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Does Agricultural Credit Mitigate the Effect of Climate Change on Cereal Production? Evidence from Sichuan Province, China

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Abstract: This study attempts to investigate the effects of global climate change (via temperature and rainfall) on cereal production in Sichuan over the 1978–2018 period, whether agricultural credit combining with technical progress (i.e., mechanical farming rate) mitigate the effect of climate change. The present study empirically analyzed the short-term and long-term interrelation among all the considered variables by using the autoregressive distributed lag (ARDL) model. The results of the ARDL bounds testing revealed that there is a long-term cointegration relationship between the variables. The findings showed that temperature significantly negatively affected cereal production, while rainfall significantly contributed to cereal production in the context of Sichuan province, China. Agricultural credit, especially in the long run, significantly improved cereal production, implying that agricultural credit is used to invest in climate mitigation technologies in cereal production. Findings further indicated that the mechanical farming rate significantly enhanced cereal production, indicating that technical progress has been playing a vital role. This study suggests that the policymakers should formulate more comprehensive agricultural policies to meet the financial needs of the agricultural sector and increase support for production technology.

Keywords: climate change; agricultural credit; technical progress; cereal production; ARDL model; Sichuan province

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1. Introduction

In recent decades, the degree of global climate change has been increasing. The fifth comprehensive report issued by the United Nations Intergovernmental Panel on climate change points out that the period from 1983 to 2012 may be the hottest 30 years in the past 1400 years, and climate change will increase the frequency of extreme weather events [1]. In the past century, global warming has accelerated significantly, and a large number of greenhouse gas (GHG) emissions, a rapidly growing population and the combustion of fossil fuels are considered to be the main reasons [2]. Rapid climate change will significantly affect global cereal production, which is specifically reflected in changes in agricultural productivity and planting patterns [3,4]. Several factors, such as the fluctuation of global rainfall, the continuous rise of average temperature, the continuous rise of carbon dioxide concentration, and the frequent occurrence of extreme events for instance drought and flood disasters, will pose a great threat to cereal production [5]. As the most direct embodiment of climate change, temperature and rainfall often affect cereal by affecting their growth and maturity time [6]. Climate change can also change rainfall patterns, so that the normal growth of crops cannot be guaranteed [7].

The impact of climate change on agriculture in developing countries is particularly prominent, especially in South Asia and Africa. Climate change has a significant impact on arid and semi-arid areas in South Asia [8]. In Pakistan, the main factors affecting agriculture include poverty, insufficient financial support, dramatically changing climate conditions and natural disasters, such as major floods and glacier melting [9]. High temperature has a significant negative impact on maize yield in the context of Pakistan, while precipitation has a significant positive impact on maize yield [10]. Based on the change of climate conditions in Malaysia from 1980 to 2010, Sarkar et al. [11] concluded that there is a significant negative correlation between the annual average temperature and palm oil production. In the case of India, rainfall has a positive impact on most crops, but cannot offset the negative impact of temperature. With the significant changes of temperature and rainfall, it is expected that by 2100, the cereal yield in India will decrease by 15% and the wheat yield will decrease by 22% [12]. Agriculture in Bangladesh is also very vulnerable to climate change. The harm caused by climate change will directly or indirectly lead to food insecurity by affecting the socio-economic status of coastal areas [13]. Climate change has also significantly affected the cereal production in Africa. In West Africa, the productivity of major crops will decline significantly due to future warming and changes in precipitation patterns [14]. The evolution of the African monsoon has led to an increase in rainfall in the eastern Sahara and a decrease in rainfall in the Western Sahara. It is expected that the per capita agricultural output in West Africa will be less than 50 kg by 2050 [15]. Attiaoui and Boufateh [16] found that the increase in rainfall has had a significant positive impact on grain production in Tunisia, which is also applicable to most other African countries, such as Burkina Faso [17].

In 2018, China's total cereal output was about 148.5 million tons, with a total planting area of 30,190 hectares, making China the world's largest cereal producer, accounting for about 28% of the global cereal output [18–20]. With the intensification of climate change, China's cereal yield may decline by 20%–36% in the next 20–80 years [21,22]. In most provinces of China, abnormal changes in temperature and rainfall often hinder the development of food crops, resulting in a decline in average grain yield [23,24]. Sichuan province is a major agricultural province and the only major grain producing province in the West region of China. In 2018, the grain output of Sichuan province reached 34.937 million tons, including 14.786 million tons of cereal, 2.473 million tons of wheat and 10.663 million tons of corn. The cereal planting area has stabilized in recent years, the wheat planting area has decreased by nearly half in recent ten years, while the corn planting area has decreased by nearly half. In general, cereal is the most important food crop in Sichuan province, regardless of planting area or total output. The climate of Sichuan province has fluctuated in recent years, generally showing the characteristics of higher temperature and less rain, and this is also the adverse result caused by the annual increase in CO_2 emission in Sichuan province in recent years. The historical trend of CO_2 emission in Sichuan province is displayed in Figure 1. In the context of rising CO_2 emissions, according to the 2019 Sichuan climate bulletin published by Sichuan Climate Center, it is pointed out that the average temperature of Sichuan province in 2019 is 15.4 °C, 0.5 °C higher than that of the whole year, ranking the ninth highest in the history. At the same time, there is less precipitation in seven months of the year, which reflects the uneven distribution of rainfall in Sichuan province. Agriculture is a highly sensitive sector to global warming. Extreme weather events, such as floods and drought, have an adverse effect on agricultural production. Therefore, changing climate will exacerbate food production [25–28].

In order to cope with the recent global warming and improve the agricultural products, it is primarily important to introduce climate-change-related financial schemes. Amidst many financial services, agricultural credit has been playing a vital role to boost agricultural production and increase the income of rural households. Agricultural credit has a significantly positive impact on agricultural output and rural development [29], and it helps to encourage farmers to participate in agricultural-related activities and accelerate the process of agricultural transformation in society [30]. Several previous empirical studies proved that agricultural credit significantly contributed toward agricultural products in different regions of the developing nations [31–33]. Agricultural credit is a driving force of rural economic development. Agricultural credit is supplied by financial institutions to farming communities and allows farmers to invest in agricultural related activities and increase agricultural products. Without an adequate amount of agricultural credit, the development of rural areas will be greatly hindered. Therefore, it is very important to actively develop the rural financial system for the farming community, increase agricultural credit and optimize the allocation of agricultural funds to solve the problem of agricultural development.

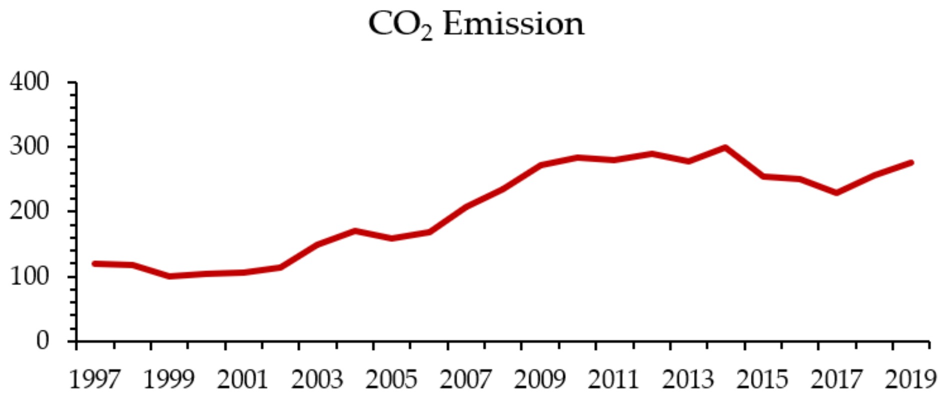

Figure 1. Historical trend of CO_2 emission in Sichuan province, China. Source: Wind Database.

In the context of China, several studies have been conducted to examine the impacts of climate change on agricultural production, for example, Pickson et al. (2020) assessed the effects of global warming on cereals production, Pickson et al. (2021) also explored the nexus between changing climate and rice productivity, Chandio et al. (2019) studied the influences of climate factors on agricultural output, and Chandio et al. (2020) examined the impacts of financial development on agricultural productivity [34–37]. However, these studies ignored some main factors of cereals production, such as agricultural credit, and technical progress (i.e., mechanical farming rate). Furthermore, to the best of the authors' knowledge, the present study attempts to contribute to the existing literature by investigating the impacts of climatical factors on cereal production using co-integration analysis with the auto-regressive distributed lag (ARDL) bounds testing approach. Conclusively, there was no study focusing on the province-based estimation of impacts of climate change on cereal production, using the time series datasets. This study also incorporates other important factors, including agricultural credit and the mechanical farming rate, which were ignored by previous studies. The present study addresses the following research questions:

- Does the increasing global warming adversely affect cereal production in the context of Sichuan province, China?
- How does agricultural credit mitigate effects of changing climate on cereal production in the context of Sichuan province, China?
- Does the mechanical farming rate improve cereal production in the context of Sichuan province, China?

The rest of the research study is arranged as follows: the second section reviews the relevant literatures, the third section presents data and methods, the fourth section reports results and discussions, and the fifth section concludes the study.

2. Literature Review

The present study investigates the long-term and short-term impacts of agricultural credit, global warming, and technical progress on cereal yield in the context of Sichuan province, China. Therefore, the literature review of this study is mainly divided into two parts. The first part is the literature on the impacts of climate change on cereal yield, and the second part is the literature on the impacts of agricultural credit on cereal yield.

2.1. Relevant Research on the Impact of Climate Change on Cereal Production

Crop growth and its development require the stable/favorable temperature, precipitation and sunshine. Low precipitation, increasing high temperature or higher sunshine intensity will lead to drought. Low level of temperature will cause freezing injury, and high level of precipitation will lead to flood disaster, which will affect agricultural production.

Cui et al. [38] used the transcendental logarithm production function model to analyze the impact of climate change during crop growth period on the unit production of one season cereal, wheat and maize in the case of China from 1975 to 2008, and reported the impact of climate change on different varieties. The impact on grain production in different regions is different. The increasing temperature can increase the unit production of spring wheat and corn in high latitudes. The impact of increased precipitation during crop growth on grain production varies with grain varieties. Although it has a positive impact on spring wheat production in the northwest region of China, it has a negative impact on winter wheat production in the southern region of China.

Zhou and Zhu [39] found that climate change has a significant negative impact on cereal production in South China, and the impact of climate on each region is different. Precipitation has a negative impact on cereal production in South China, Central China and East China, but a certain positive impact on cereal production is observed in Southwest China. Furthermore, they reported that temperature has a negative effect on cereal production in Southwest China, East China and Central China. Hou [40] stated that the temperature rise has a negative impact on the cereal production of the land, and the northwest region is the most adversely affected by the temperature rise; the increase in precipitation has a positive impact on all regions, except the South. Liu and Yang [41] observed that there is a long-term cointegration relationship between agricultural real GDP and average temperature, and the short-term change of average temperature has no obvious positive impact on agricultural real GDP.

Chloupek [42] reported that in the past 50 years, the average temperature has increased by 0.0218 °C per year, but in the past 10 years, it has increased by 0.087 °C per year. These climate changes are conducive to most cultivated crops because they produce higher production in warm years. It is also difficult to subdivide the research area due to conditions and other factors. For example, Villavicencio [43] studied that climate change is changing the rate of return of public agricultural research in a way of spatial heterogeneity, the increase in precipitation is promoting the return of agricultural research, and the impact of high temperature on agricultural research is different in different regions. Based on the data of three regions in Jiangsu province of China from the period 1988 to 2010, Zhu et al. [44] divided the cereal growth period into five growth stages, studied the impact of climate change on the total cereal production, and concluded that the impact of climate factors in different growth stages on the total cereal production is different; the total cereal production increased positively in Huaibei and Jianghuai areas and negatively in Southern Jiangsu.

Chen et al. [45] expanded the county-level data of Huang Huai Hai Plain to China's county-level crop production, irrigation, meteorological and socio-economic data from 1996 to 2009, investigated the impact of climate change on China's cereal and wheat production by using economic methods, and concluded that the impact of climate variables, such as temperature, precipitation and sunshine, on China's cereal and wheat production increased first and then decreased. There is an optimal inflection point. He et al. [46] introduced climatic factors, such as rainfall and temperature, into the transcendental logarithmic production function. Based on the micro panel data of 238 rape planting farmers in 20 rape producing counties in Hubei province of China from the period of 2009 to 2013, they studied the impact of temperature and rainfall on oilseed rape production in the recent 5 years, and concluded that increasing temperature has negatively affected production in the long-term while positively increasing it by the contribution of rainfall. Based on the above climate change related studies, this investigation tests the following hypothesis.

Hypothesis 1 (H1). *Global warming (temperature) negatively affects cereal production in the context of Sichuan province, China.*

2.2. Relevant Research on the Impact of Agricultural Credit on Cereal Production

Agricultural credit is an important source of funds for farmers to carry out agricultural activities, which can have a great impact on cereal production. Some scholars have discussed this topic to a certain extent, and most of them concluded that agricultural credit can positively enhance agricultural products and boost agricultural economic growth. Some scholars analyzed the impact of long-term and short-term credits on wheat production based on the survey data of Pakistan. The results showed that both types of credit schemes contributed significantly positively toward wheat production [47,48]. Chris o udoka et al. [49] showed that there is a significant positive correlation between Nigerian agricultural credit guarantee program funds and cereal production, which means that the increase in agricultural credit guarantee program funds may lead to the increase in cereal production in Nigeria. Xu et al. [50] used the cointegration test and error correction model (ECM) to analyze the impact of agricultural credits and agricultural fiscal expenditure on grain output in main grain producing areas from the period of 1979 to 2010. The results showed that agricultural credits and agricultural fiscal expenditure significantly increased grain output in the main grain-producing areas in the current period. Omoregie et al. [51] used the vector error correction model (VECM) method to study the impact of credit supply on cereal production in Nigeria from 1981 to 2016. The results indicated that the increase in credit supply will lead to the increase in cereal production. In addition, the research revealed that the impact of investment and labor force will lead to the decline of cereal production, while the impact of money supply and inflation rate will lead to the increase in cereal production in the country. The research of Adesiji et al. [52] reported that the increase in agricultural credit can positively promote the cereal production of cereal farmers. In addition, their research further exposed the obstacles faced by cereal farmers in order to obtain better financial services, including lack of collateral, insufficient funds and high interest rates.

Although most scholars believe that agricultural credit can positively promote crop production and boost agricultural economic growth, a few scholars hold the opposite view. Cao [53] investigated the relationship between China's rural financial development and agricultural economic growth since 1978 from the static and dynamic perspectives through structural modeling and econometric analysis of time series; the study concluded that there is a significant negative correlation between agricultural credits and the total output value of agriculture, forestry, animal husbandry, and sideline fisheries. Yu [54] empirically analyzed the relationship between China's rural financial development and farmers' income growth by using the relevant data from 1978 to 2008. The results showed that there is a negative relationship between rural credits, agricultural insurance income and farmers' income growth; there is a certain lag in the promotion of farmers' income by agricultural credits. Township enterprise credits have not become an important way to increase farmers' income but inhibit the growth of farmers' income to a certain extent. The research of Nnamocha and Charles [55] showed that there is a long-term relationship between agricultural credit and agricultural output in Nigeria. Specifically, when the bank credit increases by 1%, the agricultural output will increase by 0.19%, but the relationship between agricultural credit and agricultural output in the short term is not very obvious. Based on the above agricultural credit related previous works, this study tests the following hypothesis.

Hypothesis 2 (H2). *Agricultural credit mitigates effects of climate change and improves cereal production in the context of Sichuan province, China.*

3. Data and Methods

3.1. Data Sources

The data in this study can be divided into three aspects. The first part is meteorological data. The meteorological data in this study come from the monthly dataset of China's surface climate data of the National Meteorological Science Data Center, which includes the historical monthly data of 43 meteorological stations in Sichuan province from 1978 to

2018, including monthly average temperature, 20–20 h rainfall, and other indicators. These 43 meteorological stations are evenly distributed, which can well reflect the overall climate change of Sichuan province. However, Panzhihua station and Dongxing district station were added to the dataset in 1988 and 1999, respectively, and Renhe station lacks the data from 1988 to 1997. Therefore, in order to preserve the effective length of time series data and the consistency of data dimensions, this study will remove these three sites and retain the remaining 40 sites.

The second part is related to agricultural credit data. The agricultural credit data in this paper come from China financial yearbook, China rural financial service report, and wind database. Due to the particularity of agricultural credit data, the data length of this study is selected from 1978 to 2018, of which 1978–2008 is the agricultural credit data of Sichuan province over the years, and 2009–2018 is the data of agricultural, forestry, animal husbandry and fishery credits in Sichuan province over the years. This is because before 2008, agricultural credit mainly refers to "credits for agriculture, rural areas and farmers", that is, rural credits, farmers' credits and agricultural credits. With the economic development, the central bank issued the special statistical system for agriculture-related credits in 2007 in order to better serve agriculture, rural areas and farmers; these three kinds of credits are put under one framework to form the current agriculture related credits, while the previous "agriculture, rural areas and farmers' credits" become the three discussion dimensions of agriculture-related credits. Therefore, on the premise that the scope is almost the same and considering the feasibility of the data length of this study, the agricultural credit referred to in this study is expressed by the amount of agricultural credits before 2008 and after 2008 by the amount of credits for agriculture, forestry, animal husbandry and fishery.

The third part is related to cereal production data. The cereal production data in this paper are obtained from the Sichuan statistical yearbook over the years, and the data length is from 1978 to 2018.

3.2. Variable Setting

The dependent variable selected in this study is cereal production, while explanatory variables include agricultural credit, annual average temperature, annual cumulative rainfall, agricultural labor force, mechanical farming rate and farming size. Specific variable definitions are shown in Table 1.

Table 1. Variable definitions and data sources.

Variable	Definitions	Data Sources
CP	**Cereal production** Cereal production per unit area = total cereal production/cereal sowing area	Sichuan Statistical Yearbook
CR	**Agricultural credit** Before 2008, it was the agricultural credit of Sichuan province, and after 2008, it was the agricultural, forestry, animal husbandry and fishery credit of Sichuan province	China Financial Yearbook, China rural financial service report, Wind Database

Table 1. *Cont.*

Variable	Definitions	Data Sources
TEM	**Temperature** Select the monthly temperature data from April to July of 40 weather stations in Sichuan province from 1978 to 2018, and calculate the average to obtain the annual average temperature	Monthly dataset of surface climate data in China
RF	**Rainfall** Select the monthly rainfall data from April to July of 40 weather stations in Sichuan province from 1978 to 2018, and add the total to obtain the annual cumulative rainfall	Monthly dataset of surface climate data in China
LAB	**Agricultural labor force** Select the number of employed persons in agriculture, forestry, animal husbandry and fishery in Sichuan province from 1978 to 2018	Sichuan Statistical Yearbook
MFR	**Mechanical farming rate** Mechanical farming rate = acreage under mechanized farming/total cultivated area	China Rural Statistical Yearbook
FS	**Farming size** Refers to the cultivated land area in Sichuan province, with a period from 1978 to 2018	Sichuan Statistical Yearbook

3.3. Methods

The ARDL (auto regressive distributed lag) model is an advanced method and it is widely used by previous studies. This method was originally proposed by Pesaran et al. (2001) [56]. It has many advantages that other models do not have: firstly, the ARDL model requires that each variable can be stable on I(0) or I(1), which is more relaxed than other time series models, such as VAR; secondly, the ARDL model is suitable for small sample data estimation, and it can analyze the long-term and short-term relationship between the variables at the same time; finally, in order to better estimate the short-term relationship between all the variables under the analysis framework, the ARDL can also be well combined with the ECM.

The sample model of the ARDL study can be expressed as

$$Y_t = \alpha_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon_t \tag{1}$$

After substituting the above variables, the following relationship can be obtained:

$$CP = f\ (CR,\ TEM,\ RF,\ LAB,\ MFR, FS) \tag{2}$$

Further, the equation can be refined into

$$LNCP_t = \alpha_0 + \beta_1 LNCR_t + \beta_2 LNTEM_t + \beta_3 LNRF_t + \beta_4 LNLAB_t + \beta_5 LNMFR_t + \beta_6 LNFS_t + \varepsilon_t \tag{3}$$

In order to find the long-term and short-term relationship between climate change, agricultural credit, technical progress and cereal production, this study needs to continue to refine formula (3), and the ARDL model is as follows:

$$\begin{aligned}\Delta LNCP_t = \alpha_0 + \; & \gamma_1(LNCR)_{t-1} + \gamma_2(LNTEM)_{t-1} + \gamma_3(LNRF)_{t-1} \\ & + \gamma_4(LNLAB)_{t-1} + \gamma_5(LNMFR)_{t-1} + \gamma_6(LNFS)_{t-1} \\ & + \sum_{i=1}^{p} \phi_1 \Delta(LNCP)_{t-i} + \sum_{i=1}^{q} \phi_2 \Delta(LNCR)_{t-i} \\ & + \sum_{i=1}^{q} \phi_3 \Delta(LNTEM)_{t-i} + \sum_{i=1}^{q} \phi_4 \Delta(LNRF)_{t-i} \\ & + \sum_{i=1}^{q} \phi_5 \Delta(LNLAB)_{t-i} + \sum_{i=1}^{q} \phi_6 \Delta(LNMFR)_{t-i} \\ & + \sum_{i=1}^{q} \phi_7 \Delta(LNFS)_{t-i} + \varepsilon_t \end{aligned} \quad (4)$$

It can be seen from Equation (4) that the ARDL model is composed of long-term and short-term analysis parts. If taken apart, the first half can be used as long-term analysis. The specific formula is as follows:

$$\begin{aligned}LNCP_t = \alpha_0 + \; & \sum_{i=1}^{p} \gamma_1(LNCP)_{t-i} + \sum_{i=1}^{q} \gamma_2(LNCR)_{t-i} + \sum_{i=1}^{q} \gamma_3(LNTEM)_{t-i} \\ & + \sum_{i=1}^{q} \gamma_4(LNRF)_{t-i} + \sum_{i=1}^{q} \gamma_5(LNLAB)_{t-i} + \sum_{i=1}^{q} \gamma_6(LNMFR)_{t-i} \\ & + \sum_{i=1}^{q} \gamma_7(LNFS)_{t-i} + \varepsilon_t \end{aligned} \quad (5)$$

Accordingly, in order to better verify the short-term relationship between the variables, the ECM (error correction model) is established based on the ARDL model. The specific formula is as follows:

$$\begin{aligned}\Delta LNCP_t = \alpha_0 + \; & \sum_{i=1}^{p} \phi_1 \Delta(LNCP)_{t-i} + \sum_{i=1}^{q} \phi_2 \Delta(LNCR)_{t-i} + \sum_{i=1}^{q} \phi_3 \Delta(LNTEM)_{t-i} \\ & + \sum_{i=1}^{q} \phi_4 \Delta(LNRF)_{t-i} + \sum_{i=1}^{q} \phi_5 \Delta(LNLAB)_{t-i} \\ & + \sum_{i=1}^{q} \phi_6 \Delta(LNMFR)_{t-i} + \sum_{i=1}^{q} \phi_7 \Delta(LNFS)_{t-i} + \eta ECM_{t-i} + \varepsilon_t \end{aligned} \quad (6)$$

Among them, the coefficients representing the short-term relationship between variables, the ECM is the error correction term, which provides the adjustment speed to the long-term balance. In order to establish the relationship, the ECM must be significantly negative.

4. Results and Discussions

4.1. Descriptive Statistics

The descriptive statistics of all variables in this study are shown in Table 2, in which the mean value of the dependent variable LNCP is 1.95 and the standard deviation is 0.13. The mean values of key explanatory variables, including LNCR, LNTEM and LNRF, were 5.53, 2.78 and 6.70, respectively, and the standard deviations were 1.55, 0.03 and 0.08, respectively. The mean values of other explanatory variables, such as LNLAB, LNMFR and LNFS were 7.83, −1.43 and 6.14, respectively, and the standard deviations were 0.18, 0.66 and 0.16, respectively. The historical trend of the variables is displayed in Figure 2.

4.2. Unit Root Inspection

Before analyzing the time series dataset, it is necessary to test the stationarity of each variable, which will directly determine the reliability of the subsequent model. At the same time, this study constructs the ARDL model, which requires that each variable should be stable on I(0) or I(1); in other words, no variable can be stable on I(2). Only when this requirement is met is the analysis of ARDL meaningful. At present, there are many methods to test the unit root of data, such as the ADF test, GLS test, PP test, KPSS test, etc. Combined with the data characteristics, the ADF test and PP test are adopted to comprehensively test the unit root of all variable data. The specific test results are shown in Table 3. The estimated results of the ADF test revealed that LNCP, LNCR, LNMFR, LNLAB and LNFS are integrated at I(1), while LNTEM and LNRF are integrated at I(0).

Table 2. Descriptive statistics.

	LNCP	LNCR	LNTEM	LNRF	LNLAB	LNMFR	LNFS
Mean	1.9544	5.5254	2.7818	6.6973	7.8314	−1.4349	6.1400
Median	2.0136	5.8775	2.7788	6.7164	7.8778	−1.6584	6.1299
Maximum	2.0755	7.5604	2.8332	6.8512	8.0710	−0.2346	6.5126
Minimum	1.5661	2.3124	2.7344	6.4974	7.4687	−2.2160	5.9671
Std. Dev.	0.1286	1.5451	0.0277	0.0765	0.1791	0.6612	0.1599
Skewness	−1.5450	−0.4814	0.1713	−0.8053	−0.5762	0.6221	1.2941
Kurtosis	4.6852	2.1997	1.8970	3.3726	2.0963	1.9341	4.0605
OBS	41	41	41	41	41	41	41

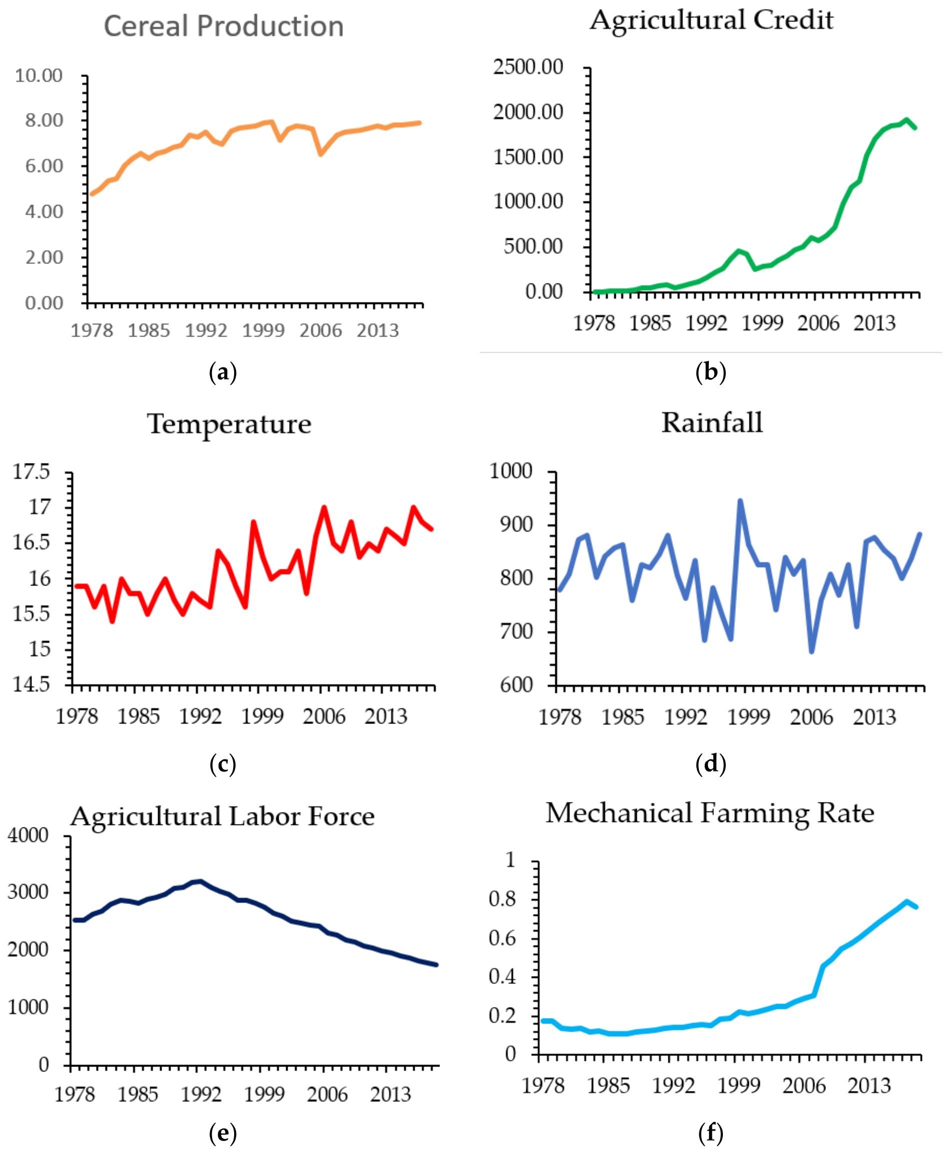

Figure 2. *Cont.*

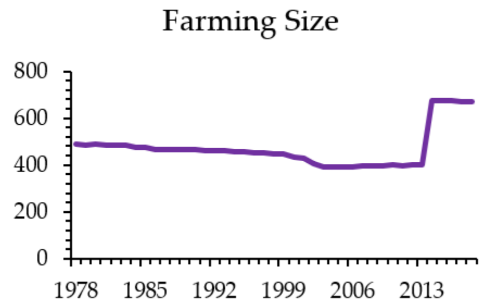

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Figure 2. Historical trend of each variable.

Table 3. Unit root tests results.

	Intercept and Trend		Intercept	
	Level	1st Diff	Level	1st Diff
Augmented Dickey-Fuller (ADF)				
LNCP	−3.0484	−6.9796 ***	−3.4001	−6.5797 ***
LNCR	−2.4442	−5.3702 ***	−2.3152	−5.0026 ***
LNTEM	−5.6681 ***	−7.3661 ***	−0.1588	−7.3580 ***
LNRF	−5.5349 ***	−5.6426 ***	−5.5894 ***	−5.6191 ***
LNMFR	−3.1235	−6.4317 ***	1.2928	−5.3968 ***
LNLAB	−2.9892	−4.3390 ***	0.5671	−2.0924
LNFS	−0.9339	−6.3017 ***	−0.8768	−6.0483 ***
Phillips and Peron (PP)				
LNCP	−3.6220 **	−7.3022 ***	−6.8658 ***	−6.6558 ***
LNCR	−2.0468	−5.3526 ***	−2.2571	−5.0026 ***
LNTEM	−6.6494 ***	−23.9532 ***	−2.7825 *	−21.1014 ***
LNRF	−5.5452 ***	−27.3467 ***	−5.6008 ***	−21.7643 ***
LNMFR	−3.3151 *	−6.4774 ***	0.8976	−5.5859 ***
LNLAB	−2.8409	−4.4958 ***	1.0170	−2.5621
LNFS	−0.9339	−6.3428 ***	−1.0278	−6.0483 ***

***, **, * indicates that the presence of unit root hypothesis for the ADF and PP unit root tests was rejected at the 1%, 5%, and 10% significance levels.

4.3. Cointegration Test

Whether there is a long-term equilibrium relationship between the variables is usually determined by the cointegration test, but traditional cointegration test methods such as the EG test and Johansen test have a strict restriction, that is, each variable must be a single integration relationship of the same order. However, in the actual operation process, it is a common phenomenon that there is no single integer of the same order between variables. To solve this problem, Pesaran (2001) proposed the ARDL bounds testing method [56]. The biggest advantage of this method is that it no longer requires that all variables are of the same order. In other words, if some variables are I(0) stationary and some variables are I(1) stationary, the cointegration test can still be carried out although the variables have different orders. The rule of this test is that if the F statistic value obtained by the bounds testing is higher than the upper bound I(1) under the significance level, it can be said that there is a long-term cointegration relationship between the variables under the significance level. The specific ARDL bounds testing results are shown in Table 4. When LNCP is the dependent variable and the other independent variables are LNTEM, LNRF, LNCR, LNMFR, LNLAB and LNFS, respectively, the optimal lag structure is (1, 0, 0, 0, 0, 1, 1), because the F statistic value is higher than the upper boundary value at the significance level of 1%, Therefore, it is proved that there is a long-term cointegration relationship between independent variables (i.e., LNTEM, LNRF, LNCR, LNMFR, LNLAB and LNFS) and dependent variable (i.e., LNCP) at the significance level of 1%. After obtaining the above conclusions, we can continue to analyze the specific long-term and short-term relationship of the constructed ARDL model.

Table 4. Inspection results of ARDL bound test.

Bounds Critical Value			F-Statistic Value
Significance levels	Lower Bound I(0)	Upper Bound I(1)	
10%	1.99	2.94	
5%	2.27	3.28	5.33
2.5%	2.55	3.61	
1%	2.88	3.99	

4.4. ARDL Long-Term and Short-Term Analysis

One advantage of the ARDL model is that it can reflect the long-term and short-term relationships between the variables at the same time. For the long-term relationship, as shown in Table 5, agricultural credit has a very highly significantly positive impact on cereal production in the long term. Specifically, when the amount of agricultural credit increases by 1%, it will increase cereal production by 0.107% in the long term, which is consistent with the previous research [9]. More recently in the context of Pakistan, Chandio et al. [9] investigated the impact of climate change, domestic credit from banks to the private sector and technological progress on grain production in Pakistan from 1977 to 2014. The results of the ARDL boundary testing method confirmed that there was a long-term relationship between the variables, and in the long-run, domestic credit had a positive impact on grain production. An increase of 1% of domestic credit would increase grain production by 0.03%.

Table 5. Long-term and short-term regression results of the ARDL.

Variables	Coefficient	Std. Error	t-Statistic	Prob.
Long-Run Analysis				
LNCR	0.107099 ***	0.017418	6.148641	0.0000
LNTEM	−0.679704	0.549725	−1.236444	0.2259
LNRF	0.342674 ***	0.119907	2.857838	0.0077
LNMFR	0.059265	0.078891	0.751227	0.4584
LNLAB	0.522860 **	0.215313	2.428378	0.0214
LNFS	0.037835	0.062508	0.605292	0.5495
Short-Run Analysis				
D(LNCP(−1))	0.225356	0.133492	1.688157	0.1018
D(LNTEM)	−0.652947 ***	0.198015	−3.297469	0.0025
D(LNRF)	0.201094 ***	0.069350	3.306751	0.0069
D(LNLAB)	0.678963 **	0.306320	2.216515	0.0344
D(LNCR)	0.044181	0.031626	1.396990	0.1727
D(LNMFR)	0.089340 **	0.040720	2.194013	0.0361
D(LNFS)	−0.078594 **	0.036039	−2.180789	0.0372
ECM(−1)	−0.952772 ***	0.274494	−3.471007	0.0016
C	0.007154	0.005319	1.345012	0.1887
R squared	0.590900	Mean dependent var		0.011692
Adj R squared	0.481806	S.D. dependent var		0.046976
F statistic	5.416458	Akaike info criterion		−3.736596
Prob. (F statistic)	0.000289	Schwarz criterion		−3.352697
Hannan–Quinn criter.	−3.598856	Durbin–Watson stat		2.067782

Note: This study uses Eviews 10 (IHS Global Inc. 4521 Campus Drive, #336, Irvine, CA 92612-2621,USA.) ***, **, and * indicate significant at the 1%, 5%, and 10% significance levels, respectively.

In the long-run, rainfall also has a very higher significant promoting effect on the unit production of cereal. It can be seen from Table 5 that when the rainfall increases by 1%, the unit production of cereal will increase by 0.343%, which is consistent with the reality of Sichuan province. In most years, the drought area in Sichuan province is larger than the flood area, and the cereal production in Sichuan province is more affected by drought; at the same time, the warming trend is obvious in recent years, and the increase in rainfall can well neutralize the drought risk brought by drought to cereal production. This result is also consistent with [57]. Han F et al. [57] used the cereal input–output data and climate data of 29 provinces (autonomous regions and municipalities directly under the central government) in China from 1978 to 2015 to construct an "economy climate". The model explores the impact of climate change on China's total cereal production and its regional differences. The research shows that the increase in precipitation is conducive to the increase in cereal production in southwest, Huang Huai Hai, northwest and Qinghai Tibet. Similarly, Yin C et al. [58], based on the extended C-D production function model, using the cereal input–output and meteorological data of 15 provinces from 1984 to 2014, discussed the impact of climate change during the growth period on cereal production. The research shows that the marginal impact of increased precipitation during the whole growth period of cereal-on-cereal production in Southwest China is positive.

The impact of temperature on cereal production is negative, but not significant. This coefficient reveals that when temperature rises, the cereal yield will decrease. The reason why the long-term coefficient is not significant may be that farmers have adopted new equipment and more advanced technology through obtaining agricultural credit, which makes the negative impact of temperature on cereal production diluted. This finding supports the previous empirical evidence by Khan et al. (2019), Husnain et al. (2018), Chandio et al. (2020) [10,59,60]. Due to the availability of data, other agricultural technology progress variables other than MFR are not added in this study; this is also one of the directions for further research. In the long run, the agricultural labor force also plays a strong role in promoting the unit yield of cereal. It can be seen from Table 5 that when the agricultural labor force increases by 1%, the unit yield of cereal will increase by 0.523%, which is also in line with the reality. It is generally acknowledged that the rice production is labor intensive and Sichuan province's arable land is mainly located in hilly areas, where large agriculture machines are not applicable. The increase in agricultural labor force can improve sowing, farming and harvesting. This increase in unit yield is a long-term effect. This study is compatible with the empirical evidence by Pickson et al. (2020), Ahsan et al. (2020) and Sial et al. (2011) [34,61,62]. In the long run, cultivated land is an important household asset. Farming size has a positive impact on cereal production, partly because farmers can achieve economy of scale, and partly because the farmland can be used as collateral for bank credit, which can be used to improve planting technology or purchase agricultural machinery to improve cereal yield.

In this study, the short-term relationship between various variables is investigated by establishing ARDL-ECM. As shown in Table 5, the coefficient of error correction term ECM (-1) is -0.952772, which is significantly negative, indicating that the deviation of the system from the long-term trend will be corrected by 95% in the next period. For other key explanatory variables, temperature and rainfall have significant negative and positive effects on cereal production in the short term. This result can be verified by the research of Attiaoui and Boufateh (2019), Sossou et al. (2019) and Eregha et al. (2014) [16,17,63]. Specifically, when the temperature increases by 1%, the cereal production decreases by 0.653% in the short term, while when the rainfall increases by 1%, the cereal production will increase by 0.201% in the short term, which is also in line with the actual situation of Sichuan province. In recent decades, the average temperature in Sichuan province has been rising. The average temperature from April to July 2018 has increased by 1.2°C compared with 40 years ago, which poses a great challenge to rice production. The agricultural labor force plays a significant role in promoting cereal production in the short term. When the agricultural labor force increases by 1%, cereal production will increase by 0.679%. Similarly, the mechanical farming rate (MFR) also plays a significantly positive role in promoting cereal production in the short term. When MFR increases by 1%, cereal production will increase by 0.089%. It also adds confidence to continue to increase technical support for farmers in the future. This study is compatible with the empirical evidence of Zhai et al. (2017) and Pilo (2019) [64,65]. Farming size shows that it has a negative impact on cereal yield in the short run. The main reason is that this study researches the yield per unit area rather than the total yield, and the expanded farm does not achieve economy of scale in the short run. Therefore, in the short run, farming size will have a slight negative impact on cereal yield; however, according to the above analysis, it has a slightly positive impact in the long run.

4.5. Diagnostic Test

For the robustness test of the ARDL model, the CUSUM and CUSUM of the squares testing methods are adopted in this investigation. The testing results are shown in Figures 3 and 4. It can be seen that the broken line formed by the CUSUM and CUSUM of the square does not exceed the boundary under the 5% significance level, and then it can be concluded that the ARDL model in this study is stable.

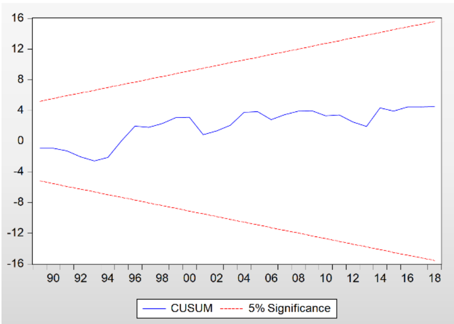

Figure 3. CUSUM Test.

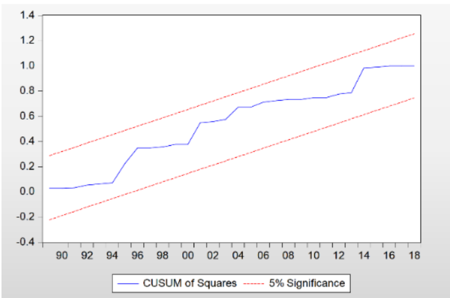

Figure 4. CUSUM of square test.

For whether there is a sequence-related problem in the model, the Breusch Godfrey LM test is adopted in this study. H_0 of this test means that there is no sequence-related problem. The specific test results are shown in Table 6. The *p*-value of the F statistic is 0.7175, and the *p*-value of the sample size multiplied by R^2 is 0.6258. It is not significant at the significance levels of 1%, 5% and 10%, that is, the original hypothesis is accepted, so it is concluded that there is no sequence-related problem in the ARDL model in this study.

Table 6. LM inspection.

F-statistic	0.335978	Prob. F (2,17)	0.7175
Obs *R-squared	0.937441	Prob. Chi-Square (2)	0.6258

For the test of heteroscedasticity of the model, this paper adopts the ARCH test method. The H_0 of the test is that there is no heteroscedasticity problem. The specific test results are shown in Table 7. The *p*-value of each statistic is not significant at the significance level of

1%, 5% and 10%, that is, the original hypothesis is accepted. Therefore, it is concluded that there is no heteroscedasticity problem in the ARDL model in this paper.

Table 7. Heteroscedasticity test.

F-statistic	2.519543	Prob. F (1,37)	0.1210
Obs *R-squared	2.486420	Prob. Chi-Square (1)	0.1148

5. Conclusions and Policy Implications

Based on the time series dataset of Sichuan province from 1978 to 2018, this study empirically analyzed the short-term and long-term impacts of climate change (via temperature and rainfall) and agricultural credit on cereal production by establishing the ARDL model. This study also incorporated other control variables, including mechanical farming rate, agricultural labor force and farming size in the estimation. In this study, the ADF test and PP test were used to check the stationarity of the variables. It is concluded that all variables are stable on I(0) or I(1). The results of the ARDL bounds test showed that there is a long-term cointegration relationship between cereal production, agricultural credit, climate change, mechanical farming rate, agricultural labor force and farming size. The long-run and short-run effects of the explanatory variables on cereal production were further analyzed by ARDL model. The results showed the following:

1. The impact of climate change on cereal production in Sichuan province is very significant in the long- and short run. Specifically, temperature has a significantly negative impact on cereal production in the short term. In the long term, the impact of temperature on cereal production is negative, but not significant. The reason may be that farmers have adopted new equipment and modern agricultural technologies through obtaining agricultural credit, which makes the negative impact of temperature on cereal production diluted.
2. Rainfall has a significantly positive impact on cereal production in the long- and short-run, and the long-run effect is more significant than the short-term effect, which indicates that the current drought risk response in Sichuan province is not ideal, and the impact of weather risk on agricultural production needs to be further controlled in the future.
3. Agricultural credit has well hedged the adverse impact of climate change on cereal production in Sichuan province. Specifically, in the long run, agricultural credit has a significantly positive impact on cereal production, and in the short run, agricultural credit also positively promotes cereal production. On the whole, the long-run effect is greater than the short-run effect, as it shows that the long-run credit that may be used for the purchase of agricultural machinery and land consolidation has reduced the adverse effects of climate. Therefore, agricultural credit is a powerful tool to deal with the adverse effect of climate change on agricultural production, and the government should encourage the supply of agricultural credit, especially the long-term ones that may be used for technology advances to mitigate the effect of climate change.
4. Mechanical farming rate represents the degree of agricultural technology progress, and it also positively promotes cereal production in Sichuan province in the long- and short term. Therefore, the above conclusions tell us that we should continue to increase the popularization of agricultural technology and strengthen the publicity and popularization of agricultural machinery.
5. Agricultural labor force has a significantly positive impacts on cereal production in the long- and short run, and the short-run effect is stronger than the long-run effect. Therefore, relevant departments should create corresponding policies to further prevent the loss of agricultural labor force, so as to stabilize and promote cereal production in Sichuan province.
6. Farming size is positively but not significantly related to the cereal production in the long run, implying that farmers can slightly achieve economy of scale in the long run.

However, farming size is significantly and negatively related to the cereal production in the short run, which need to be further analyzed in the future.

Based on the above conclusions, this study believes that agricultural credit, especially the long-term credit, should be encouraged in Sichuan province so that farmers have more abundant funds to adopt climate mitigating or adapting technologies. Although the volume of agricultural credit in Sichuan province has increased continuously in recent years, if we want to continue to improve cereal production and promote farmers' income, the volume of agricultural credit, especially the long-term credit, should be further expanded. At the same time, we should pay more attention to the impact of drought on the growth of cereal. Although the average rainfall in Sichuan province from April to July every year has been rising, the corresponding temperature is also increasing. There is a need to check whether the water in the paddy field is sufficient from time to time, especially at the heading stage and seed-setting stage, which require a lot of water and mineral nutrition.

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References

1. IPCC. *Working Group I Contribution to the IPCC Fifth Assessment Report Climate Change 2013: The Physical Basis*; Cambridge University Press: Cambridge, UK, 2013.
2. Li, G. Cause analysis global climate warming. *J. Nat. Disasters* **2005**, *14*, 38–42.
3. Kumar, P.; Sahu, N.C.; Kumar, S.; Ansari, M.A. Impact of climate change on cereal production: Evidence from lower-middle-income countries. *Environ. Sci. Pollut. Res.* **2021**, *28*, 51597–51611. [CrossRef] [PubMed]
4. Schmidhuber, J.; Tubiello, F.N. Global food security under climate change. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 19703–19708. [CrossRef] [PubMed]
5. Chijioke, O.B.; Haile, M.; Waschkeit, C. *Implications of Climate Change on Crop Yield and Food Accessibility in Sub-Saharan Africa*; Interdisciplinary Term Paper; University of Bonn: Bonn, Germany, 2011.
6. Gregory, P.J.; Ingram, J.S.I.; Brklacich, M. Climate change and food security. *Trans. R Soc. B Biol. Sci.* **2005**, *360*, 2139–2148. [CrossRef] [PubMed]
7. IFAD. *Research and Innovation for Smallholder Farmers in the Context of Climate Change: Discussion Paper for Round Table 3, Thirty-Second Session of the Governing Council*; IFAD: Rome, Italy, 2009.
8. Hussain, S.S.; Mudasser, M. Prospects for wheat production under changing climate in mountain areas of Pakistan—An econometric analysis. *Agric. Syst.* **2007**, *94*, 494–501. [CrossRef]
9. Chandio, A.A.; Jiang, Y.; Akram, W.; Adeel, S.; Irfan, M.; Jan, I. Addressing the effect of climate change in the framework of financial and technological development on cereal production in Pakistan. *J. Clean. Prod.* **2021**, *288*, 125637. [CrossRef]
10. Khan, A.; Ali, S.; Shah, S.A.; Khan, A.; Ullah, R. Impact of climate change on maize productivity in Khyber Pakhtunkhwa, Pakistan. *Sarhad J. Agric.* **2019**, *35*, 594–601. [CrossRef]
11. Sarkar, M.S.K.; Begum, R.A.; Pereira, J.J. Impacts of climate change on oil palm production in Malaysia. *Environ. Sci. Pollut. Control Ser.* **2020**, *27*, 9760–9770. [CrossRef]
12. Birthal, P.S.; Khan, T.; Negi, D.S.; Agarwal, S. Impact of climate change on yields of major food crops in India: Implications for food security. *Agric. Econ. Res. Rev.* **2014**, *27*, 145–155. [CrossRef]
13. Hossain, M.S.; Majumder, A.K. Impact of climate change on agricultural production and food security: A review on coastal regions of Bangladesh. *Int. J. Agric. Res. Innov. Technol.* **2018**, *8*, 62–69. [CrossRef]
14. Ahmed, K.F.; Wang, G.; Yu, M.; Koo, J.; You, L. Potential impact of climate change on cereal crop yield in West Africa. *Clim. Change* **2015**, *133*, 321–334. [CrossRef]

15. Defrance, D.; Sultan, B.; Castets, M.; Famien, A.M.; Baron, C. Impact of climate change in West Africa on cereal production per capita in 2050. *Sustainability* **2020**, *12*, 7585. [CrossRef]
16. Attiaoui, I.; Boufateh, T. Impacts of climate change on cereal farming in Tunisia: A panel ARDL–PMG approach. *Environ. Sci. Pollut. Res.* **2019**, *26*, 13334–13345. [CrossRef]
17. Sossou, S.; Igue, C.B.; Diallo, M. Impact of climate change on cereal yield and production in the Sahel: Case of Burkina Faso. *Asian J. Agric. Ext. Econ. Soc.* **2019**, *37*, 1–11. [CrossRef]
18. United States Department Agriculture. Grain: World Markets and Trade. 2019. Available online: http://apps.fas.usda.gov/psdonline/circulars/grain.pdf (accessed on 30 November 2021).
19. Liu, Y.; Tang, L.; Qiu, X.; Liu, B.; Chang, X.; Liu, L.; Zhang, X.; Cao, W.; Zhu, Y. Impacts of 1.5 and 2.0 C global warming on cereal production across China. *Agric. For. Meteorol.* **2020**, *284*, 107900.
20. FAO-OECD. Agricultural Outlook 2018–2027 (Chapter 3: Cereals). Food and Agriculture Organisation and Organisation for Economic Co-operation and Development. 2018. Available online: https://www.fao.org/3/i9166e/i9166e_Chapter3_Cereals.pdf (accessed on 30 November 2021).
21. Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K.B.; Tignor, M.; Miller, H.L. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2007.
22. Xiong, W.; Lin, E.; Ju, H.; Xu, Y. Climate change and critical thresholds in China's food security. *Clim. Change* **2007**, *81*, 205–221. [CrossRef]
23. Wang, D.; Xu, Z.; Zhao, J.; Wang, Y.; Yu, Z. Excessive nitrogen application decreases grain production and increases nitrogen loss in the wheat–soil system. *Acta Agric. Scand. Sect. B Soil Plant Sci.* **2011**, *61*, 681–692.
24. Huang, W.; Deng, X.; He, S. Impact of climate change on the county food production econometric analysis. *Geogr. Sci.* **2010**, *29*, 677–683.
25. Lobell, D.B.; Burke, M.B.; Tebaldi, C.; Mastrandrea, M.D.; Falcon, W.P.; Naylor, R.L. Prioritizing climate change adaptation needs for food security in 2030. *Science* **2008**, *319*, 607–610. [CrossRef]
26. Lobell, D.B.; Schlenker, W.; Costa-Roberts, J. Climate trends and global crop production since 1980. *Science* **2011**, *333*, 616–620. [CrossRef]
27. Yang, X.; Lin, E.; Ma, S.; Ju, H.; Guo, L.; Xiong, W.; Li, Y.; Xu, Y. Adaptation of agriculture to warming in Northeast China. *Clim. Change* **2007**, *84*, 45–58. [CrossRef]
28. Peng, S.; Huang, J.; Sheehy, J.E.; Laza, R.C.; Visperas, R.M.; Zhong, X.; Centeno, G.S.; Khush, G.S.; Cassman, K.G. Cereal productions decline with higher night temperature from global warming. *Proc. Natl. Acad. Sci. USA* **2004**, *101*, 9971–9975. [CrossRef] [PubMed]
29. Rehman, A.; Chandio, A.A.; Hussain, I.; Jingdong, L. Fertilizer consumption, water availability and credit distribution: Major factors affecting agricultural productivity in Pakistan. *J. Saudi Soc. Agric. Sci.* **2019**, *18*, 269–274. [CrossRef]
30. Saqib, S.E.; Ahmad, M.M.; Panezai, S. Landholding size and farmers' access to credit and its utilisation in Pakistan. *Dev. Pract.* **2016**, *26*, 1060–1071. [CrossRef]
31. Ahmad, N. Impact of institutional credit on agricultural output: A case study of Pakistan. *Theor. Appl. Econ.* **2011**, *18*, 99–120.
32. Ahmad, D.I.; Chani, M.; Afzal, M. Impact of formal credit on agricultural output:empirical evidence from Pakistan. *Sarhad J. Agric.* **2018**, *34*, 640–648. [CrossRef]
33. Chisasa, J.; Makina, D. bank credit and agricultural output in South Africa: Cointegration, short run dynamics and causality. *J. Appl. Bus. Res.* **2015**, *31*, 489–500. [CrossRef]
34. Pickson, R.B.; He, G.; Ntiamoah, E.B.; Li, C. Cereal production in the presence of climate change in China. *Environ. Sci. Pollut. Res.* **2020**, *27*, 45802–45813. [CrossRef]
35. Pickson, R.B.; He, G.; Boateng, E. Impacts of climate change on rice production: Evidence from 30 Chinese provinces. *Environ. Dev. Sustain.* **2021**, 1–19. [CrossRef]
36. Chandio, A.A.; Jiang, Y.; Abbas, Q.; Amin, A.; Mohsin, M. Does financial development enhance agricultural production in the long-run? *Evidence from China. J. Public Aff.* **2020**, e2342.
37. Chandio, A.A.; Jiang, Y.; Rehman, A.; Rauf, A. Short and long-run impacts of climate change on agriculture: An empirical evidence from China. *Int. J. Clim. Change Strateg. Manag.* **2020**, *12*, 201–221. [CrossRef]
38. Cui, J.; Wang, X.; Xin, X.; Wu, W. Impact of climate change during growth on unit production of major grain crops in China. *China Rural. Econ.* **2011**, *9*, 13–22.
39. Zhou, S.; Zhu, H. Economic analysis of climate change impact on the cereal production in southern China and its adaptive strategy. *China Popul. Resour. Environ.* **2010**, *20*, 152–157.
40. Hou, L.; Qiu, H.; Wang, Y.; Sun, L. Impacts of climate change on cereal production in China: Base on a multi-input and multi-output production function. *J. Agrotech. Econ.* **2015**, *3*, 4–13.
41. Liu, L.; Yang, X. Analysis on the impact of wetland ecological environment on agricultural development in Dongting Lake area. *Agric. Technol. Econ.* **2014**, *9*, 108–115.
42. Chloupek, O.; Hrstkova, P.; Schweigert, P. Production and its stability, crop diversity, adaptability and response to climate change, weather and fertilisation over 75 years in the Czech Republic in comparison to some European countries. *Field Crops Res.* **2004**, *85*, 167–190. [CrossRef]

43. Villavicencio, X.; McCarl, B.A.; Wu, X.; Huffman, W.E. Climate change influences on agricultural research productivity. *Clim. Change* **2013**, *119*, 815–824. [CrossRef]
44. Zhu, X.; Wang, J.; Zhou, H. Analysis on the contribution rate of climate change to cereal production in Jiangsu Province. *Agric. Technol. Econ.* **2013**, *4*, 53–58.
45. Chen, S.; Xu, J.; Zhang, H. Impact of climate change on China's grain production—An Empirical Analysis Based on county-level panel data. *China Rural. Econ.* **2016**, *5*, 2–15.
46. He, Y.; Leng, B.; Feng, Z. The impact of climate factors on rapeseed production in Hubei by using translog production function. *Resour. Sci.* **2015**, *37*, 1465–1473.
47. Chandio, A.A.; Jiang, Y.; Wei, F.; Xu, G. Effects of agricultural credit on wheat productivity of small farms in Sindh, Pakistan. *Agric. Financ. Rev.* **2018**, *78*, 592–610. [CrossRef]
48. Ahmad, N.; Jan, I.; Ullah, S.; Pervez, S. Impact of agricultural credit on wheat productivity in District Jhang, Pakistan. *Sarhad J. Agric.* **2015**, *31*, 65–69.
49. Udoka, C.O.; Mbat, D.O.; Duke, S.B. The effect of commercial banks' credit on cereal production in Nigeria. *J. Financ. Account.* **2016**, *4*, 1–10.
50. Xu, Y.; Miao, S.; Xu, Z. Comparative analysis of the effect of agricultural credits and agricultural fiscal expenditure on grain production in main producing areas. *Guangdong Agric. Sci.* **2014**, *41*, 193–196.
51. Omoregie, K.; Ikpesu, F.; Okpe, A.E. Credit supply and cereal output in Nigeria:empirical insight from vector error correction model approach. *Int. J. Econ. Financ. Issues* **2018**, *8*, 68–74.
52. Adesiji, G.B.; Matanmi, B.M.; Falola, A.; Ahmed, T.A. Effects of credit utilization on youth farmers' cereal output in Patigi local government area of Kwara state, Nigeria. *J. Agric. Soc. Res. JASR* **2011**, *11*, 1–8.
53. Cao, X. Analysis on the relationship between agricultural economic growth and rural financial development. *Issues Agric. Econ.* **2008**, *11*, 49–54.
54. Yu, X.; Xiong, F.; Xiong, D. Rural financial development and farmers' income growth in China. *China Rural. Econ.* **2010**, *6*, 77–86, 96.
55. Nnamocha, P.N.; Eke, C.N. Bank Credit and Agricultural Output in Nigeria (1970–2013): An Error Correction Model (ECM) Approach. *Br. J. Econ. Manag. Trade* **2015**, *10*, 1–12. [CrossRef]
56. Pesaran, M.H.; Shin, Y.; Smith, R.J. Bounds testing approaches to the analysis of level relationships. *J. Appl. Econom.* **2001**, *16*, 289–326. [CrossRef]
57. Han, F.; Zhang, J.; Cheng, L.; Tong, Q.; Liu, Y. Impact of climate change on cereal production and its regional heterogeneity in China. *J. Ecol. Rural. Environ.* **2019**, *35*, 283–289.
58. Yin, C.; Li, G.; Fan, L.; Gao, X. Impact of climate change during growth period on unit production in main cereal producing areas in China—An Empirical Analysis Based on extended C-D production function. *J. China Agric. Univ.* **2018**, *23*, 183–192.
59. Husnain, M.I.U.; Subramanian, A.; Haider, A. Robustness of geography as an instrument to assess impact of climate change on agriculture. *Int. J. Clim. Change Strateg. Manag.* **2018**, *10*, 654–669. [CrossRef]
60. Chandio, A.A.; Ozturk, I.; Akram, W.; Fayyaz, A.; Aamir Ali, M. Empirical analysis of climate change factors affecting cereal yield: Evidence from Turkey. *Environ. Sci. Pollut. Res.* **2020**, *27*, 11944–11957. [CrossRef] [PubMed]
61. Ahsan, F.; Chandio, A.A.; Fang, W. Climate change impacts on cereal crops production in Pakistan. *Int. J. Clim. Change Strateg. Manag.* **2020**, *12*, 257–269. [CrossRef]
62. Sial, M.H.; Awan, M.S.; Waqas, M. Role of institutional credit on agricultural production: A time series analysis of Pakistan. *Int. J. Econ. Financ.* **2011**, *3*, 126–132. [CrossRef]
63. Eregha, P.B.; Babatolu, J.S.; Akinnubi, R.T. Climate change and crop production in Nigeria: An Error Correction Modelling approach. *Int. J. Energy Econ. Policy* **2014**, *4*, 297–311.
64. Zhai, S.; Song, G.; Qin, Y.; Ye, X.; Lee, J. Modeling the impacts of climate change and technical progress on the wheat yield in inland China: An autoregressive distributed lag approach. *PLoS ONE* **2017**, *12*, e0184474. [CrossRef] [PubMed]
65. Pilo, M. Dynamics of agricultural productivity and technical efficiency in Togo: The role of technological change. *Afr. Dev. Rev.* **2019**, *31*, 462–475. [CrossRef]