



The impact of climate change on agricultural productivity and agricultural loan recovery; evidence from a developing economy

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Abstract

Agricultural loans are critically linked with agricultural productivity. Agricultural productivity has a significant dependency on climate contingencies. This motivates us to explore the impacts of the climate change on recovery of agricultural loans caused by losses in agricultural productivity. Using panel data from 82 districts of Pakistan over a period of 21 years, i.e., 2000–2020, we estimate the sensitivity of agricultural productivity to climate change in each district. Using these sensitivities, we then apply Panel-Corrected Standard Errors (PCSE) Regression to estimate whether climate change sensitivities of agricultural productivity have any impact on the recoveries of agricultural loans across the sampled districts. We find that the impact of climate change on agricultural loan recoveries is asymmetric. Specifically, negative sensitivities to climate change result in lower recoveries, while positive sensitivities led to enhanced loan recoveries. Our study is unique as it provides evidence of the impact of climate change on agricultural productivity as well as loan recoveries in a set of district-level data. We built a unique climate change index to measure the level of climate change and also introduced a framework to measure climate change sensitivities of agricultural productivity in our sample districts. We believe that this novel approach is an addition to the existing literature on climate change. We suggest that while devising agricultural and credit policies the governments and banks must consider investing in educating the farmer's on climate change adaptation strategies.

Keywords Climate change · Agricultural productivity · Agricultural loan recovery · Pakistan

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1 Introduction

With scarce land and economic resources, meeting the needs of food and Agri-based industrial goods has always been a challenge for the developing countries. On the other hand, carbon emissions and greenhouse gases are adversely impacting the global climate and agricultural productivity. Developing countries, like Pakistan, are most affected by climatic changes as they have a scarcity of resources to cope with it (Schelling, 1992). According to the Climate Risk Country Profile of Pakistan (2021) issued by the World Bank Group and the Asian Development Bank, Pakistan is one of the most vulnerable countries to the risk of climate change risk where it adversely impacts the current food security. Above that the issue of climate change is predicted to become even more severe in future according to a report by the International Union for Conservation of Nature (IUCN), Department for International Development (DFID), Government of Pakistan (Pakistan, 2009).

Geologically, Pakistan is located in South Asia and is classified in the extreme-temperatures zone where the summers are becoming more and more scorching while the winters are getting colder. These climatic changes and extreme climate events such as flooding and soil erosion are adversely impacting human health, labor force efficiency and the yields of major food crops such as wheat, rice, maize, and cash crops cotton and sugarcane.

Pakistan is mainly an agricultural country where the agriculture sector contributes 18.9% to its GDP. According to a report of the Finance department of Pakistan in 2021, around 42.3 percent of the country's labor force was engaged in the agriculture sector of Pakistan (Finance Department, 2021). Above that in a majority of the cases agriculture is often the sole source of income for such labor. The adverse impacts of climate change on agricultural productivity therefore also have an adverse impact on the income levels and loan repayment ability of the farmers (Tuyen, 2016).

The government of Pakistan has an intensive program to support and finance the agriculture sector. Recently, the government of Pakistan launched the "National Agriculture Emergency Program" to support and finance the agriculture sector for food security and other cash crops. Pakistan has had an intensive agriculture credit program since 1956. The State Bank of Pakistan (SBP) Act 1956, under Sect. 8 (3) stresses the SBP to create the "Special Agriculture Credit Department." The main purpose of this department was to perform the consultation and coordination roles for the federal and provincial governments and Banks to facilitate the farmers and their financial support across Pakistan by providing equal opportunities to all the farmers. Before 1972, the lending to the agriculture sector was nominal, later in December 1972; Agricultural Loans Scheme was initiated by implementing the "Mandatory Agriculture Financing" scheme. Under this scheme, all the commercial banks in the country are liable to grant agriculture credit to the farmers through their branch-network across Pakistan.

The agriculture credit facility is available depending on the different sizes of the land holdings. Table 1 summarizes the ranges of the land holding across the provinces of Pakistan.

Since July 1997, the price of the credit facility to the farmers has the minimum cap rates. Later in October 1995, SBP lifted this minimum cap rate and banks are free to charge the interest based on the market prevailing rates. Further, the SBP binds the banks to disburse their "Mandatory Credit Targets" to eligible farmers (Table 2).

Anaka (1992) highlights the credit policies, loan security credit allocation, loan repayment, and other procedures for the agriculture credits in Pakistan. He concludes that there

Table 1 Credit facilities against land holdings

Province	Subsistence holding	Economic holding	Above economic holding
Punjab	Up to 12.5 Acres	Above 12.5 Acres to 50 Acres	Above 50 Acres
K.P.K	Up to 12.5 Acres	Above 12.5 Acres to 50 Acres	Above 50 Acres
Sindh	Up to 16 Acres	Above 16 Acres to 64 Acres	Above 64 Acres
Baluchistan	Up to 32 Acres	Above 32 Acres to 64 Acres	Above 64 Acres

Source: The State Bank of Pakistan

Table 2 Major banks and their agriculture credit products

Banks	Agriculture-credit products
Allied Bank Limited	HariBhari agricultural revolving credit Tractor financing Agriculture finance for dairy farming Agricultural finance for poultry farming and allied activities
Habib Bank Limited	Running Finance Farm Production Dairy and Livestock Finance Poultry Finance Fisheries Finance Tractor Finance
National Bank of Pakistan	Kisan Dost' and 'Kisan Taqat Dairy Farm' schemes include the products: Poultry farming in a controlled environment Dairy farming Off-season vegetable farming in tunnels Floriculture in Pakistan Kinnow processing plant Dehydrated fruits and vegetable plant feasibility Dates processing plant
Soneri Bank Limited	Farm Production Loan Farm Development Loan Non-Farm Working Capital or Development Loan for dairy farming Non-Farm Working Capital or Development Loan for poultry farming Non-Farm Working Capital or Development Loan for fish farming Non-Farm Working Capital or Development Loan for cattle farming Mustaqeem Tractor Loan Mustaqeem Murabaha Non-Farm Working Capital Loan for Poultry Farming
Zarai Taraqiati Bank Limited	Kisan Dost Scheme Sada Bahar Scheme Warehouse Receipt Financing Scheme Tahafuz-e-Ajnas Scheme Soghat-e-Shireen Scheme Tobacco Barn Financing Scheme Khushk Ratab Scheme Rural Development Scheme for AJK

Source: The State Bank of Pakistan

is a need to have effective measures to recover the agriculture loans and supervised credit for agriculture development. He finds that smaller farmers with the small size of farms failed in the loan recovery and were declared as the defaulter of the bank. Qureshi et al.

(1992) find that the higher credit distributed among the farmers and a positive relationship between the agriculture added values and institutional credit.

The studies of Mehmood et al. (2012) and Afolabi (2010) conclude that agriculture credit for the farmers in Pakistan plays a vital role in the development of agriculture communities. The credit for the buying of modern agriculture equipment including tractors, threshers, etc., and other agricultural inputs including seed, fertilizers, pesticides, etc., provides financial support to the small and poor farmers to grow the crops. Ahmad et al. (2021) explore the farmers' decisions live in Khyber Pakhtunkhwa province, Pakistan. They conclude that their decisions are mainly dependent on the adaptation strategies due to the uncertain natural hazards. The adaptation strategies are related to the different significant factors including the farmers' socioeconomic characteristics in terms of farm size and land ownership. The credit disbursement is insufficient for the deprived areas and typical credit procedures make agricultural credit facility difficult and delay disbursement. Furthermore, they suggest having the close monitoring policies for the effective use of the agricultural loans.

So, based on the chronic development of the agriculture institutional credit in Pakistan, along with, the challenges of the recovery from the farmers, we conclude that there is a lack of the empirical study that captures the impact of climate sensitivity on the banks' specific variables on the recovery of the agriculture credit across the eighty-two districts of Pakistan. To the best of our knowledge, it is the pioneer empirical study that estimates the impact of climate change index sensitivity impacts on the agriculture productivity that causes to recovery size of the agriculture credit.

The motivation of this study is to investigate the impacts of climate change on the recovery of agricultural loans across the eighty-two sampled districts. First, we test the impacts of climate change on agricultural productivity across the sampled districts. We then estimate the impact of climate related sensitivities of the agricultural productivity on the agriculture loans recovery in each of the sampled districts.

2 Literature review and hypothesis development

Climate change and weather's unpredicted patterns, including the minimum and maximum temperature, rainfall, flood, and precipitation, have serious implications for the agricultural productivity as well as economic stability in developing countries. Its other indirect impacts include the shortage of food supplies causing inflation, reducing the profitability of financial firms, increase in the importation of crop items and even an impact on the exchange rate (Kaiser & Drennen, 1993; Han et al., 2022). The agriculturally based developing economies are potentially the most affected economies due to the direct impacts of climate change on the agricultural production (Mendelsohn, 2014; Rosegrant et al., 2009; Bezabih et al., 2011).

Darwin et al. (1995) find that global climate change significantly impacts agriculture products. They argue that crop yields mainly come from the field data, including climatic and non-climatic variables. The arid and sub-humid regions, for instance, South Asian and African regions, cannot reduce the climate change impacts due to the lack of technology and being economically weak (Mendelsohn, 2014). Asian farmers in remote and moderately situated areas such as mounts, drylands, and desert areas that lack natural resources are faced with significant threats to climate change. The majority of farmers farming rain-fed land are descendants of over 500 million rural poor in Asia. The South Asian rural

economies are affected due to climate change (UNFCCC, 2002). Their economic, social, and ecological systems are at serious stake (Anderson, 2009). The crop yields reduce due to the negative impacts of the high temperature on the crops' growth rate, transpiration rates, photosynthesis, moisture availability, and others (IPCC, 2007). The growth of food crops is also being damaged due to soil depletion, erosion, pollution, and salinization of land (Kirchmann & Thorvaldsson, 2000; Xu et al. (2022)). The climate change in the arid regions of Northern Pakistan and India, and Western China, temperatures are expected to rise.

In order to pull the farmers out of the vicious circle of poverty and to increase agriculture investment and its growth, access to credit plays a catalyst role (Kumar et al., 2020). Agriculture credit meets the different needs of farmers for the production cycle and agriculture activities including pre-planting, planting, and post-planting (Feder et al., 1990). In developing countries the need for agricultural credit becomes even more pivotal because for several reasons such as the lower income levels of the labor involved in this sector, the unpredicted and drastic change in climate patterns and also because agriculture is often the major contributing sector to the GDP. For example, Mehmood et al. (2012) and Afolabi (2010) conclude that agriculture credit for the farmers in Pakistan plays a vital role in the development of agriculture communities. The credit for the buying of modern agriculture equipment including tractors, threshers, etc., and other agricultural inputs including seed, fertilizers, pesticides, etc., provides financial support to the small and poor farmers to grow the crops.

Farmers have two choices to finance their agriculture needs: formal and informal credit. In the past, the farmers used to mainly center on informal credit across the world due to the absence of formal credit facilities in their rural areas and limited financial instruments to finance the agriculture sector (Klein et al., 1999).

The formal credit for the agriculture sector has higher risks as it is associated with unforeseen climate and other unfavorable events and expenditures that may adversely impact agriculture productivity. The risks come from the variations in market prices of agricultural products, natural disasters due to climate change, and others (Klein et al., 1999). Allen et al. (2019) conclude that the significance of formal credit plays a more vital role in the growth of businesses than informal credit. The farmers have mixed choices of formal and informal credit to finance their agriculture business to avoid the market and human risks whereas in the presence of legal, financial and productivity risks prefer the formal credit (Dang et al., 2019). Muhammad et al. (2011) find that the loan recovery trends are improved due to the improved productivity of the agriculture sector in the Gilgit district of Pakistan.

Thus, due to its pivotal role of credit in this sector and due to the various challenges faced by farmers, governments in developing countries have often targeted and centered their agricultural policies and credit programs over providing ease and access to cheap credit to the farmers. However, research studies find that in developing economies these programs often fail due to a higher default rate (see, for example, Okorie & Iheanacho, 1992; Ishikawa, 1982 and FAO, 1978; Huang et al. 2021).

The research literature on loan default usually has focused on the effect of collateral on default, and the heterogeneity of borrowers (Savitha & Kumar, 2016; Zhou et al., 2016; Yin et al., 2020). However, very few studies can be found dedicated to the reasons of default on sector-specific credit, particularly the agri-loans in emerging markets. Ijaz (2019) analyzed the factors that influence the delay to repay the agriculture loans for the Sahiwal Pakistan, zone. They conduct a survey of 110 default farmers of Zarai Taraqiati Bank branches in Sahiwal. They conclude that agriculture loans for agricultural production

purposes can increase economic activities and eliminate poverty. But small farmers use the loans for their purposes which creates problems to recover the agriculture loans. The other bank policies including Special Assets Management (SAM) policies, higher-priced loans, involvement of different beneficiaries, and non-arrest powers are causing to increase in the non-performing loans (NPL) and reducing the bank's profitability. Wood and Skinner (2018) estimate the impacts of different determinants of non-performing loans (NPL) for commercial banks in Barbados. They find that ROA, ROE, loan-to-deposit ratio and capital adequacy ratios are the significant determinants of the NPL. They find that the profitability ratio is negatively significant on the NPL and the loans to deposit ratio positively impacts the NPL. Kadanda and Raj (2018) estimate the determinants of the non-performing assets (NPA) of the Indian banks for 2004–2017 by applying the Arellano–Bond dynamic econometric technique. They find that the ROA negatively impacts the NPA as the profitable banks are more able to write off the bad debts in case of non-recovery of loans. They find that size of the bank has a positive impact on NPA. Similarly, Ashraf et al. (2014) while estimating the comparative performance of micro-financing institutions in Muslim and Non-Muslim countries in a data set of 754 institutions across eighty-three countries find that profitability and size of assets positively significantly impact the recovery of loans for the sample countries.

While these studies have focused on analyzing the causes of defaults, one still finds a very few studies that have investigated the link of defaults to the farmer's economic conditions, agricultural productivity as well as climate-induced agricultural losses to farmers. For example, Rahji and Fakayode (2009) point out the different issues that adversely impact the credit policy for the agriculture sector. The limited access and costly information for the financial products for the agriculture credit, credit rationing, and higher risk exposure to uncertain climate and natural disasters make the agriculture credit unfavorable for the major banks in Nigeria. Bhat and Tariq (2020) investigate the factors that impact the microfinance loan settlement performance in rural area of Oromia Regional State, Ethiopia based on primary data. They conclude that loan diversion and supervision, loan size and settlement period have significance in settlement of the loan performance. The agricultural income enables the farmers to repay the credit in time. In case of natural disaster, heavy rains and flood, abnormal rise and fall in the temperatures may cause the loss of income from the agricultural productivity and make the loans default.

It can be concluded that the farmer-specific reasons to agriculture loan recoveries in developing countries and especially in Pakistan have mostly remained ignored in the literature. In particular, there is a dearth of studies that concern both the characteristics of financial institutions and climate impacts on agriculture productivity and agricultural loan recoveries.

This study therefore mainly aims to contribute to this literature and thereby propose the following hypotheses;

H1 Climate change sensitivity of the agriculture productivity has impact on the recovery of agriculture loans in Pakistan.

H2 Positive climate change sensitivity of the agriculture productivity has a positive impact on the recovery of agriculture loans in Pakistan.

H3 Negative climate change sensitivity of the agriculture productivity has a negative impact on the recovery of agriculture loans in Pakistan.

3 Data and methodology

We tested our hypothesized relationships in a panel sample of eighty-two districts of Pakistan over a period of 21 years, i.e., 2000–2020 (1722 district-year observations). Our methodology consists of a two-stage framework. In the first stage, we estimated the district level sensitivities of agricultural productivity to climate change. Next, we used these sensitivities in the second stage to estimate whether these sensitivities have any impact on the recoveries of agricultural loans. The details of these two stages and measurement of various variables are given below.

3.1 Estimating the climate change sensitivities of agricultural productivity

In this stage of our methodology, we estimated the impact of climate change on agricultural productivity. To do this we first measured the level of climate change in our sample districts over the sample period with the help of a climate change index. We identified important climate change-related factors based on previous literature to constitute our index. These factors included annual average Minimum and Maximum Temperatures (Ali et al., 2017), Average Annual Rainfall (Ali et al., 2017) and Humidity (Ali et al., 2017). The value of Climate Change Index CCI for each year “*t*” was then calculated as follows,

$$CCI_{ij} = \sum_{j=1}^4 D_j \quad (1)$$

where D_j are dummy variables representing extreme changes in climate factor “*j*” in year “*t*” as compared to its values over the most recent 15 years. Each dummy variable is coded 1 if the related climate factor’s value in the year “*t*” falls in the first or last 30 percentiles of its values in the last fifteen years including the year “*t*” and is coded 0 otherwise.

The data on climate factors, i.e., Average annual Minimum and Maximum Temperatures, Average annual Rainfall and Humidity were taken from 9 Weather Stations of the Meteorological Department of Pakistan. The climate index was calculated for each of the 82 districts using the values of the climate factors of the closest Weather Station.

Next, we regressed the agricultural productivities of major crops produced in 82 districts of the country over the climate change index to estimate the climate change sensitivities of agricultural productivity. Our use of this specific approach is motivated from estimating similar sensitivities in other fields of research. For example, in the field of international finance Clark and Mefteh (2011) used this approach to estimate the sensitivities of stock prices of firms to changes in an exchange rate measuring index.

Further, following Ali et al. (2017), the major crops we considered for our study included Cotton, Sugarcane, Wheat, Rice and Maize. Our Model is presented in Eq. 1 ,

$$\begin{aligned} \text{AgriProd}_{it} = & \alpha_0 + \beta_1 \text{CCI}_{it} + \beta_2 \text{Fertilizer}_{it} + \beta_3 \text{Seed}_{it} + \beta_4 \text{Labour}_{it} \\ & + \beta_5 \text{Tractors}_{it} + \beta_6 \text{Water}_{it} + \beta_7 \text{Flood}_{it} + \mu_{it} \end{aligned} \quad (2)$$

where,

AgriProd_{it} : is the yield per hectare of crop “*j*” at time “*t*.” CCI_{it} : represents the value of Climate Change Index in year “*t*.” Fertilizer_{it} : is the quantity of fertilizers in tons used for crop “*i*” at time “*t*.” Seed_{it} : represents the quantity of improved seed used in tons for crop “*i*”

in year “t.” $Labor_{it}$: shows the percentage of the population engaged in agriculture at time “t.” $Tractors_{it}$: is the total number of tractors available in the country for agriculture at time “t.” $Water_{it}$: is the availability of water in acre feet per hectare at time “t.” $Flood_{it}$: is a dummy that takes the value 1 if there was a major flood recorded in the country in year “t” otherwise 0. μ_{it} : is the error term of the model.

We estimated Eq. (2) repeatedly over crop data for each of the 82 districts of our sample. The total number of districts in the country was 120; however, for our estimation procedure, we required that a district in our sample must have data on at least three crops. This reduced the number of districts to be included in our sample to a final number of 82 districts.

Moreover, in our data panel, the number of years (i.e., 21 years) is greater than the number of entities (i.e., 5 crops), so we expect that the variations in the time series data dominates the cross-sectional observations in our data set indicating the possible presence of serial correlation and heteroskedasticity. In the presence of serial correlation and heteroskedasticity, the pooled OLS, fixed effects and random effects models may yield spurious results. We tested for the presence of serial correlation and heteroskedasticity problems by running the Wooldridge panel correlation and Modified Wald tests. The results suggested the presence of both these issues. Therefore, to deal with these issues, following (Reed & Ye, 2011) we used Panel Corrected Standard Error (PCSE) model. Further, Rea and Reed (2018) find that PCSE performs best whatever the T/N ratio, either above 1.50 or below 1.5. Our study has a T/N ratio of 4.20 (21/5), so we conclude that PCSE is appropriate for this study. The other researchers who have recently applied PCSE regressions include (Bailey & Katz, 2011; Kumar et al., 2021; Kongkuah et al., 2021).

Finally, the coefficient of Climate Change Index, i.e., β_1 estimated from Eq. 1 will represent our Climate Change Sensitivity of agricultural productivity for each particular district.

3.2 Estimating the impact of climate change sensitivities on agri loan recoveries

In this stage of our methodology, we estimated the impact of district-level agricultural loan recoveries over the sensitivities of agricultural productivity to climate changes. In order to do this, we first created a dummy variable to represent whether the agricultural productivity in a particular district was sensitive to extreme climate changes. The dummy was constructed such that it took a value of 1 if the coefficient of Climate Change Index in Eq. (1) (i.e., β_1) was negative for a particular district and 0 if it was positive. We then regressed the district level agricultural loan recovery over this dummy variable and other control variables suggested by the literature as determinants of loan recoveries using the following model,

$$\begin{aligned} \text{Total Recovery}_{it} = & \alpha_0 + \alpha_1 \text{Sensitivity}_{it} + \alpha_2 \text{Sensitivity dummy}_{it} \\ & + \alpha_3 \text{Spread}_{it} + \alpha_4 \text{Loan size}_{it} + \alpha_5 \text{ROA}_{it} + \alpha_6 \text{Deposits}_{it} + \epsilon_{it} \end{aligned} \quad (3)$$

where $TotalRecovery_{it}$: is the natural log of the sum of economic and farm agricultural loan recovery of district “i” in year “t.” $Sensitivity_{it}$: measures Climate Change sensitivity of agricultural productivity in district “i” in year “t” estimated from Eq. (1). $SensitivityDummy_{it}$: is a dummy variable to capture the positive and negative impacts of climate change on agricultural productivity in district “i” in year “t.” The dummy was constructed such that it took a value of 1 if the coefficient of Climate Change Index in Eq. (1) (i.e., β_1) was negative for a particular district and 0 if it was positive. $Spread_{it}$: is the spread of the interest rates of deposits and advances of all the banks that offered agricultural loans in district “i” in year “t.” $LoanSize_{it}$: is the natural log of the size of the agricultural advances of all the financial institutions in district “i” in year “t.” ROA_{it} : is the returns of

assets of the financial institutions in district “i” in year “t.” $Deposits_{it}$ is the ratio of total deposits to total assets of financial institutions in district “i” in year “t.” While ε_{it} is the error term of the model.

Like Eq. (2), we also estimated Eq. (3) using the Panel Corrected Standard Errors (PCSE) Regression approach. We chose PCSE because of the presence of Serial Correlation and heteroskedasticity in our data.

4 Results and discussion

Table 3 presents the descriptive statistics of the main variables used in our study. The table shows that in our sample the total recoveries from the agricultural loans over the sample period have remained at an average of Rs. 2828 million. The climate sensitivity impact on agricultural productivity (obtained from the regression model of climate change index with other control variables on the agricultural productivity across the eighty-two districts of Pakistan over the period of 2000–2020) has mean value of 0.64 with the highest value of 2.435 and lowest value of 0.006. The interest rate spread has the mean value of 5.152 with the standard deviation value of 1.207. Similarly, the banks in districts in our sample have an average total loan size of Rs. 4091 million and have an average return of about 1.1% of the total assets.

Table 4 presents the correlations among the variables. We see that the correlation coefficients are smaller and there is no serious issue of the multicollinearity among the variables.

5 Regression results

Table 5 summarizes the results of our PCSE regressions of Eq. (2). In this table, the significance of the diagnostic tests: Hausman test, Wooldridge test for autocorrelation, and Modified Wald test for heteroskedasticity shows that the PCSE model is appropriate for our study.

Table 3 Descriptive statistics

Variables	Mean	Median	Std. Dev	Max	Min
Total Recovery	2828.177	1261.680	4175.827	87,705.781	– 927
Sensitivity	0.640	0.593	0.475	2.435	0.006
Spread	5.152	5.540	1.207	7.100	3.101
Loans Size	4090.849	3440.234	1724.511	8296.120	2155.719
ROA	0.011	0.012	0.005	0.021	0.002
Deposits	0.740	0.745	0.043	0.809	0.592

This table summarizes the descriptive statistics of our data. Where Total Recovery is the sum of economic and farm agricultural loan recovery in Million of Rs., *Sensitivity* is the district level Climate Change sensitivity of agricultural productivity estimated from Eq. (2), *Spread* is the spread of the interest rates of deposits and advances of all the banks that offered agricultural loans at district level, *LoanSize* is the total of agricultural advances of all the financial institutions in a district Million of Rs., *ROA* is the return on assets of the financial institutions in a district while *Deposits* represents the ratio of total deposits to total assets of financial institutions in a district

Table 4 Correlation matrix

	Total recovery	Sensitivity	Spread	Loans size	ROA	Deposits
Total recovery	1					
Sensitivity	0.0878	1				
Spread	− 0.0624	− 0.00001	1			
Loans size	0.0963	0.000013	− 0.7871	1		
ROA	0.02	− 0.00001	− 0.069	− 0.0634	1	
Deposits	0.0274	− 0.000032	0.0415	0.0254	0.464	1

Table 5 Panel corrected standard errors (PCSE) regression results

	Coefficients	Z-Statistic	P-values
Sensitivity	0.446193	7.74	0.00
Dummy	− 0.8246673	− 15.55	0.00
Spread	0.0857528	2.9	0.004
Loans size	0.6764101	9.04	0.00
ROA	14.45974	2.63	0.009
Deposits	0.5745948	1.02	0.309
Constant	− 8.971266	− 5.14	0.00
R-Square	0.0424		
Wald chi2(6)	705.24		
Prob > chi2	1841.49 ($p = 1841.49$)		
<i>Diagnostic tests</i>			
Hausman test	4.87 ($p = 0.0875$)		
Wooldridge test for autocorrelation	21.577 ($p = 0.0000$)		
Modified Wald test for heteroskedasticity	41,178.29 ($p = 0.0000$)		

This table presents the coefficient estimates from our Panel Corrected Standard Errors (PCSE) Regression (Eq. 2) over our sample data of District level recoveries and Climate Change sensitivities of Agricultural productivity. Where Total Recovery is the sum of economic and farm agricultural loan recovery Million of Rs., *Sensitivity* is the district level Climate Change sensitivity of agricultural productivity estimated from Eq. (1), *Spread* is the spread of the interest rates of deposits and advances of all the banks that offered agricultural loans at district level, *LoanSize* is the total of agricultural advances of all the financial institutions in a district Million of Rs., *ROA* is the returns on assets of the financial institutions in a district while *Deposits* is the ratio of total deposits to total assets of financial institutions in a district

Table 5 shows that our Sensitivity Dummy is significant with a coefficient of − 0.825 and which is highly significant. This suggests that that negative climate change sensitivities adversely impact the total recoveries. This is quite in line with our hypothesis and means that unfavorable climate in the different districts reduces the agriculture productivity and income of the farmers which eventually reduces the total recoveries in that district.

Contrary to that, positive climate change sensitivities of agricultural productivity improve the total recoveries in Pakistan. A favorable climate environment in the form of suitable rains, humidity and temperature increases the agriculture productivity which in turn results in a higher income for the farmers. The farmers with improved income are in a better position to repay their agriculture loans, improve their creditability and effectively reduce the interest expense on further loans. Based on these findings, we conclude that favorable climate changes improve the agricultural loan recoveries while unfavorable climate changes reduce the agriculture loan recoveries in our sample districts.

We further find from Table 5 that among other control variables the spread of the interest rate of the financial institutions, loan size, banks profitability and Deposits to Assets ratio positively impact the loan recoveries across the sampled districts in Pakistan.

Widening the spread rate of the banks speeds up the recoveries from the farmers which means that the farmers may repay the loans to avoid the highly priced loans. In Pakistan, agriculture loans are linked with Karachi Inter-Bank Rate (KIBOR) or at the market rates. So, an increase in the KIBOR tends to increase the loan costs for the farmers and they repay their loans to avoid the higher interest expenses. Other studies who also find a positive relationship between the spread rate and the costs of loans include (Bongini et al., 2019; Wang et al., 2020; Ijaz, 2019; Rahji & Fakayode, 2009).

Similarly, a higher volume of the bank advances may increase the risks of the non-performing loans. But, in Pakistan, the agriculture loans are granted against two major projects: against the agricultural land or other collateral and the group collaboration. In the group collaboration, farmers do not need to provide the collateral against the loans, but the group of the collaborative farmers provides the guarantee of each other in case of a non-payment of loans. They exert a moral pressure on their peers to repay so as to save their credit reputation. This finding is consistent with the findings of other previous studies such as Bongini et al. (2019), Wang et al. (2020), Kumar et al. (2020) and Ashraf et al. (2014) to quote a few.

The increases in banks' profitability also increase the loan recoveries. The higher profitability means the banks have more resources and can effectively recover the loans from the farmers. The other researchers including Bongini et al. (2019), Ghosh (2018), and Ashraf et al. (2014) find positive associations with the loan recoveries.

A higher the deposits base also increases the loan recoveries, meaning that banks have more funds to grant in the form of advances to the farmers to achieve the agriculture credit as targeted by the government of Pakistan. The banks have an effective way to recover the loans from the farmers against the group pressures and collateral value of the assets. Ghosh (2018) and Wood and Skinner (2018) also find the higher deposit to assets ratio positively impacts the loan recovery.

6 Conclusion and implications

We conclude that the impact of climate change on the total recovery of agricultural loans is non-symmetric. A favorable climate increases the agriculture production that causes to increase the farmers' income and hence their ability to repay their loans. In contrast to that, an unfavorable climate change (i.e., having a negative impact on agricultural productivity) reduces the farmers' income and increases the loan costs due to the inability to repay the loans. Their assets are at risk due to the collateral against the loans and lower pressures

from the group's members. The banks may restructure the agricultural loans to avoid the court and other associated costs.

Our study has implications for financial institutions and governments. The government should take simultaneous steps to mitigate the impacts of climate change by aggressive and effective policies to reduce greenhouse gases, increase the plantation and control the cutting of trees and reduce the burning of organic fuels in energy, transportation, and other sectors by gradually shifting to the renewables ones. In addition to this, the government and banks, in their agricultural loan programs and policies, must include efforts to educate the farmers regarding the adaptation techniques to reduce the adverse impacts of climate change on agriculture production.

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References

- Afolabi, J. (2010). Analysis of loan repayment among small-scale farmers in Oyo State Nigeria. *Journal of Social Sciences*, 22(2), 115–119.
- Ahmad, D., Afzal, M., & Rauf, A. (2021). Farmers' adaptation decisions to landslides and flash floods in the mountainous region of Khyber Pakhtunkhwa of Pakistan. *Environment, Development and Sustainability*, 23(6), 8573–8600.
- Ali, S., Liu, Y., Ishaq, M., Shah, T., Ilyas, A., & Din, I. U. (2017). Climate change and its impact on the yield of major food crops: Evidence from Pakistan. *Foods*, 6(6), 39.
- Allen, F., Qian, M., & Xie, J. (2019). Understanding informal financing. *Journal of Financial Intermediation*, 39, 19–33.
- Anderson, K. (Ed.). (2009). *Distortions to agricultural incentives: A global perspective, 1955 to 2007*. London: Palgrave Macmillan and Washington, DC: World Bank.
- Anka, A. L. (1992). Analytical report on supervised agricultural credit, its problems prospects, and suggestions for implementation in Pakistan. *J. Rural Dev. Administ*, 24(1), 137–147.
- Ashraf, A., Hassan, M. K., & Hippler, W. J., III. (2014). Performance of microfinance institutions in Muslim countries. *Humanomics*, 30, 162–182.
- Bailey, D., & Katz, J. N. (2011). Implementing panel-corrected standard errors in R: The pcse package. *Journal of Statistical Software*, 42, 1–11.
- Bezabih, M., Chambwera, M., & Stage, J. (2011). Climate change and total factor productivity in the Tanzanian economy. *Climate Policy*, 11(6), 1289–1302.
- Bhat, M. A., & Tariq, S. (2020). Determinants of loan settlement performance for microfinance institutions of Oromia regional state of Ethiopia. *International Journal of Advanced Science and Technology*, 29(9s), 2609–2622.
- Bongini, P., Cucinelli, D., Di Battista, M. L., & Nieri, L. (2019). Profitability shocks and recovery in time of crisis evidence from European banks. *Finance Research Letters*, 30, 233–239.
- Clark, E., & Mefteh, S. (2011). Asymmetric foreign currency exposures and derivatives use: Evidence from France. *Journal of International Financial Management & Accounting*, 22(1), 27–45.

- Dang, H. D., Dam, A. H. T., Pham, T. T., & Nguyen, T. M. T. (2019). Determinants of credit demand of farmers in Lam Dong, Vietnam: A comparison of machine learning and multinomial logit. *Agricultural Finance Review*, 80, 255–274.
- Darwin, R. F., Tsigas, M., Lewandowski, J., & Raneses, A. (1995). *World Agriculture and Climate Change: Economic Adaptations*. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service.
- FAO. (1978). Report on the agro ecological zones project. Volume. 1. Methodologies and results for Africa. Rome. FAO Publication, World Soil Resources Report.
- Feder, G., Lau, L. J., Lin, J. Y., & Luo, X. (1990). The relationship between credit and productivity in Chinese agriculture: A microeconomic model of disequilibrium. *American Journal of Agricultural Economics*, 72(5), 1151–1157.
- Ghosh, A. (2018). Determinants of bank loan charge-off rates: evidence from the USA. *Journal of Financial Regulation and Compliance*, 26, 526–542.
- Han, Y., Tan, S., Zhu, C., & Liu, Y. (2022). Research on the emission reduction effects of carbon trading mechanism on power industry: plant-level evidence from China. *International Journal of Climate Change Strategies and Management*, 15, 212–231.
- Huang, S., & Liu, H. (2021). Impact of COVID-19 on stock price crash risk: Evidence from Chinese energy firms. *Energy Economics*, 101, 105431.
- Intergovernmental Panel on Climate Change (IPCC) (2007). Climate Change 2007: The Scientific Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., Cambridge Univ. Press, New York.
- Ijaz, A., Siddiqui, S. H., Rasheed, R., & Nawaz, M. S. (2019). Factors affecting delay in agricultural loan recovery among small scale farmers in Sahiwal region Pakistan. *Journal of Management Sciences*, 6(2), 48–53.
- Ishikawa, K. (1982). *Guide to quality control* (Vol. 2). Tokyo: Asian Productivity Organization.
- Kaiser, H., & Drennen, T. (1993). *Agricultural dimensions of global climate change*. CRC Press.
- Kadanda, D., & Raj, K. (2018). Non-performing assets (NPAs) and its determinants: A study of Indian public sector banks. *Journal of Social and Economic Development*, 20(2), 193–212.
- Kirchmann, H., & Thorvaldsson, G. (2000). Challenging targets for future agriculture. *European Journal of Agronomy*, 12(3–4), 145–161.
- Klein, B., Meyer, R., Hannig, A., Burnett, J., & Fiebig, M. (1999). *Better practices in agricultural lending*. Rome: Food and Agriculture Organization of the United Nations (FAO).
- Kumar, A., Das, R., Aditya, K. S., Bathla, S., & Jha, G. K. (2020). Examining institutional credit access among agricultural households in Eastern India: Trends, patterns, and determinants. *Agricultural Finance Review*, 81, 250–264.
- Kumar, P., Sahu, N. C., Kumar, S., & Ansari, M. A. (2021). Impact of climate change on cereal production: Evidence from lower-middle-income countries. *Environmental Science and Pollution Research*, 28(37), 51597–51611.
- Kongkuah, M., Yao, H., Fongjong, B. B., & Agyemang, A. O. (2021). The role of CO 2 emissions and economic growth in energy consumption: Empirical evidence from belt and road and OECD countries. *Environmental Science and Pollution Research*, 28, 22488–22509.
- Mehmood, Y., Ahmad, M., & Anjum, M. B. (2012). Factors affecting delay in repayments of agricultural credit: A case study of district Kasur of Punjab Province. *World Applied Sciences Journal*, 17(4), 447–451.
- Mendelsohn, R. (2014). The impact of climate change on agriculture in Asia. *Journal of Integrative Agriculture*, 13(4), 660–665.
- Muhammad, M., Janjua, P. Z., & Ullah, K. (2011). Impact of village group financial services on women empowerment and poverty: A case study of the first micro finance bank gilgit. *Dialogue (Pakistan)*, 6(4).
- Okorie, A., & Iheanacho, A. C. (1992). Agricultural loan recovery strategies in a developing economy: A case study of Imo State, Nigeria. *African Review of Money Finance and Banking*, 195–202.
- Pakistan, I. U. C. N., & Amir, P. (2009). Policy Gap Analysis. IUCN Pakistan, Islamabad, Pakistan.
- Qureshi, S. K., Shah, A. H., & Vosti, S. A. (1992). A critical review of rural credit policy in Pakistan [with Comments]. *The Pakistan Development Review*, 31(4), 781–801.
- Rahji, M. A. Y., & Fakayode, S. B. (2009). A multinomial logit analysis of agricultural credit rationing by commercial banks in Nigeria. *International Research Journal of Finance and Economics*, 24(91), 97–103.
- Reed, W. R., & Ye, H. (2011). Which panel data estimator should I use? *Applied Economics*, 43(8), 985–1000.

- Rosegrant, M. W., Ringler, C., & Zhu, T. (2009). Water for agriculture: maintaining food security under growing scarcity. *Annual Review of Environment and Resources*, 34, 205–222.
- Savitha, B., & Kumar K, N. (2016). Non-performance of financial contracts in agricultural lending: A case study from Karnataka, India. *Agricultural Finance Review*, 76(3), 362–377.
- Schelling, T. C. (1992). Some economics of global warming. *The American Economic Review*, 82(1), 1–14.
- Tuyen, T. Q. (2016). Income sources and inequality among ethnic minorities in the Northwest region Vietnam. *Environment, Development and Sustainability*, 18(4), 1239–1254.
- UNFCCC. (2002). The Delhi Ministerial Declaration on Climate Change and Sustainable Development. UNFCCC, Bonn.
- Wang, H., Forbes, C. S., Fenech, J. P., & Vaz, J. (2020). The determinants of bank loan recovery rates in good times and bad—New evidence. *Journal of Economic Behavior & Organization*, 177, 875–897.
- Wood, A., & Skinner, N. (2018). Determinants of non-performing loans: Evidence from commercial banks in Barbados. *The Business & Management Review*, 9(3), 44–64.
- Xu, L., Liu, X., Tong, D., Liu, Z., Yin, L., & Zheng, W. (2022). Forecasting urban land use change based on cellular automata and the PLUS model. *Land*, 11(5), 652.
- Yin, Z., Meng, L., & Sha, Y. (2020). Determinants of agriculture-related loan default: Evidence from China. *Buletin Ekonomi Moneter dan Perbankan*, 23, 129–150.
- Zhou, L., Zhang, Y., Dai, G., & Zhang, S. (2016). Access to microloans for households with forest property collateral in China. *Small-scale Forestry*, 15, 291–301.

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