Short and long-run impacts of climate change on agriculture: an empirical evidence from China

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Abstract

Purpose – The climate change effects on agricultural output in different regions of the world and have been debated in the literature of emerging economies. Recently, the agriculture sector has influenced globally through climate change and also hurts all sectors of economies. This study aims to examine and explore the impact of global climate change on agricultural output in China over the period of 1982-2014.

Design/methodology/approach – Different unit root tests including augmented Dickey–Fuller, Phillips–Perron and Kwiatkowski, Phillips, Schmidt and Shin are used to check the order of integration among the study variables. The autoregressive distributed lag (ARDL) bounds testing approach to cointegration and the Johansen cointegration test are applied to assess the association among the study variables with the evidence of long-run and short-run analysis.

Findings – Unit root test estimations confirm that all variables are stationary at the combination of I(0) and I(1). The results show that CO_2 emissions have a significant effect on agricultural output in both long-run and short-run analyses, while temperature and rainfall have a negative effect on agricultural output in the long-run. Among other determinants, the land area under cereal crops, fertilizer consumption, and energy consumption have a positive and significant association with agricultural output in both long-run and short-run analysis. The estimated coefficient of the error correction term is also highly significant.

Research limitations/implications – China's population is multiplying, and in the coming decades, the country will face food safety and security challenges. Possible initiatives are needed to configure the Chinese Government to cope with the adverse effects of climate change on agriculture and ensure adequate food for the growing population. In concise, the analysis specifies that legislators and policy experts should spot that the climate change would transmute the total output factors, accordingly a county or regional specific and crop-specific total factor of production pattern adaptation is indorsed.

Originality/value – The present empirical study is the first, to the best of the authors' knowledge, to investigate the impact of global climate change on agricultural output in China by using ARDL bounds testing approach to cointegration and Johansen cointegration test.

1. Introduction

Agriculture is considered most vulnerable to the global climate change, the security of food is another issue that needs great concern to all humankind, and the influence of climate change on agriculture attracted huge attention (Tao *et al.*, 2006; Wang *et al.*, 2009; Xiong *et al.*, 2007). The agriculture has a dominant source of income for most rural communities and it adopts the adverse effects of climate change to protect the livelihoods of poor rural households and also having an essential role to ensure food security. Adoption can make the rural communities better and become accustomed to climate change and unpredictability, mitigate potential damage and help them to cope with the adverse consequences, thereby significantly reducing vulnerability to climate change (Cline, 2008). The agriculture sector's reliance on climate change is quite important concern for economic development, as the majority of country's population lives in rural areas is engaged with agricultural and non-agricultural related activities (WB, 2014). Farmers constantly find ways to adapt the variations in the weather and climatic conditions. However, environmental and global climate change has expanded the scale needed for farmers to develop and implement resilience strategies (Aiello, 2009; Collier, 2013; Hess, 2003). Adapting to the current agricultural system is one of the ways to avoid climate change risks and protect livelihoods and local food security. Though the type and scope of adaptation strategies vary from region to region, and socio-economic and agro-ecological environments are constantly changing (Abid *et al.*, 2015). Therefore, the production of food is being affected by weather and climate change. It is necessary to study the influence of global climate change to meet the requirements of people and is estimated by 2100; the world population will reach about 10 billion (Boogaard *et al.*, 2014; Keyzer *et al.*, 2002). The agriculture sector is highly associated with the climatic changes, and also causes dangerous activity. Climate variability is the main source of risk for agriculture and food system. The increasing severity of extreme weather and frequent occurrence of widespread defects the agriculture. Farmers often face erratic rainfall, pests and natural disasters. For instance, farmers experience heavy rains, floods, pests, droughts and market prices (Godfray *et al.*, 2010; Huang, 2014; Iqbal *et al.*, 2016; Ullah *et al.*, 2016). On the other side, in most parts of China, climate warming usually shortens the growth cycle of food crops, which leads to demur the average production (Huang *et al.*, 2010; Wang *et al.*, 2014). Because of the numerous seasonal droughts, there is a spatial and temporal gap among precipitation and irrigation, which ensuring the adequate challenges in irrigation and water supply (Zhang *et al.*, 2006). In the future, the climate change in China may bring more uncertainty in the agricultural productivity. Several previous studies in the agronomic modeling literature have shown that yield and yield of main food crops will decline in the numerous future climates (Xiong, 2014). Furthermore, some studies have been conducted to highlight the association of CO$_2$ emissions with agricultural crops, natural gas and renewable, economic growth and energy consumption (Chandio *et al.*, 2019; Dong *et al.*, 2018; Lin and Xu, 2018; Liu *et al.*, 2016; Luo *et al.*, 2017; Rauf *et al.*, 2018a; Rauf *et al.*, 2018b; Rauf *et al.*, 2018c; Rauf *et al.*, 2018d; Rehman *et al.*, 2019; Wang *et al.*, 2018). However, in this study, authors will investigate the CO$_2$ emissions with rainfall, temperature and agricultural output by using augmented Dickey–

Fuller (ADF)[1] unit root test for the variable's stationarity and the autoregressive distributed lag (ARDL)[2] bounds testing approach to check the association among the study variables. The time series data was taken from the world development indicators (WDI) to investigate an interrelationship between the variables. The rest of the study is organized as follows: Review of relevant literature is provided in the Section 2, data and methodology are presented in the Section 3, empirical findings of the study and its discussions are described in the Section 4, and Section 5 is conclusion, policy recommendations, and finally, study limitations on Section 6.

2. Existing literature

Indeed, China is considered the most populous country in the world, feeding one-fifth of the world's population and using only 8 per cent of the world's cultivated land. Ensuring food security for the repaid growing population is a long-term priority of the Chinese Government. In China, the demand of foods will continue to increase because of population growth and economic development, while the arable land and other productive resources will cause shrinkage because the agricultural productivity will subject to the climate change (Cline, 2007; Li *et al.*, 2011; Yao *et al.*, 2007). Furthermore, among the other factors such as socio-economic, cultural, institutional characteristics and political that can promote or hinder the adaptation process. The third part refers to the multiple scales of adaptation. Climate adaptive capacity and adaptation strategies vary from plot to farm level, to national and international levels and also differ in size. Therefore, the analysis of a system's adaptive capacity and appropriate adaptation strategies should take into account the scale analysis (Vincent, 2007). Abid *et al.* (2015) reported that livelihoods of the rural households and the yield of major food and cash crops, including wheat, rice, cotton and sugarcane had heavily affected over the past two decades because of variations in the global climate. In developed economies, the concentration of CO_2 is mainly caused by several production and consumption activities. On the other hand, the change in the global climate are largely faced by developing countries, and most of the countries are located in tropical regions and mainly rely on the agricultural sector. Practically, all economic sectors are susceptible to climate change but agriculture is the most. Climate change will address crop productivity issues through changes in the rainfall patterns, sowing and harvest dates, rising temperatures, water supplies and transpiration (Rosegrant *et al.*, 2008; Zenghelis, 2006). The security of food and water supply is greatly vulnerable to rapid change in the climate. In summer, most climate models expect to increase the rainfall. Almost, 75 per cent of the Himalayan glaciers are melted and will disappear by 2035. An upgrade in the strength may result in drought and flooding, respectively. Climate change will adversely affect the production of crops and may contribute to the food security issues (Kirby *et al.*, 2016; Mendelsohn, 2014; Mirza, 1997; Misra, 2014; Pearce *et al.*, 1996; Spash, 2007). In the previous few decades, climate change impact has been evident, mainly in low-income countries. However, it has been pointed out that rural households who have not adopted any strategies have shown that lack of information, access to land and lack of formal agricultural credit are the main factors hindering their adaptation to perceived climate change (Bryan *et al.*, 2009; McCarthy *et al.*, 2001; Smit and Skinner, 2002). Climate change has gained great concern because it can trigger socio-economic disasters. Therefore, assessing the economic vulnerability is the main step in addressing climate change (Field, 2014; Zhang *et al.*, 2011). Furthermore, greenhouse gases also exacerbate climate change, and it is caused by the extra natural solar energy generated by an increase in the ocean heat. This increase in the ocean heat effect the sea level to rise and also cause the sea surface temperature to increase. The diversity of ocean currents and temperatures caused by climate change affects global climate patterns.

However, climate change effects on the oceans suggest that future generations, especially those of small island states, may no longer be able to grow there in a sustainable manner (CCI, 2018). The agronomists have made great efforts to develop adaptation strategies in response to the potential negative impacts of future climate change on agriculture. Wang *et al.* (2014) reported that in the southern regions of China, the introduction of improved new crop varieties with similar climatic conditions is mainly considered a practical approach to combating climate warming. The consequence of climate change to China's agriculture and rural economy cannot be overemphasized. About 750 million people and 250 million rural households in China are directly or indirectly affianced in agricultural activities. The challenges of global climate change and how climate change impacts on the yield of crops are important political and economic issues (Lobell *et al.*, 2007; Peng *et al.*, 2004; Wei *et al.*, 2009; Xiong, 2014). Recently, some authors have investigated the impact of climate change on cereal yield, agriculture and economic growth by using several econometric techniques. Dumrul and Kilicaslan (2017) used the ARDL bounds testing approach and found a positive and significant impact of precipitation on agriculture output while temperature has a negative impact on agricultural output in Turkey. Rahim and Puay (2017) examined the nexus between climate change and economic growth in Malaysia. The time frame for the study was 1983 to 2013. The study analyzed the variable using the unit root tests such as the Dickey–Fuller GLS (DF-GLS) and the ADF, the Johansen cointegration approach (JCA) and vector error correction model (ECM). The variables in the study were the gross domestic product (GDP), precipitation, temperature and arable land. Results of the analysis revealed that there is a long-run cointegration association between the study variables. There is a one-way causality nexus from temperature and arable land to GDP. An empirical study has been conducted in India by Alam (2013), which examined the response of agricultural output to climatic change and its long-run effect on economic growth by using time-series data between 1971 and 2011. An ARDL approach and ECM based procedures has been used to inspect the short and long-run nexus between CO_2 emissions, agricultural output and economic growth. Findings revealed that there is a negative and significant linkage between CO_2 emissions and economic growth while there is a positive and significant association between agricultural output and economic growth. As studied by Asuamah Yeboah *et al.* (2015) examined the impact of CO_2 emissions on cereal production in Ghana by using the ARDL approach. The time-series data for Ghana from the period of 1961-2010 is used, findings of the empirical analysis revealed that there is a significant unenthusiastic linkage between CO_2 emissions and cereal production while there are a positive and significant short and long-run relationships between cereal production and income. Furthermore, Rehman *et al.* (2019) study on CO_2 emissions and agricultural productivity in Pakistan by using an ARDL bounds testing approach results demonstrated that cropped area, energy usage, fertilizer offtake, GDP per capita and water availability showed a significant association with CO_2 emissions, while improved seed distribution and total food grains reveled a negative association with CO_2 emissions in Pakistan. To the best of our knowledge, no empirical study has been done in the context of China to investigate the effects of climate change on agricultural output. This study aims to examine the short-run and long-run interconnection between climate change factors and agricultural output in the context of China.

3. Methodology and data
The ARDL[2] approach was first introduced by the Charemza and Deadman (1992) and then further enhanced by Pesaran and Shin (1998) and Pesaran *et al.* (2001) The ARDL[2] approach has several advantages over the traditional cointegration methods such as Engle and

Granger cointegration approach (EGCA)[3](1987), JCA[4](1988) and Johansen and Juselius cointegration approach (JJCA)[5](1990). It takes a small sample size and simultaneity biases in the association between the variables. The main problem in the traditional cointegration approaches was that it requires all the study variables to be non-stationary at I(0) but should be stationary at the same order. The modern cointegration approach like the ARDL overcomes regarding this issue, as it is appropriate regardless of the order of integration among the variables, whether at levels I(0) or at first difference I(1) or both of mixed order of integration. Furthermore, this modern approach also has another advantage in choosing the appropriate numbers of lags for the empirical model. These estimable features validate the usage of ARDL approach to obtain robust estimates. To investigate the association of climate change factors including CO_2 emissions, temperature and rainfall on agriculture in China throughout 1982-2014, the following model can be specified as:

$$AGR_t = f(CO_{2t}, TEMP_t, RF_t, \quad CL_t, \quad FC_t, \quad EN_t, RP_t) \tag{1}$$

In the equation (1), AGR_t indicates the agriculture value added, CO_{2t} represents the CO_2 emissions, $TEMP_t$ represents the average temperature, RF_t represents the rainfall, CL_t represents the land area under cereal crops, FC_t denotes the fertilizers consumption, EN_t indicates the energy consumption and RP_t represents the rural population, respectively. Equation (1) can also be written as:

$$AGR_t = \lambda_0 + \lambda_1 CO_{2t} + \lambda_2 TEMP_t + \lambda_3 RF_t + \lambda_4 CL_t + \lambda_5 FC_t + \lambda_6 EN_t$$
$$+ \lambda_7 RP_t + \mu_t \tag{2}$$

To reduce the multicollinearity and volatility of the annual time series data, this study used all the variables in their nature logarithmic form. By applying natural logarithm to equation (2), a log-linear model is specified as follows:

$$LnAGR_t = \lambda_0 + \lambda_1 LnCO_{2t} + \lambda_2 LnTEMP_t + \lambda_3 LnRF_t + \lambda_4 LnCL_t + \lambda_5 LnFC_t$$
$$+ \lambda_6 LnEN_t + \lambda_7 LnRP_t + \mu_t \tag{3}$$

Mainly, the ARDL model contains two main steps for assessing a long-run association. Step 1 is to examine the presence of a long-run association between the study variables. Equation (4) represents the specification of ARDL model may follow as:

$$\Delta lnAGR_t = \alpha_0 + \sum_{i=1}^{p} \beta_{1j} \Delta lnAGR_{t-k} + \sum_{i=0}^{p} \beta_{2j} \Delta lnCO_{2t-k} + \sum_{i=0}^{p} \beta_{3j} \Delta lnTEMP_{t-k}$$
$$+ \sum_{i=0}^{p} \beta_{4j} \Delta lnRF_{t-k} + \sum_{i=0}^{p} \beta_{5j} \Delta lnCL_{t-k} + \sum_{i=0}^{p} \beta_{6j} \Delta lnFC_{t-k}$$
$$+ \sum_{i=0}^{p} \beta_{7j} \Delta lnEN_{t-k} + \sum_{i=0}^{p} \beta_{8j} \Delta lnRP_{t-k} + \lambda_1 lnAGR_{t-1} + \lambda_2 lnCO_{2t-1}$$
$$+ \lambda_3 lnTEMP_{t-1} + \lambda_4 lnRF_{t-1} + \lambda_5 lnCL_{t-1} + \lambda_6 lnFC_{t-1} + \lambda_7 lnEN_{t-1}$$
$$+ \lambda_8 lnRP_{t-1} + \varepsilon_t \tag{4}$$

where α_0 represents the intercept, p denotes the lag order, Δ stands for the first difference operator and ε_t denotes the error term. This study used F-test to check the long-run equilibrium link among LnAGR, LnCO$_2$, LnTEMP, LnRF, LnCL, LnFC, LnEN and LnRP. The null hypothesis of no cointegration between LnAGR, LnCO$_2$, LnTEMP, LnRF, LnCL, LnFC, LnEN and LnRP is *H0*: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = 0$ against the alternative hypothesis *H1*: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq \delta_6 \neq \delta_7 \neq \delta_8 \neq 0$. According to Pesaran *et al.* (2001), the calculated F-test or Wald-test is matched with the values of lower bound and upper bound. If the computed F-test goes above the upper level of bound, the null hypothesis of no cointegration between LnAGR, LnCO$_2$, LnTEMP, LnRF, LnCL, LnFC, LnEN and LnRP is rejected. If the computed F-test is less to the upper level of bound, it cannot reject the null hypothesis of no cointegration between LnAGR, LnCO$_2$, LnTEMP, LnRF, LnCL, LnFC, LnEN and LnRP. However, If the computed F-test lies between the lower and upper level of the bands, the null hypothesis of no cointegration of LnAGR, LnCO$_2$, LnTEMP, LnRF, LnCL, LnFC, LnEN and LnRP becomes inconclusive, which either can be testified through Johansen cointegration approach (1990) or by using the cumulative sum recursive residuals (CUSUM)[6] and cumulative of square of recursive residuals (CUSUMSQ)[7] to check the constancy of the cointegration (Brown *et al.*, 1975). Step 2 is to assess the short-run association between CO$_2$ emissions, temperature, rainfall, land area under cereal crop, fertilizers consumption, energy consumption, rural population and agriculture in China, the following ECM in ARDL formulation can be expressed as:

$$\Delta lnAGR_t = \alpha_0 + \sum_{i=1}^{p} \beta_{1j}\Delta lnAGR_{t-k} + \sum_{i=0}^{p} \beta_{2j}\Delta lnCO2_{t-k} + \sum_{i=0}^{p} \beta_{3j}\Delta lnTEMP_{t-k}$$

$$+ \sum_{i=0}^{p} \beta_{4j}\Delta lnRF_{t-k} + \sum_{i=0}^{p} \beta_{5j}\Delta lnCL_{t-k} + \sum_{i=0}^{p} \beta_{6j}\Delta lnFC_{t-k}$$

$$+ \sum_{i=0}^{p} \beta_{7j}\Delta lnEN_{t-k} + \sum_{i=0}^{p} \beta_{8j}\Delta lnRP_{t-k} + \alpha ECM_{t-1} + \varepsilon_t$$

(5)

This study used the annual time-series data of the global climate change factors and other control variables for China over the period 1982-2014. It was collected from the WDI[8]. The details of the study variables are presented in Table I. Figure 1 presents the time plots of the study variables used in the analysis.

4. Empirical results and discussions

The results of the descriptive statistics are shown in Table II, which indicates that all variables are normally distributed in the model with constant variance and zero covariance as showed by JB statistics. Similarly, the results of the correlation matrix are displayed in Table III, which shows that CO$_2$ emissions, temperature, fertilizer consumption and energy consumption are positively associated with agriculture. A positive correlation established between temperature, rainfall and fertilizer consumption and CO$_2$ emissions. A pre-condition is that to check the integration order among the study variables. The estimation of the unit root tests ensures that there are no study variables are static and integrated in the order of I(2) to prevent false outcomes. According to Ouattara (2004), if any of the study variables are stationary and integrated at I(2), then the computed ARDL bounds and F-statistics of the cointegration becomes meaningless. The critical bounds in the ARDL

approach are based on an assumption, i.e. all study variables should be stationary and integrated at I(0) or I(1) (Pesaran *et al.*, 2001).

The study has applied different unit root tests such as the Kwiatkowski, Phillips, Schmidt and Shin (KPSS), the ADF and the Phillips–Perron (PP), to find out the integration status of the study variables. The estimated results of the unit root tests (e.g. KPSS, ADF and PP) including at the levels of variables, and then at the first differences are reported in Table IV. The results disclose that all variables are stationary at the combination of I(0) and I(1). It means that stationary properties may display a robust long-run association among the variables and supports to apply the ARDL approach.

This study examines the long-run relationship between climate change factors and other control variables by using the ARDL approach. The initial step is to apply for the selection of appropriate lag length. The results of several selection criteria are presented in Table V, and the order of optimal lag length is decided by adopting the Schwarz information criterion.

The outcomes of ARDL bounds tests shown in the Table VI illustrating that the computed F-tests are 4.828, 7.142, 11.339, 7.214, 3.782, 5.486 and 7.344 go above the upper critical bound at the 1 and 10 per cent levels of significance; when LnAGR, LnCO$_2$, LnRF, LnCL, LnFC, LnEN and LnRP are used as dependent variables, while it means that there are seven cointegration vectors and we may reject the hypothesis of no cointegration. The outcomes of ARDL bounds test for cointegration confirms a long-run association between agriculture (LnAGR), CO_2 emissions (LnCO$_2$), average annual rainfall (LnRF), land under cereal crops (LnCL), fertilizers consumption (LnFC), energy consumption (LnEN) and rural population (LnRP) in China.

Furthermore, in this study, JJCA[6] has used to check the robustness of long-run connection and test results are reported in Table VII. The estimates are suggesting a rejection of the null hypothesis of no cointegration in the model because the values of the trace statistic and maximum eigenvalue are higher than the critical values at the 1 and 5 per cent levels of significance. Hence, an alternative hypothesis will be accepted where long-run association presence is valid between the agricultural output and climate change factors, by counting with other control variables in China.

The results of the long-run analysis are shown in Table VIII (Panel A). The results of the long-run analysis are shown in Table VIII (Panel A). The estimated results display that CO_2 emissions have a positive long-run impact on the agricultural output at 5 per cent significance level. A 1 per cent increase in CO_2 emissions can increase the agricultural output by 0.061325 per cent. This result is similar to Janjua *et al.* (2014). Similarly, the estimated long-run coefficients of temperature and rainfall are showing negative linkage with the agricultural output. It shows that temperature and rainfall increase, agricultural output decrease as well. The findings of this study are in line with

Variables	Explanation	Data source
AGR	Agriculture value added (constant 2010 US$)	WDI
CO$_2$	CO_2 emissions (metric tons per capita)	WDI
TEMP	Average annual temperature (°C)	WDI
RF	Average annual rainfall (mm)	WDI
CL	Land area under cereal crops (hectares)	WDI
FC	Fertilizers consumption (kilograms per hectare of arable land)	WDI
EN	Energy consumption (kg of oil equivalent per capita)	WDI
RP	Rural population (% of total population)	WDI

Table I.
Variables description
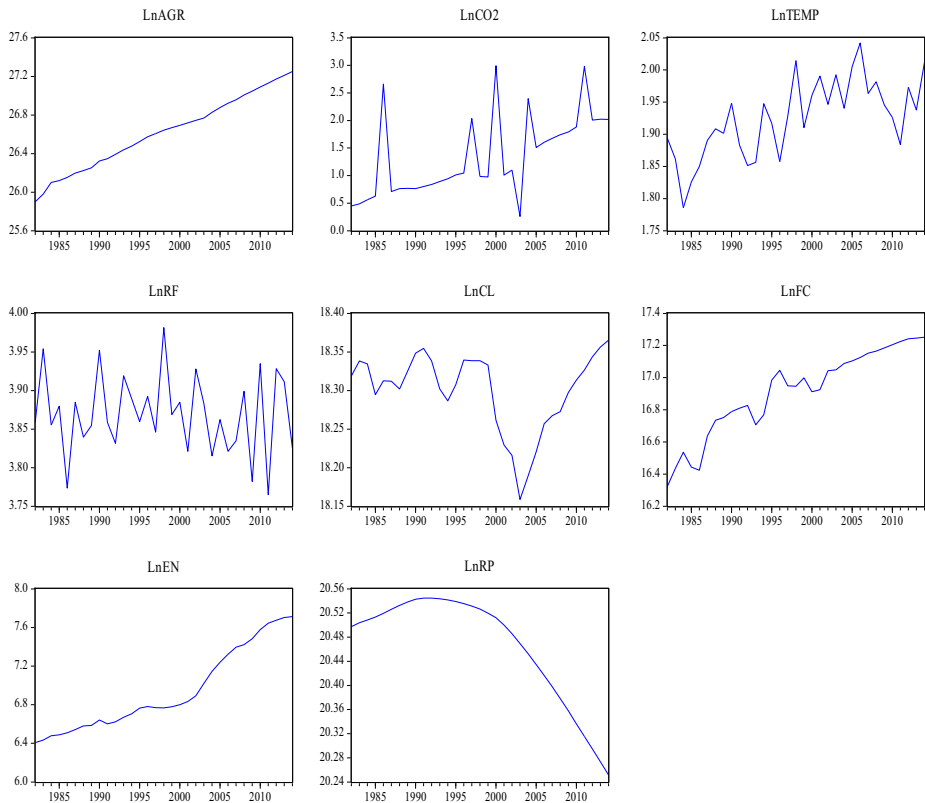
Notes: LnAGR; LnCO2; LnTEMP; LnRF; LnCL, LnFC, LnEN and LnRP refer, respectively, the natural logarithm of agriculture value added; the natural logarithm of emission of carbon dioxide; the natural logarithm of average temperature; the natural logarithm of average rainfall; the natural logarithm of land area under cereal crops; the natural logarithm of fertilizers consumption; the natural logarithm of energy consumption, and the natural logarithm of rural population

Figure 1.
Time plots series of
the study variables

Ahmed and Schmitz (2011), Mahmood *et al.* (2012), Peng *et al.* (2004), Saseendran *et al.* (2000) and their studies concluded that temperature has a negative impact on the rice production. Similarly, Ali *et al.* (2017) reported that maximum temperature has an adverse impact on wheat production. Furthermore, the coefficient of land area under cereal crops to agricultural output is positive and significant. In the long-run analysis, the area under cereal crops will play a key role in boosting agricultural output. The outcomes reveal that a 1 per cent increase in the land area of cereal crops, agricultural output increased by 1.277362 per cent. The result of this study is in line with Ahmad (2011) and Chandio *et al.* (2016). Likewise, fertilizers can also play a significant role to cope with any adverse effect toward agricultural output in the long-run. Appropriate usage of fertilizers could improve soil nutrition and soil fertility. The effect of fertilizer consumption on agricultural output is also notable. For example, this study finds out that a 1 per cent increase in fertilizer consumption could raise agricultural output by 0.383519 per cent. This result is similar to Chandio *et al.* (2018)b; Rehman *et al.* (2017). In the

Variables	LnAGR	LnCO$_2$	LnTEMP	LnRF	LnCL	LnFC	LnEN	LnRP
Mean	26.61624	1.342909	1.925240	3.869605	18.29998	16.90989	6.939429	20.43596
Median	26.64200	1.014000	1.928104	3.862299	18.31267	16.94882	6.778244	20.50836
Maximum	27.25100	2.992000	2.041862	3.981598	18.36525	17.25190	7.712770	20.54471
Minimum	25.90000	0.260000	1.785513	3.764940	18.15864	16.32307	6.408249	19.25171
Std. dev	0.381321	0.744014	0.060125	0.052059	0.050815	0.268164	0.425825	0.227454
Skewness	−0.062979	0.695057	−0.171595	0.038230	−1.109558	−0.606185	0.624162	−4.464143
Kurtosis	1.959597	2.504884	2.508000	2.629923	3.538084	2.351016	1.946547	23.71776
Jarque-B	1.510168	2.994138	0.494785	0.196355	7.169266	2.600156	3.668606	699.7924
Probability	0.469971	0.223785	0.780834	0.906488	0.027747	0.272511	0.159725	0.000000
Observations	33	33	33	33	33	33	33	33

Notes: LnAGR; LnCO$_2$; LnTEMP; LnRF; LnCL, LnFC, LnEN and LnRP refer, respectively, the natural logarithm of agriculture value added; the natural logarithm of emission of CO$_2$; the natural logarithm of average temperature; the natural logarithm of average rainfall; the natural logarithm of land area under cereal crops; the natural logarithm of fertilizers consumption; the natural logarithm of energy consumption and the natural logarithm of rural population
Source: The authors' calculation

Table II.
Descriptive statistics and correlation analysis

long-run estimation, energy consumption and rural population as a proxy of the labor force are indicating positive linkage with agricultural output. The energy consumption and rural population are statistically insignificant with the coefficients of 0.032058 and 0.084486. It implies that a 1 per cent increase in energy consumption and rural population will increase the agricultural output by 0.032058-0.084486 per cent, respectively.

The outcomes of the short-run estimation are also shown in Table VIII (Panel B). The estimated short-run results reveal that the explanatory variables (such as CO$_2$ emissions, land under cereal production, fertilizer consumption and energy consumption) are statistically positive and significant that influenced the agricultural output. Among all the repressors, the coefficient of the impact of CO$_2$ emissions in the long-run, as well as in the short-run analysis on agricultural value added is distinguished. The short-run coefficient of CO$_2$ emissions is 0.010115, which means a 1 per cent increase in CO$_2$ emissions will boost the output of about 0.010115 per cent. In the short-run estimation, this study does not find out any significant or negative effect of climate change factors, for instance, temperature and rainfall, on agricultural output. This result is similar to Janjua *et al.* (2014). In both long-run and short-run analyses, the results found that land area (area under cereal crops) is highly significant and showing to enhance the agricultural output in China. The land as a prime input displays its coefficient 0.366496; this implies a 1 per cent increase in area under cereal crops will boost the output almost by 0.366496 per cent. Similarly, in the long-run and short-run estimation, fertilizer consumption has a positive and significant influence on agricultural output. The short-run coefficient of energy consumption is 0.287169, concerning to agricultural output is highly significant at 1 per cent, which is in the line of earlier findings (Abbas and Choudhury, 2013; Chandio *et al.*, 2018a; Lili *et al.*, 2011). These estimates suggest that a 1 per cent increase in energy consumption, agricultural output increases about by 0.287169 per cent. The error correction term ECM_{t-1} denotes the speed of adjustment toward the long-run equilibrium from any short-run shock in the repressors. The elasticity estimates of ECM_{t-1} is negative, and it is highly significant at the 1 per cent. The estimated results of diagnostic tests in the ARDL model, which are also described in Table VIII (Panel C) shows the model has passed several diagnostic tests (for example, χ^2 SERIAL, χ^2NORMAL, χ^2ARCH, χ^2White and χ^2 RESET), respectively. For the stability of

Variables	LnAGR	LnCO$_2$	LnTEMP	LnRF
LnAGR	1.000000			
LnCO$_2$	0.617587*** [4.371985] (0.0001)	1.000000		
LnTEMP	0.653508*** [4.807084] (0.0000)	0.259548 [1.496384] (0.1447)	1.000000	
LnRF	−0.100633 [−0.563161] (0.5774)	−0.386284** [−2.331724] (0.0264)	0.090667 [0.506898] (0.6158)	1.000000
LnCL	−0.181616 [−1.028296] (0.3118)	−0.027397 [−0.152599] (0.8797)	−0.400964** [−2.436949] (0.0207)	0.146113* [0.822347] (0.4172)
LnFC	0.960188*** [19.13723] (0.0000)	0.511468*** [3.314006] (0.0023)	0.647124*** [4.726011] (0.0000)	−0.065914 [−0.367793] (0.7155)
LnEN	0.955049*** [17.93731] (0.0000)	0.615140*** [4.344086] (0.0001)	0.568548*** [3.847980] (0.0006)	−0.139392 [−0.783756] (0.4391)
LnRP		−0.346058*** [−2.053661] (0.0485)	−0.363643** [−2.173476] (0.0375)	0.172236 [0.973519] (0.3378)

Notes: The values of t-statistics are displayed in [] and the values of probability are shown in (). ***, ** and * denote the significant levels at 1, 5 and 10%, respectively

Source: The authors' calculations

(*continued*)

Table III.
Correlation analysis

Variables	LnCL	LnFC	LnEN	LnRP
LnAGR				
LnCO$_2$				
LnTEMP				
LnRF				
LnCL	1.000000			
LnFC	−0.179751 [−1.017382] (0.3168)	1.000000		
LnEN	−0.094059 [−0.526028] (0.6026)	0.884769*** [10.57053] (0.0000)	1.000000	
LnRP	−0.194587 [−1.104525] (0.2779)	−0.446625**** [−2.779305] (0.0092)	−0.617711*** [−4.373407] (0.0001)	1.000000

Table III.

Variables	Deterministic component	KPSS	ADF	PP
LnAGR	Intercept	0.672293**	−1.570751	−1.528224
LnCO$_2$	Intercept	0.750558***	−1.427441	−4.372953***
LnTEMP	Intercept	0.587621**	−2.647526*	−2.468565
LnRF	Intercept	0.149017	−8.242308***	−8.242308***
LnCL	Intercept	0.475547**	−2.594935	−7.551133***
LnFC	Intercept	0.744697***	−2.994883**	−3.145724**
LnEN	Intercept	0.626046**	0.222899	1.046705
LnRP	Intercept	0.624057**	−1.321710	3.147199
LnAGR	Trend and intercept	0.117321	−2.103766	−4.366799***
LnCO$_2$	Trend and intercept	0.205014**	−6.491043***	−7.836178***
LnTEMP	Trend and intercept	0.115725	−4.224725**	−4.231295***
LnRF	Trend and intercept	0.088666	−8.246404***	−8.246404***
LnCL	Trend and intercept	0.193082**	−2.249160	−6.634182***
LnFC	Trend and intercept	0.168940**	−3.456561*	−3.008186
LnEN	Trend and intercept	0.181219**	−1.748692	−1.300633
LnRP	Trend and intercept	0.195166**	−2.372337	−0.148453
ΔLnAGR	Intercept	0.229273	−5.093066***	−5.200618***
ΔLnCO$_2$	Intercept	0.235533	−5.925019***	−8.553507***
ΔLnTEMP	Intercept	0.129931	−6.448628***	−11.42700***
ΔLnRF	Intercept	0.513000***	−5.495487***	−6.166705***
ΔLnCL	Intercept	0.607482**	−4.385566***	−2.659282*
ΔLnFC	Intercept	0.500000**	−3.859721***	−7.445075***
ΔLnEN	Intercept	0.301828	−2.786180*	−2.787239*
ΔLnRP	Intercept	0.416955*	−0.355692	−0.359966
ΔLnAGR	Trend and intercept	0.125228*	−5.049756***	−5.091460***
ΔLnCO$_2$	Trend and intercept	0.229399***	−5.800776***	−7.005102***
ΔLnTEMP	Trend and intercept	0.081803	−6.366362***	−10.90011***
ΔLnRF	Trend and intercept	0.536700***	−5.311940***	−5.435658***
ΔLnCL	Trend and intercept	0.197214**	−2.619441	−1.853489
ΔLnFC	Trend and intercept	0.352003***	−4.867117***	−11.21217***
ΔLnEN	Trend and intercept	0.083175	−5.206732***	−10.01048***
ΔLnRP	Trend and intercept	0.130864*	−3.342693*	6.964039***

Notes: KPSS; ADF and PP represent the Kwiatkowski, Phillips, Schmidt and Shin test; the augmented Dickey–Fuller test and the Phillips–Perron test. ***, ** and * denote the significant levels at 1, 5 and 10%, respectively
Source: The authors' calculations

Table IV.
Unit root tests results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	273.0696	NA	5.17e−18	−17.1012	−16.7312	−16.9806
1	584.6489	442.2415	6.86e−25	−33.0741	−29.7435*	−31.9884
2	693.1771	98.0254*	9.98e-26*	−35.9469*	−29.6558	−33.8961*

Note: *Lag order selected by the criterion
Source: The authors' calculations

Table V.
VAR Lag length selection

the ARDL model, this study used CUSUM and CUSUMSQ tests suggested by Brown *et al.* (1975). Figures 2 and 3 show the plot of both stability tests such as CUSUM and CUSUMSQ that fall inside the critical boundaries at 5 per cent level of significance. Hence, it means that the estimated parameters of the model are stable over the periods.

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Variables	LnAGR	LnCO$_2$	LnTEMP	LnRF	LnCL	LnFC	LnEN	LnRP
F-statistics	4.8289***	7.1426***	2.739003	11.3391***	7.2146***	3.7827*	5.4862****	7.3442****
Optimal lag structure	(1,1,1,0,0,1,1,1)	(1,0,1,0,0,0,0,0)	(1,0,0,0,0,0,1,0)	(1,0,0,0,0,0,1,0)	(1,0,1,1,0,1,0,1)	(1,1,0,1,0,1,0,1)	(1,0,1,0,0,0,1,1)	(1,1,0,0,0,1,0,1)
Critical values	1%	5%	10%					
Lower bounds I(0)	2.96	2.32	2.03					
Upper bounds I(1)	4.26	3.84	3.13					
Diagnostic tests								
R^2	0.71859	0.7536	0.515594	0.8263	0.7840	0.7041	0.7721	0.9747
Adj-R²	0.5260	0.6572	0.326044	0.7584	0.6544	0.5267	0.6528	0.9615
F^2*statistic*	3.7321**	7.8186***	2.720096**	12.1645***	6.0514***	3.9675***	6.4713***	8.7784***

Notes: ***, ** and * denote the significant levels at 1 and 10%, respectively
Source: The authors' calculations

Table VI.
Results of ARDL
bounds testing to
cointegration

Hypothesis	Test statistic	5% CV	*p*-value
Trace statistic			
$r \leq 0$	287.3931***	159.5297	0.0000
$r \leq 1$	205.2882***	125.6154	0.0000
$r \leq 2$	142.8606***	95.75366	0.0000
$r \leq 3$	95.02472***	69.81889	0.0001
$r \leq 4$	51.60431**	47.85613	0.0213
$r \leq 5$	25.78058	29.79707	0.1354
$r \leq 6$	10.00833	15.49471	0.2801
$r \leq 7$	0.032574	3.841466	0.8567
Maximum eigenvalue			
$r \leq 0$	82.10488***	52.36261	0.0000
$r \leq 1$	62.42757***	46.23142	0.0005
$r \leq 2$	47.83589***	40.07757	0.0055
$r \leq 3$	43.42041***	33.87687	0.0027
$r \leq 4$	25.82373	27.58434	0.0826
$r \leq 5$	15.77224	21.13162	0.2384
$r \leq 6$	9.975757	14.26460	0.2135
$r \leq 7$	0.032574	3.841466	0.8567

Table VII.
Results of the
Johansen
cointegration test

Notes: *** and **denote 1 and 5% levels of significance, respectively.
Source: The authors' calculations

5. Conclusion and policy implications

Climate change is projected to unfavorably distress to the agricultural output and countryside incomes in an economy. Therefore, sensible adaptation is looked-for to diminish the potential sufferers in agricultural productivity. The main aim of this empirical study was to assess the association of climate change impacts on the agricultural output in China over the period of 1982-2014. The study used several unit root tests including the KPSS, the ADF and the PP to check variables stationarity, while the ARDL approach was used to check the causality association between the study variables with long-run and short-run analysis. Unit root test estimations confirmed that all variables are stationary at the combination of I(0) and I(1). Furthermore, the results of the ARDL approach showed the long-run association between agricultural output, CO_2 emissions, temperature, rainfall, land area under cereal crops, fertilizer consumption, energy consumption and the rural population at 1, 5 and 10 per cent levels of significance. The analysis results of the long-run and short-run coefficients show that CO_2 emissions, land area under cereal crops, fertilizer consumption and energy consumption have a positive impact on the agricultural value added. On the other hand, temperature and rainfall have a negative effect on agricultural value added in the long-run but have a positive effect in the short-run. Based on the findings of current study, it is recommended that possible steps should be taken from the Government of China to adopt new policies and modern technology regarding accurate weather forecasting, and precautionary and direct actions are also needed to develop and underpin an improved irrigation system. The construction of farmland also needed to improve to address future climate change.

In concise, the analysis specifies that legislators and policy experts should spot that the climate change would transmute the total output factors, accordingly a county or regional specific and crop-specific total factor of production pattern adaptation is indorsed. In general, climate change has hostile effects on the yield of the main food crops. Thus, the

Regressors	Coefficient	Standard error	t-ratio	Probability
Dependent variable: lnAGR; selected model: ARDL (1, 1, 1, 0, 0, 1, 1, 1)				
Panel A: long-run estimation				
$LnCO_2$	0.061325**	0.025531	2.402036	0.0267
LnTEMP	−0.142749	0.262364	−0.544087	0.5927
LnRF	−0.687591*	0.361563	−1.901719	0.0725
LnCL	1.277362**	0.516779	2.471777	0.0231
LnFC	0.383519**	0.141095	2.718160	0.0136
LnEN	0.032058	0.214315	0.149586	0.8827
LnRP	0.084486	0.533271	0.158431	0.8758
C	−7.759671	12.206394	−0.635705	0.5326
Panel B: short-run estimation				
$\Delta LnCO_2$	0.010115**	0.004975	2.033183	0.0562
ΔLnTEMP	0.063575	0.060118	1.057493	0.3035
ΔLnRF	0.080722	0.061896	1.304152	0.2078
ΔLnCL	0.366496***	0.116836	3.136829	0.0054
ΔLnFC	0.110038**	0.048459	2.270722	0.0350
ΔLnEN	0.287169***	0.104579	2.745959	0.0128
ΔLnRP	−6.471040***	1.308158	−4.946680	0.0001
ECM(−1)	−0.286916***	0.051357	−5.586710	0.0000

Panel C: residual diagnostic tests
R^2 0.7294
F-stat 4.2166***
DW-statistic 2.5560
χ^2SERIAL 1.3597 (0.2833)
χ^2NORMAL 1.5738 (0.4552)
χ^2ARCH 0.3619 (0.6995)
χ^2White 1.0691 (0.4358)
χ^2RESET 1.4675 (0.1595)
CUSUM stable
CUSUM square stable

Note: ***, ** and *indicate significance levels at 1, 5 and 10%, respectively
Source: The authors' calculations

Table VIII.
Long-run and short-
run coefficients using
the ARDL model

government should propose some solid strategies in this regard to attaining the sustainable productivity of main food crops by familiarizing the modern agriculture technological approaches. In addition, being China's population is multiplying, and in the coming decades, the country will face food security challenges. Therefore, the possible initiatives are also needed to constitute Chinese Government to cope with the adverse effects of climate change on agriculture and ensure adequate food for such massive population.

On the whole, the study also approves and calculates that climate change adaptation for agriculture productivity would offer extensive paybacks to the agriculturalists through upgraded proceeds and to society via better-quality food surety. However, agriculturalists are so far powerless to be blessed with all compensations of accustom because of several restrictions and absence of knowledge on enhanced adaptation possibilities. At this point, the Chinese administration, private formed companies and non-governmental organizations can perform a key part in focusing these restrictions by way of vagarious coordination for capacity building and schooling of agriculturalists, effortless access to micro and macro climate-specific knowledge and understanding on better-quality adjustment processes.
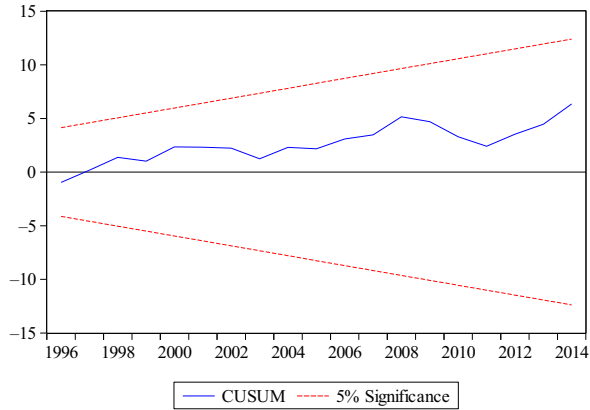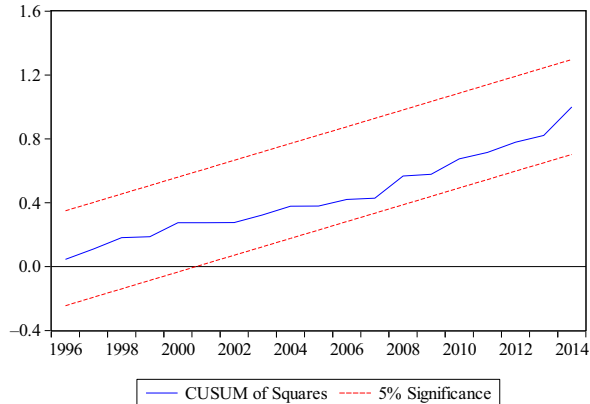
Supplementary, agricultural guidelines need to be restructured based on modern technological research and consideration should also be granted to resource-restrained and small-tier agriculturalists, who constitute in excess of two-thirds of the entire agricultural inhabitants in China. All these inferences may spread to improved adaptation of food crops to climate change and possibly will adept to sponsor the agriculturalists for expanding their crop yields and certify the homegrown food safety.

6. Limitations
The study has used a countrywide data set, which could not illustrate the factual portrait of the influence of climate change on unlike agro-environmental regions. Thus, to grasp the counties and regional disparities into consideration, area or zones-specific research investigations should be performed for better insights. The aggregated and disaggregated yields corps studies should be conducted to evaluate the impacts of climate change on such dissimilar food crops. The association between CO_2 emissions and the yield of cereal crops should be examined by using the latest econometric techniques in future studies, as the present study considered agricultural output.

Notes

1. See Augmented Dickey-Fuller (1979).

2. The ARDL bounds testing approach of cointegration.

3. See EGCA (Engle and Granger, 1987).

4. See CA (Johansen, 1988).

5. See JJCA (Johansen and Juselius, 1990).

6. CUSUM.

7. CUSUMSQ.

8. See WDI (WDI, 2014).

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