, such as wheat, cotton, maize, rice and sugarcane (Dharmasiri, 2012), but above all, wheat is the main crop in this region because of its high consumption, demand and most importantly, the available climatic conditions (Curtis and Halford, 2014). Most of the studies related to food availability emphasize the growth of agricultural output (Swaminathan and Bhavani, 2013). Climate factors (long-term) and weather (short-term) influence agricultural productivity (Shannon and Motha, 2015). For example, there was a weak monsoon system in 1987 that caused high levels of crop yield reductions in Pakistan, India and Bangladesh, contributing to a need for wheat imports by India and Pakistan (Gonzalez-Garcia and Gaytan, 2006). Countries in tropical and sub-tropical regions are most likely to be more vulnerable to warming due to additional increases in temperature, which will stress the balance of marginal water and damage agricultural sector crops. Climate change increases the vulnerability of the agricultural sector in the form of floods and famines, causing socio-economic losses for the country (Ali *et al.*, 2017). The research implies that the production of food at the domestic level must increase to reach a state of self-sufficiency in Pakistan (Clapp, 2017). Climate effects can change the time to maturity that a crop requires (Hatfield and Prueger, 2015). Soil fertility can be affected by erosional processes, frequent pest attacks can intensify, a number of products for the crops cultivated can decrease on a yearly basis, harvest periods can increase and water availability for irrigation can decrease due to climate changes (Bhardwaj *et al.*, 2018). Adams *et al.* (1998) stated that the major determinants of agricultural productivity are climatic aspects such as rains, high temperatures and occurrences of extreme events such as floods, droughts and windstorms, which have direct impacts on livestock and crops yield. Advanced research during the past 20 years by the Centre of International Maize and Wheat Improvement (CIMMYT) has explained that wheat production in warmer areas is scientifically feasible (Wang *et al.*, 2016). Wheat has been the number one domesticated food crop and was a basic staple item for European, North Africa and West Asia populations 8,000 years ago, (Fuller, 2007). Today, wheat crop is produced and harvested on more land area than any other crops and continues to the greatest significant human grain source; wheat production leads to other crops, such as potatoes, maize and rice (Shewry and Hey, 2015). The latest research anticipates that wheat production in South Asia will decrease by 50 per cent in 2050, almost equal to the 7 per cent of the global production of this crop (Jaggard, Qi, and Ober, 2010). Wheat crop has improved over a wide range of moisture conditions from xerophytic to littoral (Monneveux *et al.*, 2012). Optimal production needs a sustainable source of moisture during the growing season; however, excess rainfall can lead to yield losses due to root problems and diseases (Hatfield and Prueger, 2015). Cultivars with widely differing pedigrees are grown across wide climate and soil conditions and show wide changes in their features (Lammerts van Bueren *et al.*, 2011). However, wheat is being cultivated across the world at any time of the year, and cultivation in the temperate regions begins between April and September in the northern hemisphere and between October and January in the southern hemisphere (Percival, 1921). Therefore, the main aim of this research is to examine the long-run impacts of climate change, energy consumption, cultivated area and the agricultural labour force on cereal crops production in Pakistan for the period from 1971 to 2014 by use of the autoregressive distributed lag (ARDL) bounds testing method.

2. Data source and econometric methodology

2.1 Data source

The data for cereal crops production (kg per hectare), land under cereal production (hectares), energy consumption (kWh per capita) and rural population (million) have been taken from the World Development Indicators (WDI, 2016).

2.2 Econometric methodology

The present study aims to examine the linkages between carbon dioxide emissions, energy usage, cultivated area and cereal crops production using the ARDL cointegration approach. The association is expressed as follows:

$$LogCP_t = \alpha_0 + \alpha_1 LogCO2_t + \alpha_2 LogEN_t + \alpha_3 LogCA_t + \alpha_4 LogLF_t + \varepsilon_t \quad (1)$$

Equation (1) represents the effects of carbon dioxide emissions, energy consumption, cultivated area and rural population, used as a proxy for agricultural labour force, on cereal crops production. CP refers to cereal crops production, CO_2 refers to carbon dioxide emissions, EN stands for energy consumption, CA means cultivated area and LF means labour force, t represents the period and ε stands for the stochastic terms.

2.2.1 Autoregressive distributed lag bounds testing approach. The ARDL approach to cointegration was introduced by Pesaran and Pesaran (1997), Pesaran and Shin (1998) and Pesaran *et al.* (2000, 2001). This approach was applied without the restricted model of vector error correction to inspect the long-run linkages between changing weather conditions, energy consumption and the production of cereal crop. An economic study analysis posits that there are long-run links among the variables under consideration as required by the model. This notion means that long-run linkage features are integral to the method. In economic terms, the variance and means are constant and do not depend on time. Most empirical studies, however, have shown that the constancy of variances and means is not satisfied when considering the variables of time series. To resolve this problem, most cointegration techniques are not applied, interpreted or estimated accurately. The ARDL approach is better estimated for small-sample data properties. The ARDL model is set up to estimate as follows:

$$\begin{aligned}\Delta LnCP_t = {} & \Psi_0 + \Psi_1 \sum_{i-1}^{p} \Delta lnCP_{t-1} + \Psi_2 \sum_{i-1}^{p} \Delta lnCO2_{t-1} + \Psi_3 \sum_{i-1}^{p} \Delta lnEC_{t-1} \\ & + \Psi_4 \sum_{i-1}^{p} \Delta lnCA_{t-1} + \Psi_5 \sum_{i-1}^{p} \Delta lnLF_{t-1} + \delta_1 lnCP_{t-1} + \delta_2 lnCO2_{t-1} \\ & + \delta_3 lnEC_{t-1} + \delta_4 lnCA_{t-1} + \delta_5 lnLF_{t-1} + \varepsilon_t, \end{aligned} \quad (2)$$

where Δ denotes the difference operator, Ψ denotes the short-run coefficients, Δ denotes the long-run coefficients and $\mathcal{E}_t$ represents the error term. The co-movement of long-run among the variables of interest is determined on the basis of the estimated F-statistic. The ARDL cointegration technique does not require pre-tests for unit roots, unlike other techniques. Consequently, the ARDL cointegration approach is preferable when dealing with variables which are integrated in different orders, and the combination of both is rigorous when there is only one long-run linkage between the small sample-sized underlying variables. The long-run linkage of the underlying variables is identified with the help of the F-statistic (Wald test). Long-run relationships in the series are considered to be estimated in this approach when the F-statistic surpasses the band of critical value. The main advantage of this method lies in its cointegrating vector identification where there are various cointegrating vectors. If a long-run cointegration between CO_2, energy consumption, cultivated area, labour force and cereal crops production is found, the long-run relationship coefficients are estimated with the following equation:

$$LnCP_t = \xi_0 + \xi_1 \sum_{i-1}^{p} lnCP_{t-1} + \xi_2 \sum_{i-1}^{p} lnCO2_{t-1} + \xi_3 \sum_{i-1}^{p} lnEC_{t-1} + \xi_4 \sum_{i-1}^{p} lnCA_{t-1} + \xi_5 \sum_{i-1}^{p} lnLF_{t-1} + \varepsilon_t. \quad (3)$$

If a long-run association amongst the CO_2, consumption of energy, cultivated area, labour force and cereal crops production is found, then the short-run association coefficients are estimated by the following equation:

$$\Delta LnCP_t = \phi_0 + \phi_1 \sum_{i-1}^{p} \Delta lnCP_{t-1} + \phi_2 \sum_{i-1}^{p} \Delta lnCO2_{t-1} + \phi_3 \sum_{i-1}^{p} \Delta lnEC_{t-1} + \phi_4 \sum_{i-1}^{p} \Delta lnCA_{t-1} + \phi_5 \sum_{i-1}^{p} \Delta lnLF_{t-1} + \theta ECT_{t-1} + \varepsilon_t. \quad (4)$$

The method of error correction explains the adjustment of speed required to restore the equilibrium of the long-run following a short-run shock. Θ shows the computed error correction coefficient term for the approach that shows a speed modification.

3. Results and discussion

3.1 Descriptive summary, correlation and stationarity analysis

Table I explains the initial descriptive data statistics used for the estimation; the Jarque–Bera test suggests that all variables are normally distributed. Additionally, the estimated outcomes of the correlation analysis in Table I indicate that CO_2 emissions, energy consumption, cultivated area and the labour force are significantly and positively linked with cereal crops production. We tested if the selected studied variables were stationary at level/first difference. In the process, this study used the augmented Dickey–Fuller (ADF) test (Dickey and Fuller, 1979), the Phillips–Perron (PP) test (Phillips and Perron, 1988) and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test (Kwiatkowski *et al.*, 1992) as unit root tests to confirm whether the studied variables were stationary or not. The estimated empirical outcomes of the ADF, PP and KPSS unit root tests are described in Table II,

	lnCP	$lnCO_2$	lnEC	lnCA	lnLF
Mean	4.212078	−0.504988	5.985650	16.27248	18.14905
Median	4.273871	−0.424809	6.032609	16.29564	18.18851
Maximum	4.753504	−0.009011	6.261040	16.45170	18.59535
Minimum	3.570096	−1.175706	5.653113	16.03363	17.61582
SD.	0.383435	0.372969	0.197046	0.111385	0.299914
Skewness	−0.315324	−0.386092	−0.319321	−0.576042	−0.244040
Kurtosis	1.767174	1.796575	1.639328	2.413727	1.791692
Jarque-Bera	3.515558	3.748250	4.142037	3.063528	3.113424
Probability	0.172427	0.153489	0.126057	0.216154	0.210828
Correlation analysis					
lnCP	1				
$lnCO_2$	0.986773*** (0.000)	1			
lnEN	0.987035*** (0.000)	0.992296*** (0.000)	1		
lnCR	0.971626 (0.000)	0.963529*** (0.000)	0.958012*** (0.000)	1	
lnLF	0.993407*** (0.000)	0.985700*** (0.000)	0.986756*** (0.000)	0.969063*** (0.000)	1

Note: ***Denotes the rejection of the null hypothesis by the absence of correlation at 1 % level
Source: Researcher's compilation

Table I. Descriptive statistics and the correlation matrix

showing that all studied variables were stationary combinations of I(0) and I(1). This confirms the use of the ARDL-bound test method suggested by Pesaran *et al.* (2001) and by Pesaran and Shin (1998).

3.2 Autoregressive distributed lag bounds testing

The present study applies the ARDL bounds assessment to explain the existence of long-run cointegration. The ARDL long-run cointegration outcomes, reported in Table III, show the existence of long-run cointegrating relationships amongst the production of cereal crops, carbon dioxide emissions, energy consumption, cropped area and the labour force in Pakistan. To check the ARDL approach for stability, several diagnostic tests were applied and checked. The R^2, adjusted R^2 and F-statistic were valid, as given in Table III.

The study also used the Johansen and Juselius cointegration assessment (Johansen and Juselius, 1990) to investigate the presence of long-term cointegration. The outcomes of the Johansen cointegration test, presented in Table IV, revealed that they also showed long-term cointegrating linkages between the independent variables (CO_2 emissions, energy consumption, cultivated area and labour force) and the dependent variable (cereal crops production).

3.3 Long-run coefficients and short-run dynamics

Table V explains the estimates of both the long- and short-run coefficients of the ARDL model. According to the long-run coefficients, energy consumption and CO_2 emissions have a positive impact on cereal crops production, meaning that a 1 per cent increase in CO_2 emissions and energy consumption will increase cereal crops production by 0.20 and 0.11 per cent, respectively. The results of this research are consistent with the results of Janjua *et al.* (2014), Lili *et al.* (2011) and Chandio *et al.* (2018a). Furthermore, in the long run, this research found that cropped area and labour force have a statistically significant and positive impact on the production of cereal crops. These findings can be interpreted that a 1 per cent increase in cultivated area or the labour force will increase cereal crops production

Table II.
Unit root tests results

Variables	Tests	ADF test statistic		PP test statistic		KPSS statistic	
		Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
lnCP	Level	−2.247003	−0.472377	−1.342976	−2.441688	0.824589***	0.194344**
	1st difference	−2.619498*	−3.688592**	−12.49418***	−14.61820***	0.233267	0.188480**
$lnCO_2$	Level	−2.303465	0.219760	−0.611764	−2.192460	0.798242***	0.173827**
	1st difference	−2.732289*	−10.29602***	−8.854989***	−10.29140***	0.188081	0.172586**
lnEN	Level	−1.879681	0.339009	−1.770804	0.339009	0.807794***	0.181579**
	1st difference	−5.160352***	−5.697265***	−5.184510***	−5.697265***	0.376240*	0.139551*
lnCA	Level	−1.059588	−2.602977	−0.999199	−2.602977	0.803078***	0.191269**
	1st difference	−7.584285***	−7.628937***	−7.982182***	−9.484679***	0.111054	0.086092
lnLF	Level	−1.357117	−1.685258	−4.446582***	−1.685258	0.837996***	0.216062**
	1st difference	−4.405490***	−4.446582***	−1.357117	−4.405490***	0.623274**	0.126102*

Notes: Automatic lag length selection based on AIC; ***; ** and *represent statistical significance at 1, 5 and 10 % levels, respectively
Source: Researcher's compilation

$lnCP_t = f(lnCP_t \| lnCO2_t, lnEC_t, lnCA_t, lnLF_t)$ F-statistic 8.188674[a]		
Significance	I(0) bound	I(1) bound
Critical value bounds		
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06
Diagnostic tests		
R^2	0.549615	
Adjusted R^2	0.459538	
F-statistic	6.101613	
Probability (F-statistic)	0.000106	

Note: [a]indicates significant at 1 %
Source: Researcher's compilation

Table III. ARDL-bounds test results

Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical value	Probability
None	116.5694***	69.81889	0.0000
At most 1	63.52499***	47.85613	0.0009
At most 2	31.55501**	29.79707	0.0310
At most 3	12.12888	15.49471	0.1509
At most 4	0.315797	3.841466	0.5741
Maximum eigenvalue			
None	53.04442***	33.87687	0.0001
At most 1	31.96998***	27.58434	0.0128
At most 2	19.42613*	21.13162	0.0852
At most 3	11.81308	14.26460	0.1179
At most 4	0.315797	3.841466	0.5741

Note: ***; ** and *represent statistical significance at 1, 5 and 10 % levels, respectively
Source: Researcher's compilation

Table IV. Johansen cointegration tests

by 0.56 and 0.74 per cent, respectively. Sial *et al.* (2011) found that cultivated area and agricultural labour force have a significant positive effect on agricultural production in Pakistan. Chandio *et al.* (2018b) reported that the total area under cultivation has a significant positive effect on rice productivity in Pakistan. The coefficient of CO_2 emissions in the short run is negatively associated with cereal crops production in Pakistan. CO_2 emissions (a proxy for climate change) may have both positive and negative impacts on cereal crops production. However, this one type of influence may outweigh the other types of effects due to changes in temperature, precipitation and extreme climate events. Furthermore, the study found a positive and significant effect of energy consumption on cereal crops production. The energy consumption coefficient was 0.96 ($P < 0.04$) in the short run, which means that a one per cent increment in the consumption of energy would lead to a 0.96 per cent increase in cereal crops production. The coefficient for the cultivated area showed a statistically significant positive influence on the production of cereal crops, which

Variables	Coefficient	SE	*t*-statistic	Probability
Estimated long-run coefficients				
$lnCO_2$	0.209601	0.214086	0.979050	0.3343
lnEN	0.115288	0.348949	0.330388	0.7431
lnCA	0.561365**	0.256915	2.185020	0.0357
lnLF	0.749812***	0.166788	4.495592	0.0001
C	−19.118092***	5.028836	−3.801693	0.0006
Estimated short-run coefficients				
ΔlnCP(−1)	−0.001081	0.152381	−0.007096	0.9944
$\Delta lnCO_2$	−0.191140	0.221681	−0.862230	0.3944
$\Delta lnCO_2(-1)$	0.400969***	0.147336	2.721449	0.0101
ΔlnEN	0.964148**	0.453684	2.125150	0.0407
ΔlnEN(−1)	−0.848734**	0.417452	−2.033128	0.0497
ΔlnCA	0.571972**	0.240649	2.335231	0.0254
ΔlnLF	0.750622***	0.207070	3.624973	0.0009
ECM(− 1)	−1.001081***	0.152381	−6.569613	0.0000
R^2	0.991364			
Adjusted R^2	0.989636			
F-statistic	573.9448			
Probability (*F*-statistic)	0.000000			
Durbin–Watson stat	2.057348			

Note: ***; ** and *represent statistical significance at 1, 5 and 10 % levels, respectively
Source: Researcher's compilation

Table V. Estimated long- and short-run coefficients from error correction model

means that a 1 per cent increase in the cultivated area would lead to a 0.57 per cent increase in cereal crops production. Our results for cultivated area are consistent with Ahmad (2011), Faridi *et al.* (2015) and Chandio *et al.* (2016), while they contradict the results of Iqbal *et al.* (2003). Faridi *et al.* (2015) revealed that the cropped area has a positive effect on agricultural output. Similarly, the labour force also has a positive impact on cereal crops production. This means that a one per cent increase in the labour force would lead to a 0.75 per cent increase in cereal crops production. These outcomes are in agreement with the research by Ahmad (2011), indicating that the labour force has a positive impact on agricultural productivity.

3.4 Diagnostic tests

After investigating the long- and short-run coefficients of the ARDL model, our research then performed various diagnostic tests (Table VI). The outcomes of diagnostic tests such as the Breusch–Godfrey Serial Correlation LM and ARCH tests showed that the ARDL

Diagnostic tests	*F*-statistic	Probability
Serial correlation	2.084206	0.1405
Normality	3.603798	0.1649
Functional form	0.252985	0.8018
Heteroscedasticity	0.725256	0.3995

Source: Researcher's compilation

Table VI. Diagnostic tests of the ARDL model approach has no problems with autocorrelation. Likewise, the Ramsey RESET and Jarque–Bera tests indicated that the form of the ARDL functional model is correct with no misspecifications and that the residuals were normally distributed. To test the constancy of the ARDL model, the CUSUM and CUSUMSQ tests were used. The plots of CUSUM and CUSUMSQ were within a 5 per cent level of significance (Figures 1 and 2); therefore, the ARDL approach is constant over the period.

3.5 Results of the Granger causality test

This study used the pairwise Granger causality test to check the direction of causality between the variables, and the following linkages were analysed: the causal linkage between $\ln CO_2$ (natural logarithm of carbon dioxide emissions) and lnCP (natural logarithm of cereal crops production); the causal linkage between lnEC (natural logarithm of energy consumption) and lnCP (natural logarithm of cereal crops production); the causal linkage

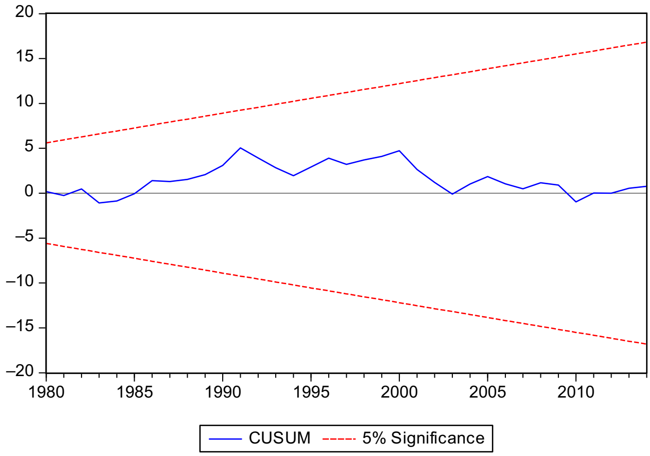

Figure 1. Plot of the cumulative sum of recursive residuals

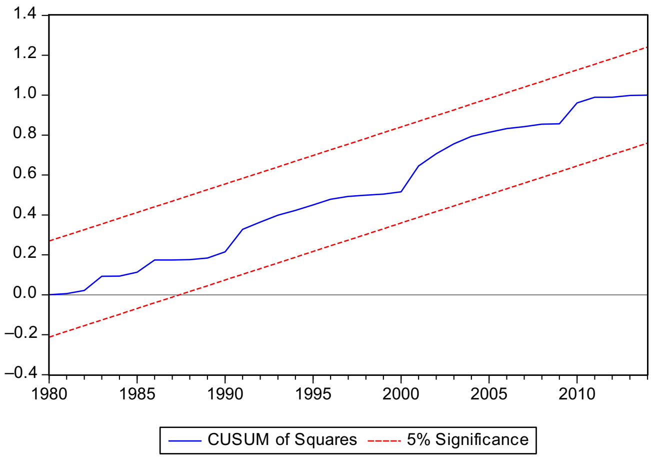

Figure 2. Plot of the cumulative sum of squares of recursive residuals

between lnCA (natural logarithm of cropped area) and lnCP (natural logarithm of cereal crops production); and the causal linkage between lnLAB (natural logarithm of the labour force) and lnCP (natural logarithm of cereal crops production). The outcomes of the pairwise Granger causality technique are reported in Table VII. The null hypothesis that carbon dioxide emissions do not cause cereal crops production declines is rejected at the 1 per cent significance level. There is evidence of bidirectional causality running from $\ln CO_2 \leftrightarrow \ln CP$. Likewise, the null hypothesis that energy consumption does not increase cereal crops production is rejected at the 5 per cent significance level. There is evidence of unidirectional causality running from $\ln EC \rightarrow \ln CP$. In addition, the null hypothesis that cropped area does not cause cereal crops production increases is rejected at the 10 per cent significance level. There is evidence of bidirectional causality running from $\ln CA \leftrightarrow \ln CP$. Moreover, the null hypothesis that the labour force does not cause cereal crops production is accepted. There is no evidence of causality between lnLAB and lnCP.

4. Conclusions

Pakistan is an agriculturally based economy which provides 19.8 per cent of the gross domestic product (GDP) and 42.3 per cent of rural areas directly depend on this sector. The main purpose of this sector is to ensure the availability of food for its inhabitants by increasing production levels to cope with the increasing population. Pakistan is highly vulnerable to climate change because of its population growth rate, its geographical location and its traditional technological methods of production. History shows that Pakistan has suffered due to floods and the negative impacts of climate on crops. Research has shown that up to approximately US$14bn is required to cope with the prevailing climate effects on crops yield. Pakistan has a serious weather challenge, which reduces agricultural production because of the probable change in weather and natural droughts, floods and heat waves. In addition, the melting rates of glaciers in Pakistan are higher than for other countries (GOP, 2016). In this research, an effort was made to evaluate the long-run effects of energy consumption, CO_2 emissions, the labour force and cropped area on cereal crops production in Pakistan by interpreting the annual statistics from 1971 to 2014. The study used the Johansen cointegration test and the ARDL method to evaluate the long-run cointegration links between cereal crops production, CO_2 emissions, energy consumption, cropped area and the labour force. Before testing the ARDL-bounds cointegration method, the present research used the ADF, PP and KPSS unit root tests. The estimated outcomes of ARDL-bounds cointegration approach outcomes confirmed the long-term existence of

Null Hypothesis	F-statistic	Probability
$\ln CO_2$ does not Granger cause lnCP	11.9239***	0.0013
lnCP does not Granger cause $\ln CO_2$	15.5902***	0.0003
lnEN does not Granger cause lnCP	5.60213**	0.0229
lnCP does not Granger cause lnEN	2.61871	0.1135
LnCA does not Granger cause lnCP	3.25470*	0.0788
lnCP does not Granger cause lnCA	3.08841*	0.0865
lnLAB does not Granger cause lnCP	23.1363	2.E-05
lnCP does not Granger cause lnLAB	0.20656	0.6519

Notes: ***; ** and *represent rejection of null hypothesis at 1, 5 and 10 % levels of significance, respectively
Source: Researcher's compilation

Table VII.
Pairwise Granger causality test results

statistically substantial cointegrating associations among the variables. Outcomes of the long-run coefficients for CO_2 emissions, energy consumption, cultivated area and the labour force have positive impacts on cereal crops production. These outcomes reveal that a 1 per cent increase in CO_2 emissions, energy consumption, cultivated area and labour force will increase cereal crops production by 0.20, 0.11, 0.56 and 0.74 per cent, respectively, in the long run. The Granger causality test shows bidirectional causality running from CO_2 emissions and cultivated area to cereal crops production. Moreover, there is a unidirectional causality running from energy consumption to cereal crops production. On the basis of the study outcomes, it is suggested that, to cope with the adverse effects of climate change, heat- and drought-resistant varieties of improved cereal crops should be developed and introduced to ensure food security for the country. Additionally, the government should control the load shedding of electricity, pay further attention to improving the infrastructure of the energy sector and to increase the supply of electricity in the agricultural sector to boost this sector.

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