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Economic assessment of the impact of climate change on the agriculture of Pakistan

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Climate Change in Pakistan among others manifests itself in temperature increases, rainfall reduction in the arid plains and increases in the monsoon areas and last but not least, accelerated glacial melt. All these and other developments call for a deeper insight into the effects Recent Climate Change - or Weather Change has had on Pakistan in the course of the last 17 years. In this context the threats to food security remain one core issue to be investigated based on productivity analysis. This article studies how climate change affects the agricultural productivity in Pakistan's four provinces Punjab, Sindh, Balochistan and the N.W.F.P., measured as weighted food crop yields per hectare, for the food crops wheat, rice and maize. By considering the RABI (Nov-Apr) growing season and including a measure for drought to capture the occurrence of extreme events, exacerbated through climate change, the proposed hypothesis is that changing climatic variables have reduced and are reducing the agricultural productivity and thus posing a threat to long term food security. To depict the effect of climate change, several control variables are introduced in a panel framework for intertemporal analysis. As a result, we should expect lower levels of productivity in the arid zones with greater climatic pressure and adverse effects on food security through lower agricultural yields.

JEL Classifications: Q54, C23, O11

Keywords: Climate change, Pakistan, panel model, econometric analysis, adaptation.

Introduction

Pakistan is situated in the South Asian region between 24-37°N of latitude and 61-76°E of longitude. The Agricultural Sector in Pakistan still remains the most important sector of the economy, responsible for almost 70% of the livelihoods of the population, directly or indirectly linked to the sector. Pakistan having a population of approximately 160 million with 32% living below the poverty line has serious challenges to overcome (ESP, 2007). Especially vulnerability of the poor to food insecurity will increase as an indirect effect of decreasing food crops' yields. The countries climate can be classified as continental with great diversity due to different topology and altitude (Khan et al., 2010). The agriculture sector consists of crops, livestock, fishing and forestry. Major crops include wheat, cotton, rice, sugarcane and maize. There are two agricultural seasons in Pakistan named "kharif" and "rabi." The kharif season refers to the summer growing period from May to November, with the major crops cultivated being rice, corn and cotton. The rabi or winter growing season runs from November/December through April, with the major crops being wheat, barley and millet (USDA, 2010). Weather and climate are key factors influencing agricultural productivity. For example, weak monsoon rains in 1987 caused large shortfalls in crop production in India, Bangladesh, and Pakistan, contributing to reversion to wheat importation by India and Pakistan (World Food Institute, 1988). As the frequency and the intensity of climate related extreme events in Pakistan have increased in the recent decade, the present study aims to reflect on the developments in the agricultural production of Pakistan in the Period 1987-2004, this with respect to climate change and its impacts on the food crop sector. For the purpose of this study the three major food crops, wheat, rice and maize have been depicted. The choice of period is mainly due to data availability and especially the exacerbation of extreme events in Pakistan, especially in the last 15-20 years.

The paper is organised as follows. A brief overview of the development of agriculture in Pakistan with respect to the food crops wheat, rice and maize is provided first. The following section will also shed light into development of the climatic variables over the period at study. Next section is devoted to the empirical analysis. Having shed light on the theoretical framework and the specific methodology used, the last section moves on to present the major findings of the empirical investigation and outlines their key implications. The paper concludes with a short summary of major findings in the final chapter.

Literature review

The LEAD Climate Change Action Plan of Pakistan declares the country to be highly vulnerable to climate change. According to the vulnerability index Pakistan is ranked 12th globally, economic losses of approximately 4,5 billion \$ are anticipated, grassland productivity and consequently crop and livestock yields are expected to suffer severely from climatic change manifested in significantly higher temperatures and decreased surface water availability and changing precipitation patterns (LP, 2008). Despite these concerns and forecasts, not many studies have been undertaken in Pakistan on the economic losses and social welfare impacts that are expected to result from climate damage to agriculture. It was not until 2002 that a research center devoted to research on climatic and environmental change could be established in the country, the Global Change Impact Studies Centre (GCISC). The center serves as a think tank in aid of the national decision makers and planners in areas such as climate change and environmental degradation, since 2005 it has been recognized as an autonomous body that alongside the ministry of Environment serves as a Secretariat to the Committee on climate change (UNFCCC, 2008). To date the center in its eight years of existence has produced only three articles published in international journals, none of them addressing the economic impact of climatic change on the agricultural sector specifically considering implicit adaptation. The center has primarily made use of the following simulation models: Regional Climate Models (e.g., RegCM3); Watershed Models (e.g., WatBal); Crop Simulation Models (e.g., CROPGRO). Despite an internationally extensive interest in the measurement of the economic impacts of climate change, the empirical research on Asia remains scarce. By using two different climate response functions, one derived from a cross sectional Ricardian study of India (Mendelsohn et al., 2001) and the other estimated from agricultural-economic simulation results (Adams et al., 1999), the Yale University study titled "Climate Change Impacts on Southeast Asian Agriculture" based on a GIM (Global impact Model) tries to compute the economic impacts of climate change and extrapolates the results to all countries in the region (Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Laos, Malaysia, Nepal, Pakistan, Philippines, Taiwan, Thailand, Vietnam). In summary the study finds that the agricultural impacts of a change in climate are dependent on four factors: the response function, the size of the agricultural sector, the initial temperature and precipitation, and the climate scenario. The study provides some initial evidence on the impact of climate change in this region, predicting losses in the range of two to sixteen billion dollars (mild & extreme scenario) for Pakistan's agriculture until 2100, while at the same time stressing the need for further empirical research in this region, particularly mentioning the need to include more countries than just India, which was used as a proxy for all Southeast Asian Countries. More research is clearly needed to refine the estimates of impacts in this vulnerable region. Potential adaptation measures have to be indentified for both, farmers and governments (Mendelsohn, 2005).

Development of the agricultural sector under climate change 1987-2004

To understand the effects of climate change on agricultural output, prior to conducting forecasts, it is highly essential to understand the determinants of agricultural output

growth. Most studies to date have tried to forecast the development of agricultural output based on trends that have been seen in the past. Forecasting for a considerable amount of years such as 50 years is bound to serious biases as per the development of other buffering factors is concerned, such as the development of better technologies and growing methods. For this reason the present study is mainly interested in its first phase to understand the determinants of agricultural output in Pakistan's four major provinces and to depict the role of climatic variables and extreme events on the food crop yields in Pakistan. How agriculture in this geographical region has developed, remains an important question to be addressed. Although the provinces at study in many regards share homogenous traits, the development of agricultural productivity throughout the period considered from 1987 to 2004 shows a differential development.

TABLE 1. PROVINCE WISE IMPORTANCE AND PERFORMANCE OF FOOD CROPS

Province	Total Food Crop Area (in thousands ha)	Share in Total Food Cropped Area (in %)			Yield (kg/ha)		
		Wheat	Rice	Maize	Wheat	Rice	Maize
Punjab	7694	77.03%	18.10%	4.87%	2189.609	1382.779	1777.463
Sindh	1664	61.56%	37.74%	0.70%	2316.732	2544.54	520.87
N.W.F.P.	1398	58.31%	4.53%	37.16%	1330.483	1936.872	1554.785
Balochistan	462	70.73%	28.40%	0.87%	2067.09	2618.139	1015.957

Source: Own computations using Agricultural Statistics of Pakistan, 2005.

As Table 1 shows, the lion share of the area devoted to the production of food crops is located in the Punjab. The main agricultural food crop produced throughout the country is wheat, with a share between 60%-80% in total cropped area for food crop production. As per the productivity is concerned, for the production of wheat the provinces Sindh, Balochistan and Punjab in the period 1987-2004 have been especially suitable. Rice productivity has been better in Balochistan and Sindh, whereas maize has been comparatively more successfully grown in the Punjab and the Northern Western Frontier Province. Whereas wheat in Pakistan throughout the period at study has been an important food crop throughout the provinces, maize predominantly is grown in the N.W.F.P., whereas rice has been important in Sindh and Balochistan.

FIGURE 1. SHARE IN PROVINCE WISE TOTAL FOOD CROPPED AREA (%) 1987-2004

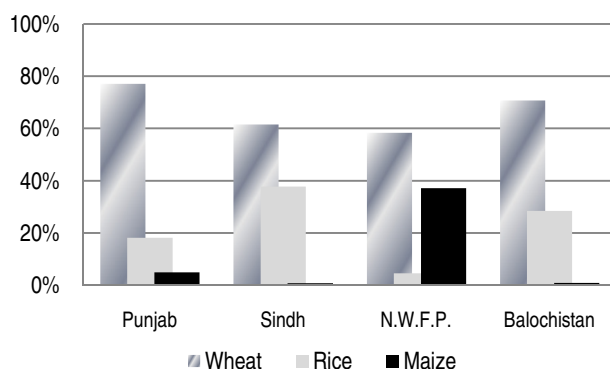
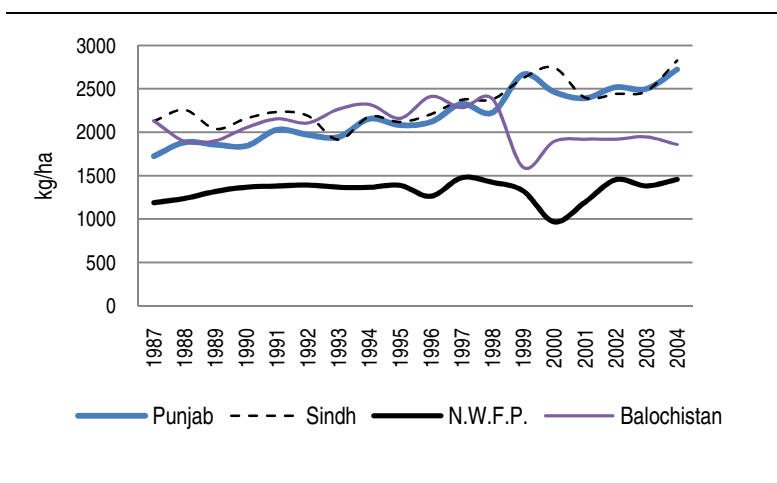


FIGURE 2. WHEAT YIELD 1987-2004



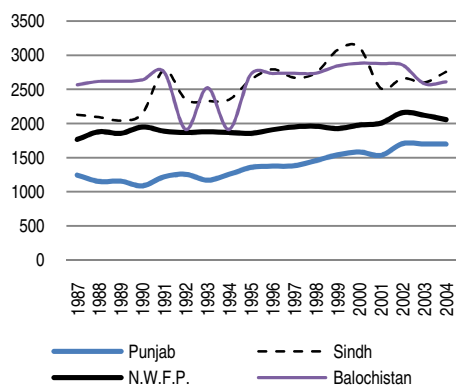
As the forgone considerations revealed, wheat is the main staple food in the country, this also on the provincial levels as Figure 1 highlights. Each province's total cropped area has been predominantly devoted to wheat production. Moreover, wheat contributed about 45 percent of the daily caloric consumption of the population. Wheat is also a critical commodity in terms of total contribution to national food security (USAID, 2009). To this effect, for purpose of analysis the present paper has selected the “rabi” growing season.

The following illustrations aim to highlight the developments in the food crop yields throughout the four provinces of Pakistan for the period at study.

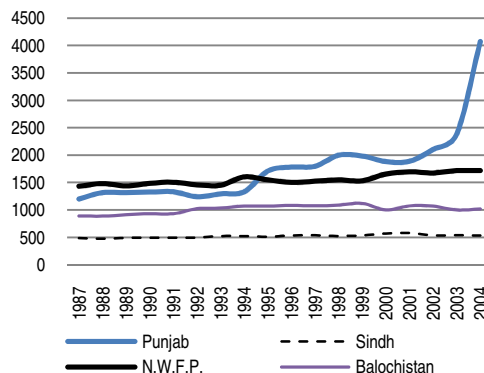
Overall, during the past 17 years the country has experienced good wheat crops, albeit having relatively low yields. The significant drops especially in the period 1998-2002 have been induced by factors like water shortages caused by severe drought conditions (see Figure 6).

FIGURE 3. RICE AND MAIZE YIELD 1987-2004, kg/ha

Rice yield 1987-2004



Maize yield 1984-2004



The key constraint to wheat production is generally the timing and availability of the irrigation water supply, and the efficiency of water use on-farm (USAID, 2009). Rice is the second most important food crop, accounting for about 6 percent of the daily caloric intake. The national rice crop is predominantly rainfed and it is planted from May-June during the kharif season. Punjab is the major rice growing area, whereas major high yielding varieties are produced in the Sindh province. Rice has emerged as a major export commodity and Pakistan enjoys a near monopoly status in the export of fine aromatic Basmati- rice (Junejo et al., 2007).

After wheat and rice maize is the third most important food crop in Pakistan. More than 50 percent maize of the country is grown in the Northern Western Frontier Province (N.W.F.P.). In 2008 the total area cropped with maize in Pakistan amounted to 1051.7 thousand hectares with a production of 3604.7 thousand tons and an average grain yield of 3427 kg per hectare. In the N.W.F.P., it was planted on 509 thousand hectares (almost half of the country's acreage) with a total production of 903.9 thousand tons and average yield of 1776 kg per hectare (Hussain et al., 2010).

As Figure 4 shows especially Balochistan in the last 17 years has shown a more or less steady warming trend. The other provinces with higher levels of fluctuations in general have also shown slightly shift towards increased levels of temperature.

FIGURE 4. TEMPERATURE TRENDS IN °C FOR THE PERIOD 1987-2004

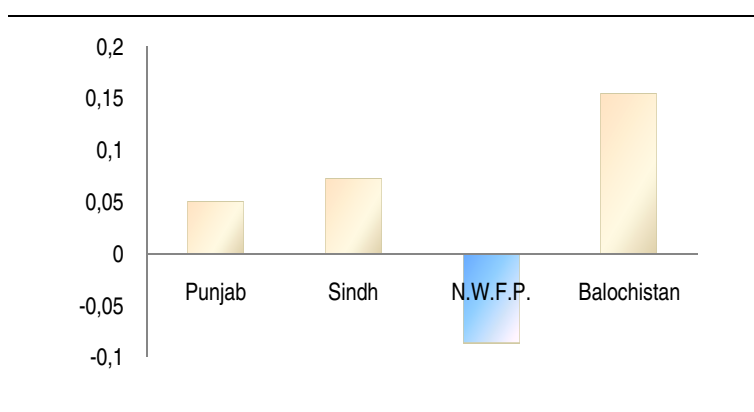


FIGURE 5. AVERAGE RABI RAINFALL 1987-2004 NOV-APR

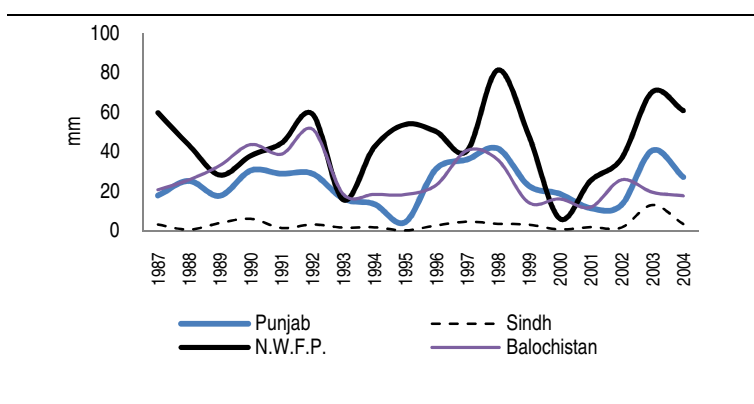
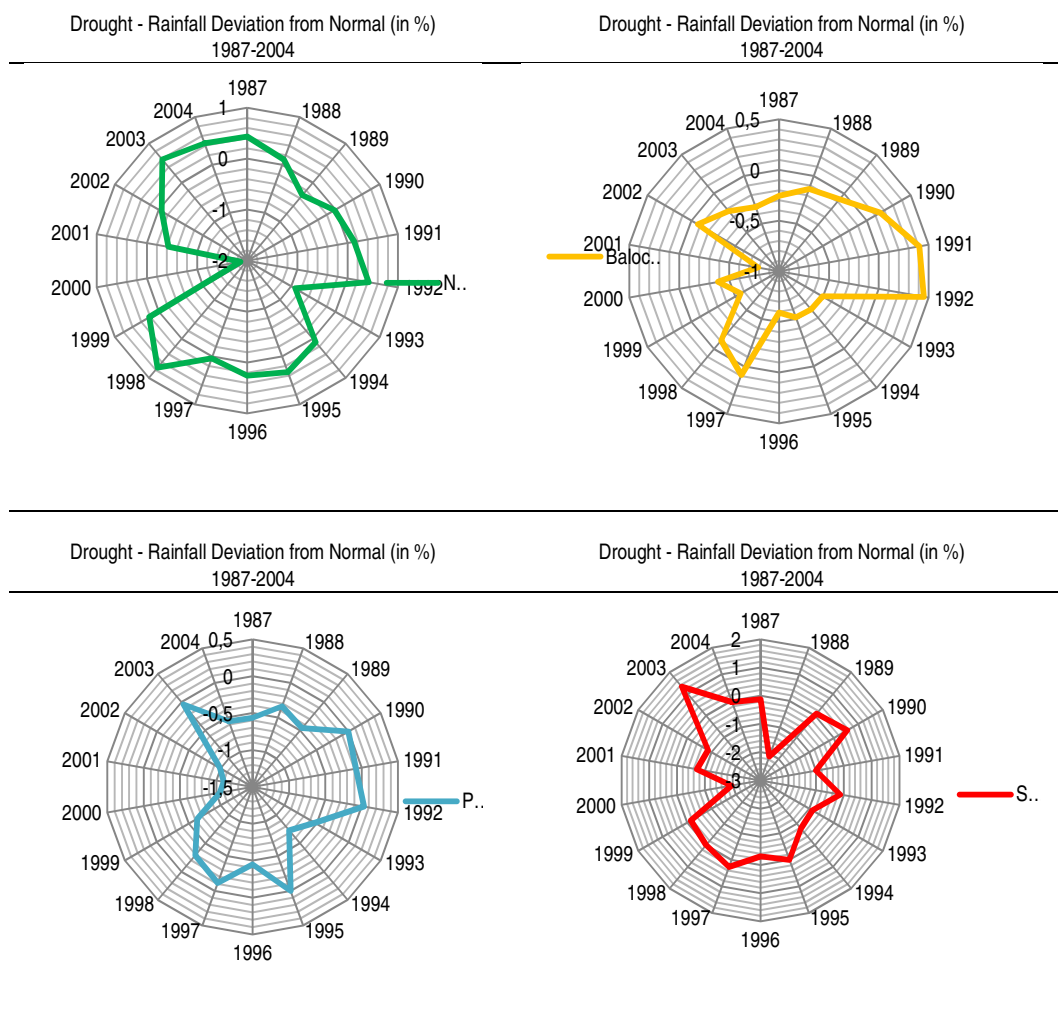


FIGURE 6. INCIDENCE OF DROUGHT IN PAKISTAN 1987-2004



As per rainfall is concerned, the greatest rainfall variability can be observed for the N.W.F.P., whereas Sindh has received low levels of precipitation.

As Figure 5 shows, the incidence of drought in Pakistan has been quite frequent in Pakistan, all provinces have suffered from drought, especially the period 1998-2002 in all provinces has been extremely affected.

Data and methodology

An appropriate framework to analyze the food crop output in Pakistan is the neo-classical growth model first proposed by Solow (1956). Basically, the productivity i.e. output or weighted food crop yield per ha, is assumed to be a function of fertilizer used per ha, credits devoted to the agricultural sector, irrigation (proxied by public and private tube wells per ha), labor force per ha, tractors per ha to control for technology parameters and the climate proxies in form of temperature averages for the “rabi” growing season (Nov-Apr), average monthly rainfall in mm (rabi) and a drought variable. The general formulation of the production function is $Q=A(t)f(K,L)$ where Q denotes the output, K

and L are, respectively, capital and labour. The factor $A(t)$ measures productivity shifts over time which may be induced by technological progress or through adaption linked to changes in climatic conditions, as per land productivity is concerned.

In order to implement the above framework consider the following model using fixed effects panel data notation:

$$Wfcy_{it} = a + \beta_1 fert_{it} + \beta_2 cred_{it} + \beta_3 tubepub_{it} + \beta_4 tubpriv_{it} + \beta_5 lf_{it} + \beta_6 trac_{it} + \beta_7 temp_{it} + \beta_8 rain_{it} + \beta_9 drought_{it} + \beta_{10} drought_{it-1} + \beta_{11} wfcy_{it-1} + \delta_2 T_2 + \dots + \delta_i T_i + \varepsilon_{it}$$

where δ_i is the coefficient for the binary time regressors, T_i is time as binary variable (dummy), so we have $t-1$ time periods. Whenever unexpected variation or special events may affect the outcome variable, it is recommended to control for time effects. ε_{it} is the error term. An overview of the abbreviations, definitions and data sources is given in Table 2 and will be explained in greater detail in the next subsection. The use of panel data methodology offers the advantage of controlling for unobserved country-specific effects and thus allows accounting for heterogeneity across countries, or in this case provinces.

TABLE 2. LIST OF VARIABLES AND DATA SOURCES

Variable	Definition	Data Source
wfcy	Productivity - defined as weighted average food crop yield (kg/ha)	ASP (2005)
Fert	Fertilizer consumption- all food crops (kg/ha)	ASP (2005)
Cred	Agricultural credits advanced per hectare (mill. Rupees)	ESP (2006), ASP (2005)
Tubepub	Number of public tube wells (per ha)	ASP (2005)
Tubpriv	Number of private tube wells (per ha)	ASP (2005)
Lf	Labor force per hectare	FAO (2010); ASP (2005)
Trac	Number of tractors per hectare	FAO (2010); NWFP Statistics, 2010
temp	Average rabi season temperature in °C	WCDC, 2010 FAO, 2010
rain	Average rabi season precipitation in mm	
Drought	Incidence of severe drought, measured as deviations of rainfall from long term normals; <-50%=drought (%)	Khan & Muhammad (2000); FAO (2010); PMD (2010)

Source: Authors' own composition.

The literature on panel data basically proposes two different approaches to estimate the country-specific effects, the random effects (RE) and the fixed effects (FE) approach (Todd, 2007). Using fixed effects to control for the differences between one province and another, the model controls for all the permanent differences between the counties including climate as well as other differences that are hard to measure, however at the same time fixed effects also control for adaptation that farmers have made to adjust to climate. This approach is in principal an ideal method to measure short term responses to sudden changes in weather (Mendelsohn and Dinar, 2009). In order to assure that the assumption holds true and the appropriate model specification is used, a Hausman test is carried out. As the null hypothesis of no correlation between the country-specific effects and the regressors could be rejected, a FE model is considered as the appropriate approach (Greene, 2008). Moreover, in order to detect misspecification problems the modified Wald test for groupwise heteroskedasticity in fixed effect regression models and the Wooldridge test for autocorrelation in panel data have been carried out. In the case of the Wald test the null is homoskedasticity (or constant variance). The null is rejected and

heteroskedasticity is confirmed. In case of the Wooldridge test the null is no serial correlation. The null could not be rejected, thus it is concluded that the data does not have first-order autocorrelation. Consequently, in order to ensure reliable statistical inference robust standard errors are calculated. In order to see if time fixed effects, to control for time effects whenever unexpected variation or special events may affect the outcome variable, are needed a post estimation test is carried out. It is a joint test to see if the dummies for all years are equal to 0, if they are then no time fixed effects are needed. The null that all years coefficients are jointly equal to zero is rejected; therefore time fixed-effects are needed.

The dataset covers the period 1987-2004 for the four provinces. As outlined above several explanatory variables are included in the model, which are chosen upon theoretical consideration. The selection of explanatory variables allows us to isolate the effects of changes in the climatic variables on food crop yield per hectare and thus productivity. Table 3 summarizes the basic descriptive statistics of explanatory variables.

TABLE 3. SUMMARY STATISTICS OF THE VARIABLES (N = 72)

VARIABLE	MEAN	STD. DEV.	MIN	MAX
wfcy (kg/ha)	2018.74	413.318	1279.87	2880.61
fert (kg/ha)	1915.87	119.4303	42.25	553.72
cred (mill.R./ha)	0.05347	0.0861404	0	0.5
tubepub (/ha)	2179.02	2.175202	0.33	9.98
tubepriv (/ha)	3026.27	23.89279	3.81	98.21
lf (/ha)	2201.38	0.590083	1.4	3.57
trac (/ha)	0.0187	0.013376	0.01	0.04
temp (°C)	1669.30	3.885436	9.54	23.18
rain (mm)	2425.87	19.02716	0	81.15
drought (%)	-0.25597	0.5861035	-2.1	1.33

Note: Remaining units are explained in Table 2. Source: Authors' own composition.

As the analysis is specifically interested in the effects of climatic extremes and changes on the food crops wheat, rice and maize, a weighted average yield per hectare was created to serve as the dependent variable in the model. This has been achieved by considering the shares of the individual crops in the total area cropped for food purposes. Moreover, the agricultural employment per hectare is included in the model, by dividing the crop weighted total labor force by the total cropped area for food. In order to include a measure for irrigation, the number of privately owned and publicly provided tube wells has been considered. To better capture the impact of temperature and precipitation on agricultural production, one needs to use the values of those variables during the growing season (Boubacar, 2010). This has been achieved by considering the growing season "rabi". The dataset for constructing the climatic variables has been constructed based on availability of data from meteorological departments for the provinces, thus the Punjab province is modeled as Lahore, Multan, Jhelum and additionally Islamabad/Rawalpindi. The N.W.F.P has been proxied by Peshawar only. For constructing the climate variables for the Sindh province the districts Nawabshah, Hyderabad and Jacobabad have been depicted. Data for the Balochistan province has been created by obtaining data for the districts Quetta, Zhob and Kalat. It has been argued that the average annual value of precipitation is a poor measure of climatic change. It has no meaningful explanation in a cross-country study as an average precipitation in one country is surely not comparable to an average precipitation in another country (Boubacar, 2010). However, in the present study this should not be an issue, for the comparison is between provinces not countries as such. The reference to a dummy variable as a measure of drought has often been applied (see Thiele, 2003). Other authors as for instance Little et al. (2006) have used the subjective assessment of country experts to construct their drought dummy variable. The present

analysis employs an alternative measure for drought which has not been commonly used in previous studies on yield analysis and productivity, namely a drought severity assessment framework created by the estimation of the deviations of rainfall in the period 1987-2004 from the long term precipitation normals in the districts delimited (Sheikh, 2009). In order to test for convergence across the four provinces and to assess the impact of initial productivity levels on the following years the value of weighted food crop yield has been lagged by one year and is chosen as explanatory variable. Finally, to test for the effects of a dry year onto the following years, a lagged value of drought has been included as well.

Results and discussion

The detailed results of the model are reported in Table 4.

TABLE 4. SUMMARY STATISTICS OF THE VARIABLES (N = 72)

Variable	coeff.	Variable	coeff.
Cons	2206.158 (4.77)*	Trac	3958.439 (0.68)
Fert	2.662 (3.48)*	Temp	-43.917 (-2.47)**
Cred	1163.072 (3.4)*	Rain	1.558 (1.10)
Tubepriv	-10.082 (-0.38)	Drought	-89.795 (-1.92)***
Tubepriv	5.862 (2.97)*	Drought (t-1)	-51.887 (-2.18)**
LF	-134.712 (-0.99)	wfcy (t-1)	1209.419 (5.14)*
R-sq:	within = 0.8778 between = 0.1672 overall = 0.3005		
F(27.37)	= 29.60		
Prob > F	= 0.0000	Obs. = 68	
corr(u.i.Xb)	= -0.3249	Groups = 4	

Notes: t-values are reported in parenthesis. Standard errors are robust to heteroscedastic and contemporaneous correlated disturbances. ***, **, and * denote 1%, 5%, and 10% significance level, respectively. Results for time-fixed effects are not reported. Source: Own calculations.

As the analysis has shown, fertilizer use per hectare has a significant positive effect on food crop yields. Thus, one way to cope with yield decrease induced by climate change is to improve the access of the province and especially of the farmers to fertilizer. This will be one key adaptation measure, which will have to be actively assisted and implemented by the respective government agencies. The availability of fertilizer and its effective application, e.g. through strong extension services, will be one key aspect. Furthermore, in order to implement the adaptive measures, the farmers will require a healthy supply of credits devoted to the agricultural sector (Akram et al., 2008; Iqbal et al., 2003). The model clearly shows the significant effect of agricultural credits on the food crops' yields, with a one unit increase in agricultural credits per hectare leading to an increase in food crop yields of about 1100kg per hectare.

The model included a proxy for irrigation as a measure to control for the fact that 90 percent of the major food crop wheat is irrigated. However, the model shows no significant effect on food crop yield for the variable public tube wells per hectare. This is most probably owing to the effect that public tube wells are plagued with the incidence of waterlogging. For particular public tube wells which are uneconomical to repair and

operate, replacing these tube wells with farmer-owned small tube wells appears likely to improve agricultural productivity and reduce government outlays. The model depicts a significant positive effect of privately owned and operated tube wells on farm output. To this effect, operable public tube wells should be kept in service unless they are replaced by equal or greater alternative pumping capacity in the private sector to prevent waterlogging (Chaudhry and Young, 1990). Temperature as shown in chapter 2, in Punjab, Sindh and Balochistan over the last seventeen years has slightly increased only in NWFP a slight cooling has been observed. As the major wheat growing regions have encountered temperature increases, the model clearly indicates a significant negative impact of the temperature variable. In the model considered, a one degree increase in temperature reduces food crop yields by forty four kilos per hectare. The incidence of climatic extremes has been modeled using a measure for drought constructed via precipitation deviations from long term normals. As expected, this variable has a negative significant effect on food crop yields. Pakistan has a long history of droughts e.g., 1974, 1951, 1991-2002, especially the recent drought periods have clearly resulted in significant yield reductions in the areas most vulnerable to drought, such as Balochistan and Sindh. Especially in these years for a vast number of people food insecurity has been the most life threatening issue. The droughts have not only affected people, but also livestock. To test for how drought affects the following- season yields, a lag was included in model, showing that climatic extreme events can have long term effects, as recovery especially in income or monetary terms after a loss-year can be relatively harsh. Vice versa, the lagged variable of weighted food crop yield per hectare shows that higher initial levels of yield positively affect the following year's performance. Although not significant, the model output for the variable labor force per hectare suggests that reduction of dispensable employment in the agricultural sector has a major impact on productivity growth. In the case of farm mechanization results are not significant, but as expected show the correct direction of impact on food crop yields, namely a substantial increase in productivity.

Conclusion

As in many modeling exercises in this paper the idea was to approximate the effects of climatic change and thus extreme events on the agricultural productivity in Pakistan's food crop sector. As a contribution, this paper has developed a panel model for modeling climate change impacts on agriculture in Pakistan. Previous studies have used forecasting models to forecast the development of yields for the years to come, without strictly controlling for factors that might buffer the effect of climate change on agricultural production. This neglect can lead to serious over-or underestimations of the effects of climate change on agricultural output. For this reason, a set of control variables for irrigation and credit were introduced to see if certain existing mechanisms and practices can compensate the losses induced by climatic variability and change. For this reason, the results of the utilized model framework indicate a relatively small negative effect of climate change on the food crop sector, as it is dominated by wheat, which is an irrigated crop in Pakistan. Thus, especially irrigated farming seems to be less affected by climate change.

One key issue requiring a deeper insight is the hydrological cycle of Pakistan, especially the availability of water for irrigation will be a key aspect for determining the future impacts of climate change on yields in Pakistan. For glacial-melt-water fed river systems, the differentiation between long-and short term effects will have to be undertaken. It is particularly important keeping in mind that a developing country like Pakistan will be most probably more suitable for adaptation to climate change than mitigation. However, this remains a controversial issue to be discussed.

Awareness for climate change and its adverse effects for the livelihoods of the population has to be raised and existing adaptive measures have to be used to maximum effect, such as in the case of agricultural credits. The government of Pakistan has to establish schemes that can compensate farmers for their losses, as a consequence of implementing certain

adaptive measures, which might result in income reduction. Adaptation can include new cropping-patterns, introduction of heat and drought resistant crop varieties, water harvesting, especially in years where weather developments are indicating water shortages from precipitation. Nevertheless, in order to implement adaptation strategies successfully, the respective agencies, such as agricultural extension services will have to be strengthened, their outreach will have to be significantly increased. A closer cooperation between government agencies and research institutions will have to be established, to guarantee a thorough understanding of climate change and a consequently a sound scientific basis for the implementation of either adaptive or mitigation measures. In this context good governance will have to be ensured, as any additional obstacle to development will consume valuable resources, which could be devoted to tackling climate change.

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