Adaptation to Climate Change and cotton Productivity: A Microeconomic Analysis

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Adaptation to Climate Change and cotton Productivity: A Microeconomic Analysis

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Submitted By

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To

My

Parents, brother, and sisters

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ABSTRACT

Climate Change is one of the growing and a severe concern that covers all the challenges that are being faced by the human being. Specifically the agriculture sector is affected through the climate change. There is lot of literature on the effect of climate change on agriculture crops, estimation techniques were under great debate and many researchers pointed out the problems present in literature. This study used Climate Change Impact Survey 2013 (CCIS,2013) data collected by Pakistan Institute of Development Economics and applied the Heckman Type Treatment Effect Model to investigate the impact of selected adaptation strategies adopted by cotton growers in isolation and portfolio (combination of two or more) on net revenue gained from cotton production in Pakistan. The implemented strategy input intensification (S-3) has a positive and significant impact on net revenue if adapted as isolated or as a part of combination. Amongst all observed beneficial strategies, those farmers who are found adopting input intensification stand-alone (S-3) are gaining more profits as compared to other strategy adapters. The result shows that the impact of temperature and precipitation depends upon the Phenological stage of cotton crop. There are four stages of cotton crop according to growth namely sowing and germination stage, vegetative stage, flowering and fruit formation stage and last one is boll opening stage. The overall effect of temperature on cotton is positive but impact of precipitation on yield of cotton varies according to growth stage. The results found that land fertility, education, age, land ownership, loan, sources of information and family size are determinants of selection of various adaptation strategies.

Chapter 1

INTRODUCTION

1.1: Background of the Study

Climate Change is one of the evolving and a serious concern in today's world that comprises all the challenges that are being faced by the human/living being i.e. food scarcity, deteriorating ecosystem, losing fresh water reservoirs and increasing health issues. Climate Change impacts are revealing in the form of extreme weather like storms, cyclones, floods, drought escalating as a result of high frequency and intensity.

It is predicted that precipitation will decline in presently semi-arid to arid regions. Reduction in soil moisture in sub humid zones is one of the major effects of climate change that may cause difficulty for water resources of sub humid regions in future.

Heat Waves with high frequency and long durations are predicted in tropical Asia that will enhance the vulnerability of elderly poor population towards serious health issues and hence mortality. In South Asian countries as a result of Global Warming, water borne diseases can become more prevalent (UN-OHRLLS, 2009).

According to the 'Intergovernmental Panel on Climate Change (IPCC)', revealed that the average global temperature is expected to rise in the range of 1.4-5.8^{o}C before the 21st century ends.

Such an exceptional increase in temperature will have destroying impact on hydrological system, ecosystem and agriculture. These effects can be more threatening in tropical region that comprises most of developing countries (Mustafa, 2011).

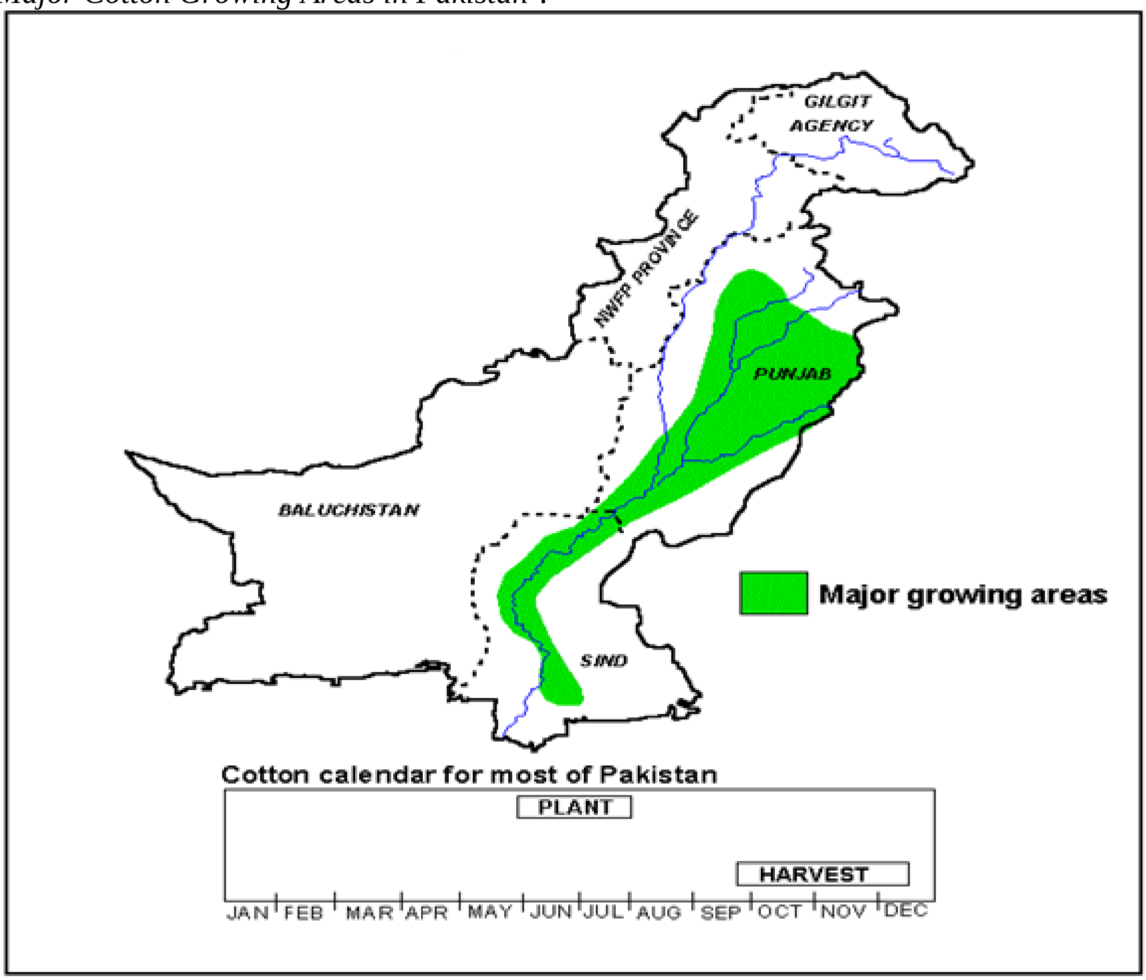
Agriculture Sector with outdoor production actions is one of the major climate-sensitive sectors that depend exclusively on intensity of temperature and precipitation. Climate change has adversely affected the economic performance of the agriculture sector worldwide. Climate change may negatively affect the agricultural productivity by varying the bio-physical structure of crops and resultantly reduction in crop production. Rescheduled the crop sowing periods, increasing stress due to varying irrigation water demand, changing soil characteristics and increasing pests and crop diseases (Shams ul Mulk, 2010).

About 21 percent of total GDP of Pakistan's economy depends on the agriculture sector and 45 percent work force engage in agricultural activities. The agriculture sector in Pakistan comprises of five sub-sectors namely major crops, minor crops, livestock, fisheries and forestry. The major crops (Cotton, rice wheat and sugarcane) contribute 6.5 percent to total GDP where cotton is the non-food crop that is used by textile industries as raw material. Pakistan is the fourth largest producer of cotton in the world (Raza et al., 2012).

Cotton is one of the major cash crops of Pakistan and known as "White Gold". It contributes about 2 percent to GDP and accounts 8.2 percent of the value added in agriculture sector. It's a major source of foreign exchange earnings. Besides, Pakistan is titled as the third largest exporter of cotton and stands second in Yarn export (Azam et al., 2013).

About 26 percent of the total farmer population grows cotton and about 15 percent of the total operated land is devoted to its production. Cotton is mainly produced in two main provinces i.e. Punjab produces 80 percent with dry climate and Sindh produce 20 percent with relatively more humid climate (Nazli et al., 2012).

Major Cotton Growing Areas in Pakistan[1]:



[1] http://www.google.com.pk/imgres?imgurl

Because of Cotton's economic importance it constantly receives substantial status in research and development agenda. Cotton is produced in seventy countries of the world whereas two third of cotton is produced by four major countries that includes USA, China, India and Pakistan (Ashraf Saleem, 2013).

The cotton sector has large variety with respect to unit size, industrial structure and nature of competition. On the one hand there are 1.3 million cotton farms are producing under the perfect competition conditions while on the other hand these farm owners have limited access to required know how and modern technology. At the very basics, it is also sensitive to cultural and governance regulations.

Cotton crop is sensitive to various environmental factors. The primary factor affecting the crop development and growth is temperature. Crops have basic requirements for temperature to complete the whole life cycle. Daily temperature also play an important role in determining the earliest date of sowing, defining season length which can both influence yield potential as well as quality and determine where cotton should be produced sustainably (Luoa *et al*.2013).

Climate change impact cotton yield through increase in atmospheric carbon dioxide (CO_2) concentration, reduced water availability, increased atmospheric evaporation demand (lower humidity) and increase in temperature (Bange, 2007).

Studies report that cotton production level declines as precipitation is decreased and temperature is increased. While other factors such as soil fertility and farming practices have a significant influence on performance of the crop, climate remained the leading factor influencing cotton productivity (Gwimbi and Mundoga, 2010).

It is also reported that in order to offset the adverse effect of global climate change on cotton production, farmers have adopted some strategies i.e. Changing crop varieties and adaptation of soil and water conservation especially for long run changes carried by main climatic variables i.e. temperature and rainfall.

In case of Pakistan most of the research and debates on climate change are based on impact of climate change instead of the role of Adaptation. There is also need to identify the various adaptation strategies implemented by cultivators and analyze the importance of various adaptations approaches and further to differentiate among the successful strategies to be adopted by cotton growers.

1.2: Significance of the Study

The present research seeks to explore the effects and influence of adaptation to climate change on cotton productivity in Pakistan by using farm level data. The study also focuses and analyzes decisions of farmers regarding adaptation by employing various strategies in major climatic variables i.e. temperature and rainfall in long run changes in cotton productivity of Pakistan.

It has been reviewed in literature that agronomic, economic and agro-ecological models have produced authentic results related to agricultural production and climatic variables without incorporating farmer's adaptation strategies regarding climate change in their analysis. The present study analyzes the impact of this adaptation to climate change on cotton production by using Ricardian cross sectional approach that incorporates framers adaptation strategies in isolation and portfolio to climate change.

1.3: Objectives of the Study

This research aims to explore adaptation to climate change on cotton productivity in Pakistan. The main objectives of the study are:

- to analyze the effects of climatic factor, adaptations and other variables on cotton productivity;
- to investigate various socio-economic variable that influence farmers' adaptation decisions;
- to identify various adaptation strategies implemented by cotton growers in response to change in climate change in Pakistan; and
- to suggest policy recommendation based on empirical evidence found in this research.

1.4: Hypotheses

H_0: Climate change has no effect on cotton productivity.

H_1: Climate change has significant effect on cotton productivity.

H_0: Adaptation to climate change has no effect on cotton productivity.

H_1: Adaptation to climate change has significant effect on cotton productivity.

Chapter 2

LITERATURE REVIEW

The idea of David Ricardo (1772-1823) about the land was that the value of land is furtive by the net revenue or net productivity of the land, if the net revenue of land is higher; higher will be its value. Net revenue of land can be estimated by total profit minus total cost. The profit of any crop is affected by the intensity of input use, climatic properties, other socioeconomic variables and private adaptation by farmer. The number of studies has been conducted to analyze the relationship of climate change and crop productivity.

Gorst *et al.* (2015) explored the relationship between the crop productivity and adaptation to climate change in Pakistan using an endogenous switching model. The data used for this study is plot-level data, collected via survey conducted in 2013. The impact of adaptation is estimated for three of the most important crops (wheat, rice and cotton) gowning in Sindh and Punjab provinces. The results are suggestive that for those who actually did adopt, benefits are positive in case of wheat and cotton but not significantly different from zero for rice.

Abid *et al.* (2014) examined farmers' perception regarding adaptation strategies in response to climate change in Punjab, Pakistan. The study is based on data collected from 450 households from the three districts of Punjab, representing major agro-ecological zones of Punjab. They reported that 58 percent farmers' response to climate change are different adaptation strategies which are change in varieties, changing planting periods, plantation of trees, and changing fertilizers. The household characteristics are positively associated with adaptation measures to climate change.

Di Falco (2014) under took a study on Sub-Saharan agriculture to explore the impact of adaptation in response to climate change by using structural Ricardian model. The study employed two stage frame work to explicitly model the underlying endogenous decision by farmers. The study concludes that changing in crop varieties resulted positive and significant impact on net revenue when coupled with water and soil conservation strategies, but its effect is insignificant when implemented in alone. Study results also show that tenure security and access to extension services are important elements of decision to adapt.

Di Falco *et al.* (2012) used Ricardian framework to estimate the impact of climate change on cereal crops in the Nile Basin, Ethiopia. Thin plate spline method of spatial interpolation was used to forecast household specific rainfall and temperature values by utilizing meteorological station data comprised for thirty years across the regions. The results are indicative that adaptation to climate change has a significant impact on farm productivity and farm net revenues. They found that extension services (formal and farmer to farmer) as well as access to credit and having information about future climate changes are key factors of adaptation.

Siddiqui *et al.* (2012) investigated the effect of climate change on major agricultural crops in province Punjab Pakistan by using data for the period 1980-2010. Fixed effect model estimation technique was employed to explore the results. Results are suggested that effect of climate change on wheat crop is positive and negative for cotton, rice and sugarcane.

Di Falco *et al*. (2011) studied whether adaptation to climate change ensure food security or not by using Ricardian model on primary data of Nile Basin, Ethiopia and also analyzed the driving factors behind farm households' adaptation decision to climate change and its impact on farm households' food productivity specifically. Extenuation, access credit to overcome liquidity constraints and information are explored the main factors behind adaptation. They found three results from the study; firstly, farm households group is systematically different in terms of characteristics as compared to households that did not adapt. Secondly, adaptation to climate change increases food productivity. Finally, adaptor's farm household belongings have some characteristics that assure them food security even without any adaptation strategy.

Deressa *et al.* (2011) used the Hackman sample selection model to examine the factors that affect farmers' decisions to climate change adaptation in Nile Basin, Ethiopia. Results are indicative that farmers' adaptation to climate change decisions are related to age, household head's education and age, size of the household, wealth, knowledge of climate change, livestock ownership, access to credit services and extension .

Shakoor *et al.* (2011) explored the impact of climate change on arid agriculture region by using Ricardian Approach. They used household level data to estimate relationship between net farm revenue and climatic variable while controlling for the effect of other socio-economic variables. The results suggested increase in temperature has significant negative impact on agriculture production. Overall, extent of temperature's negative impact is higher than the rainfall's positive effect in the region.

Drine (2011) investigated the climate variability and agricultural productivity in Middle East and North Africa (MENA) region using panel data regarding 11 countries of the region over the period 1980-2007. The study used the nonparametric Malmquist DEA method to estimate the total factor productivity in agriculture. The Bio-physical conditions (the current agricultural productivity to extent that technological progress), socio economic conditions and state of technology are the main factors behind the vulnerability to climate change in the specific region. A small reduction in rainfall, extreme events such as drought and heat waves caused decrease in agricultural production resulted food supply shortage, particularly for small landholders in rural areas. Study suggests that the use of tractors and fertilizers help to improve the agricultural productivity.

Ekpoh (2010) studied the rural farmers' adaptation to impact of climatic variations on agriculture in North-Western Nigeria. The study used the methods for estimation was in two directions. The first modeling use to estimate the relationship between climatic variation and crop production. The second involved farm surveys to elucidate information from farmers on adaptive strategies to climate change. A combination of these methods provided information on both the sensitivity of crop production to climatic variations and cropping strategies implemented by farmers in North Nigeria. The result indicates that rainfall has positive relationship with crop yield with 70 percent variations in the region. The North Nigerian rural farmers are quite innovative while response towards drought adaptation.

Di Falco *et al.* (2009) used pseudo Fixed effect and 2-stage least square model to control unobserved heterogeneities and endogeniety and analyzed the factors affecting climate change adaptation strategies and explored the impact of climate change adaptation on food production by using primary data of 1000 farm households from the Nile Basin, Ethiopia. They identified three adaptation strategies named as changing crops, adopting soil conservation planting trees. They found that adaptation has a positive and significant effect on crop production.

Yesuf et al. (2008) measured the impact of climate change on food production in developing countries context and investigated the factors of adaptation to climate change and implication of adaptation strategies for farm productivity. The analysis based on the primary data suggested that climate change and adaptation have significant effect on food production in developing countries. Extension services, credit access, information about future climate change affect adaptation positively and significantly.

Kurukulasuriya and Mendelsohn (2008a) examined the impact of climate change on crops in Africa by employing Ricardian Model and using data collected from a sample of 5000 farmers, across 11 countries in Africa. Results indicate that crop choice is highly sensitive for temperature and precipitation. Farmers choose such crops from their crop choices which are suitable to the local conditions. The study resulted that farmers chose some crop combinations to survive harsh condition in Africa. These combinations deliver the farmers flexibility across climates better then growing a single crop on its own.

Kurukulasuriya and Mendelsohn (2008b) used the Ricardian analysis to examine the impact of climate change on African cropland. This results based on data collected from 9000 African farmers belonging to 11 African countries suggest that farm values decreased with increase in temperature. Temperature and precipitation elasticity is estimated -1.3 and 0.4 with respect to net revenue of African farms respectively.

Kurukulasuriya and Ajwad (2007) used Ricardian approach to calculate the impact of climate change on small landholder farming in Sri Lanka. They found that climate change has a significant effect on small landholder profitability. The results suggest that with mild warming and large increase in precipitation, predicted losses would be 23 percent.

Benhin (2006) applied Ricardian approach to estimate the impact of climate change on South African agriculture. The results are suggestive that climatic variable especially precipitation, has non-linear relationship with crop net revenue in South Africa. However there are seasonal differences in the climate effects. Increased temperature is harmful in summer and beneficial in winter season. The analysis also shows that effects of changing temperature and precipitation may vary for different farming system in the same country. Adaptation has a significant positive impact for dry land farms.

Reddy K. R. *et al.* (2002) studied the impact of climate change on cotton production in Mississippi Delta by utilizing simulation techniques. They concluded that overall 9 percent decrease in cotton yield is obtained for future climate. The projected temperature and rainfall are the most important climatic factors affecting cotton production. High temperature hastened development and shortened the growing period by up to 11 days.

Mendelsohn *et al.* (1996) measured the impact of climate change on aggregate farm value accounting for adaptation .They found a hill-shaped relationship between aggregate farm value and temperature with the maximum attained at temperature of 63^0 F.

From the review of the studies regarding the subject it can be concluded that three major approaches namely agronomic model, crop suitability model and Ricardian cross-sectional model have been used to estimate the impact climate change and adaptations to climate change on agriculture. The brief descriptions of these models as well as the strengths and weaknesses/limitation of each model are presented in the next chapter.

Chapter 3

THEORETICAL FRAMEWORK

Three basic approaches have been used during previous few decades to estimate the effect of climate change on agriculture: these approaches are agronomic models, agro-ecological models or crop suitability models and Ricardian cross section models and their strength and limitation are given below.

3.1: Agronomic Models

These types of investigative models make to apply of well-calibrated crop models from carefully controlled experiments in which crops are grown in laboratory setting that simulates diverse climates and intensity of carbon dioxide(Mano & Nhemachena, 2007).To make sure that all variations in variable of interest crosswise experimental situation can be allocated to the climatic factors that are being examined (carbon dioxide temperature and precipitation), no inconsistency is acceptable in farming methods. Such models have limitations such as its failure to incorporate farmers' adaptation response to changing climate.

3.2: Crop Suitability Models

This model also called the agro-ecological zoning model. The agro-ecological zoning models analyze changes due to climate change in agro-ecological region and crops and calculate the alternative impact of climate scenarios on crop yields. Although the economic models calculate supply and market effects by using the yields changes(Mano and Nhemachena, 2007). The climate change scenarios can be comparatively simple stories of consistent changes crossway a country. They can include difficult geographic distributions of changes. As an end result most impact studies observe multiple climate scenarios (Mendelsohn and Dinar, 1999).The disadvantage of the agro-ecological zone models is that it is not feasible to calculate ultimate results without explicitly including all the related components and hence the exclusion of one important factor would significantly influence the methodology’s predictions(Mendelssohn andTiwari, 2000).

3.3: Ricardian Cross-sectional Model

Cross-sectional models calculate farm value across climatic zones [(Mendelsohn and Dinar (1999); Mendelsohn et al. (1994); Mendelssohn and Tiwari (2000); Sanghi (1998))].The Ricardian approach is the general cross-sectional technique that has been used to estimate the effect of climate change on agriculture sector. This technique was named after “David Ricardo” as of his creative observation that land rents would reproduce the net output of farmland. The Ricardian cross-sectional technique investigates a cross section of farms under diverse climatic conditions and analyses the association between the value of land or net revenue and agro-climatic feature(Mendelsohn et al., 1994). The method has been used by regressing net revenue or land value on climatic factors(along with other socioeconomic variables) to assess the contribution that climatic factors make to farm income, along with other socio-economic variables and thus examining the marginal contribution that each input makes to farm income. Net revenue or price of land can be used as dependent variable. Mendelsohn et al. (1994) used both net revenue and land value, while Polsky and Easterling (2001) included only land value as the dependent variable in their studies to show the impact of climate change on agriculture in the United States. Moreover, Sanghi (1998)used land value for Brazil and Indian agriculture to check the impact of climate change.

The plus point of Ricardian approach is that it has capacity to integrate private adaptations. Due to increase in their profit through increased production, farmers adopt certain adaption strategies in order to cope with climate change. The farmers' reactions involve expenditures that are reflected in net revenue. Hence, the net revenue or land value should be the variable (not yield) to check the cost and benefits of private adaptation by farmers. For that reason, the Ricardian approach incorporate the adaptation by taking account the economic damages inform of decreasing net revenue and land value due to climatic factor. The other plus point of Ricardian approach is that it is cost effective, since secondary data on cross-sectional sites can be relatively easy to collect on climatic, production and socio-economic factor (Deressa, 2007).

The standard Ricardian model relies on a quadratic formulation such as given below:

$NR = \beta + F\alpha + F^2\gamma + Z\delta + G\,\gamma + u$

Where:

NR = net revenue per acre

F = vector of climate variables

Z = vector of soil variables

G = vector of socioeconomic variables

u = error term

Agronomic and crop suitability models generate reliable outcomes concerning agricultural production and climatic factors. On the other hand, these techniques not only complicated and have high requirements they also integrate private adaptation to changing climate in their study as an exogenous variable although it is not an exogenous.

There are many factors that affect the farmer's decision whether to adapt (dummy variable D=1 if farmer adapts) or not to adapt (D=0 otherwise). As such, the dummy of adaptation decision is an endogenous variable and should be modeled directly; or else the regression examining the impact of dummy variable will be biased.

Ricardian cross-sectional model is easy and includes private adaptations resulting to climate change, this method is used to calculate the economic impacts of climate change by dealing adaptation as an endogenous variable(Mano & Nhemachena, 2007). The decision to adapt is based on self-selection. The approach for correcting the selection bias was pioneered by Heckman (1974, 1978, and 1979) known as the sample selection model.

3.3.1: Sample Selection Model

The sample selection model by Heckman was developed via an econometric frame work for managing limited dependent variables. Maddala (1983) developed the sample selection perception to the valuation of treatment effectiveness. This model is among the most important contributions to program evaluation; however the treatment effect is partial solution of various types of evaluation problems.

Since development of the sample selection model researchers have formulated many new models and estimators commonly known as Heckman-type Treatment Effect Models or "Heckit" Models. The more important development of these models is direct application of this model to evaluation of treatment effects in observational research studies. The approach is named as Treatment Effect Model.

The Treatment Effect Model always involves two equations: i) the regression equation or outcome equation, determining the outcome or dependent variable and ii) The selection equation that determines the selection process. It is important to note that in Sample Selection Models the outcome variable of regression equation is observed only for which the dummy variable indicating treatment condition takes value of one (the data on outcome variable is not observed for values of dummy equal to zero). The CCIS, 2013 contains information on relevant variables for adapting as well as non-adapting farm households therefore the Treatment Effect Model is the most suitable model for the analyses of impact of adaptation to climate change on cotton productivity.

Chapter 4

DATA AND METHODOLOGY

This chapter gives details about the data and methodology adopted. This Section covers the survey data description; geographic and climatic information about the study area of survey overlooked the description of explanatory variables and covers the methodology of the study.

4.1: Data Sources

This study used data from two sources: 1) Data regarding climatic factors (temperature and precipitation) obtained from Pakistan Meteorological Department (PMD) and 2) Climate Change Impact Survey2013 (CCIS, 2013) data collected by Pakistan Institute of Development Economics, Islamabad under the project "Climate Change, Agriculture, and Food Security in Pakistan: Adaptation Options and Strategies". The total sample size of CCIS, 2013 consists of 3430 farm households belonging to 16 randomly selected districts from Punjab, Sindh, and Khyber Pakhtunkhwa (KPK) provinces of Pakistan. The selected sample represents various categories of farms (by size and tenancy), cropping patterns, and variations in agro climatic conditions. In order to save the financial and time costs, instead of selecting sample farm household in selected districts by listing down all the farm households in the districts and then selecting farm households through random procedure, twelve villages were selected randomly in each of the sampled district and then farm households were selected from each village.

The sample includes 1206 cotton growers belonging to 7 districts from Punjab and Sindh province of Pakistan. These farming households make the sample for the current study.

The district wise distribution and composition of the sample by tenancy status is given in the following table.

Table 4.1

Distribution of Sample Cotton Growers by District and Tenancy:

Province	**Tenants**	**Ownership**	**Total sample**
PUNJAB	**69**	**550**	**619**
Bahawalpur	21	194	215
Vehari	24	190	214
Jhang	11	79	90
Bhakkar	13	87	100
SINDH	**282**	**303**	**587**
Nawabshah	91	83	174
Mirpurkhas	94	96	192
Sanghar	97	124	221
Total	**351**	**853**	**1206**

Source: Climate Change Impact Survey 2013

The collected information includes data regarding household profile and farm characteristics; cotton production practices inputs used, yields realized and prices etc., farmer's perceptions about climate change and adaptation strategies adopted by them to mitigate the adverse effects of climate change.

The climatic data (temperature, rainfall) obtained from PMD was mapped with farm level data by using village level longitude and latitude information.

4.2: Description of the Study Area

This study has been done randomly selected districts of Punjab and Sindh provinces of Pakistan. These selected districts from Punjab include Bahawalpur, Bhakkar, Vehari, and Jhang. The selected districts from Sindh are Nawabshah, Sanghar, and Mirpurkhas. The profiles of selected districts are given in the following sub-sections.

4.2.1 Bahawalpur

The district of Bahawalpur has a population of 2.43 million and a population density of 98 persons per square kilometers. Bahawalpur is located between 29.39℃ N latitudes and 71.68 ℃ E longitudes, in southern part of Punjab province of Pakistan. Area of Bahawalpur district is 24830 square kilometers. The important crops produced in the district include wheat, sugarcane, cotton, gram and dates. The Bahawalpur district in summer has very hot and dry climate and winter of Bahawalpur is dry and cold. The highest temperature goes up to 48℃ and lowest temperature goes down to 7℃ . Wind and dust storms are normal in summer. On average the recorded rainfall is 168 mm in Bahawalpur. (Malik, 2009a).

4.2.2: VEHARI

Vehari district has an area of 4,364 square kilometers and is located between 30.04℃ N latitudes and 72.35℃ E longitudes in Punjab province. The district is the home of 2.09 million persons with a population density of 479 persons per square kilometers. The climate of Vehari district is hot and temperature reaches 48.7 ℃ in summer and in winter falls below freezing point. The recoded rainfall is about 127 mm on average. It has good fertile land. The main crops grown in the district under irrigation conditions include sugarcane, cotton, wheat, maize, rice (Malik, 2009d).

4.2.3: BHAKKAR

The district Bhakkar is spread over 8153 square kilometers and is a home of 1.05 million people of Punjab. The population density of Bhakkar stands at 129 persons per square kilometer. The district is geographically located between 31.62℃ N latitudes and 71.06℃ E longitudes. Bhakkar district has extreme hot and cold climate. In summer temperature of Bhakkar may cross 50℃ . The land largely comprises plane and deserts. The crops grown in Bhakkar include wheat, gram, sugarcane, cotton, and mustard etc. (Malik, 2009c).

4.2.4: JHANG

Jhang district of Punjab is located between 31.26 ℃ N latitudes and 72.31 ℃ E longitudes. The geographic area of district Jhang is 8809 square kilometers. It has population of 2.83 million with a population density of 322 persons per square kilometers. It has hot and dry climate in summer, cold and dry in winter. The district Jhang is characterized by mixed cropping system growing crops like sugarcane, maize, cotton, rice, and gram (Malik, 2009b).

4.2.5: SANGHAR

Sanghar is included in the list of the largest districts of Sindh province of Pakistan and has a population of 1.45 million people. It is located between 26.00℃ N latitudes and 69.25℃E longitudes. The distirict is principally an agrarian district and except a small portion the rest of district land is quite fertile. The main crops grown in Sanghar are wheat, rice, sugarcane and cotton. The climate in summer is dry and hot (43℃) while winters are dry and cold (6℃). Sanghar receives quite a low annually average rainfall (12 mm).

4.2.6: MIRPURKHAS

Mirpurkhas district of Sindh province starches over an area of 2925 square kilometers and is a home of 0.91 million people. The population density of the district stands at about 310 persons per square kilometers. The main crops grown in Mirpurkhas are wheat, corn, sugarcane and cotton.

4.2.7: NAWABSHAH

Nawabshah is also included in our study area, another district of Sindh province. The geographical area of Nawabshah is 4502 square kilometers and population of the district is 1.07 million people. The district has a population density of 238 persons per square kilometers. The main crops grown in Nawabshah are rice, sugarcane and cotton.

4.3: Description of Variables

The variables used in the analyses are education, age, crop area, operational area, ownership of land, average fertility, good fertility, poor fertility, dummy variables for loan access, and dummies for government extension, and other formal and informal sources of information and variables related descriptions in brief are listed in the following table.

Table 4.2

List of explanatory variables

Variables	Symbols	Descriptions
Net revenue	NR	The net revenue of cotton growers per acre in PKR
Farmer and Farm characteristics		
Education	Edu	Education of household decision maker in completed school years
Age	Age	Age of the household's decision maker in years
Crop area	CA	Area of the farm under cotton crop (acres)
Operational area	OP	Farm area operated by the sample household (acres)
Land ownership dummy	OW	Dummy=1 if farmer has a title to operated farm land or to part of it, 0 otherwise
Fertility average	FA	Percent area of operational holding having average soil fertility
Fertility good	FG	Percent area of operational holding having good soil fertility
Fertility poor	FP	Percent area of operational holding having poor soil fertility
Family size	FS	Total number of members in the household.
Loan access	LA	Dummy=1 if the farm household availed any kind of loan informal or formal , 0 otherwise
Government extension	GE	Dummy=1 if extension department is the only source of technical information available to the farm household, 0 otherwise
Formal information	FI	Dummy=1 if farming household get information about weather from formal sources
Traditional knowledge	TK	Dummy=1 if farmer use the

		traditional knowledge about weather information
Climatic factors		
May_t_20year	TM_{20}	Average of mean temperatures of May in last 20 years (^{0}C)
June_july_t_20year	TJJ_{20}	Average of mean temperatures of June and July in last 20 years (^{0}C)
Aug_sep_t_20year	TAS_{20}	Average of mean temperatures of August and September in last 20 years (^{0}C)
Oct_t_20year	TO_{20}	Average of mean temperatures of October in last 20 years (^{0}C)
May_p_20year	PM_{20}	Average of precipitation of May in last 20 years (mm)
June_july_p_20year	PJJ_{20}	Average of precipitation of June and July in last 20 years (mm)
Aug_sep._p_20year	PAS_{20}	Average of precipitation of August and September in last 20 years (mm)
Oct_p_20year	PO_{20}	Average of precipitation of October in last 20 years (mm)
May_t_20year deviation	$devTM_{20}$	Deviation of May temperature from average of last 20 years
June_july_t_20year deviation	$devTJJ_{20}$	Deviation of June and July temperature from average of last 20 years
Aug_Sep._t_20year deviation	$devTAS_{20}$	Deviation of August and September temperature from average of last 20 years
Oct_t_20year deviation	$devTO_{20}$	Deviation of October temperature from average of last 20 years
May_p_20year deviation	$devPM_{20}$	Deviation of May precipitation from average of last 20 years
June_july_p_20year deviation	$devPJJ_{20}$	Deviation of June and July precipitation from average of last 20 years
Aug_Sep_p_20year deviation	$devPAS_{20}$	Deviation of August and September precipitation from average of last 20 years
Oct_p_20year deviation	$devPO_{20}$	Deviation of October

		precipitation from average of last 20 years
InterM_20	$InterM_{20}$	Interaction term (20 year Avg. of May temperature) * (20 year Avg. of May precipitation)
InterJJ_20	$InterJJ_{20}$	Interaction term (20 year Avg. of June and July temperature) * (20 year Avg. of June and July precipitation)
InterAS_20	$InterAS_{20}$	Interaction term (20 year Avg. of August and September temperature) * (20 year Avg. of August and September precipitation)
InterO_20	$InterO_{20}$	Interaction term (20 year Avg. of October temperature) * (20 year Avg. of October precipitation)
S-i		Is i^{th} adaptation strategy(S-i) as describer in Table 4.3

The adaptation strategies adopted by the cotton growers were divided into four groups namely varietal change (S-1), change in sowing time (S-2), input intensification (S-3), and soil and water conservation (S-4). Thus in total 15 mutually exclusive of adaptation strategies are possible when implemented in isolation or adopted in portfolios that combine two or more strategies. Various possible adaptation strategies (isolated or portfolios) are described in following table.

Table 4.3

Climate Change Adaptation Strategies:		
Strategy No.	**Strategy**	**Description**
1	Changing cotton varieties(S-1)	Dummy=1 if the farm household only changed crop varieties(i.e. planted drought tolerant varieties, planted short/long cycle variety, and stopped growing a variety etc.) as adaptation strategy, 0 otherwise
2	Change in sowing time of cotton (S-2)	Dummy=1 if the farm household only adapted change in cotton sowing time as adaptation strategy, 0 otherwise
3	Changed inputs use(seed and fertilizer) (S-3)	Dummy=1 if the farm household only adapted changed inputs use (changed seed rate and fertilizer use) as adaptation strategy, 0 otherwise
4	Water and soil conservation strategies (S-4)	Dummy=1 if the farm household only adapted water and soil conservation strategies (i.e. changed number of irrigations, changed time of irrigation, built a water harvesting scheme, laser leveling, deep tillage, manuring, changed crop rotation, introduced intercropping and liming) as adaptation strategy, 0 otherwise
5	Changing cotton varieties and sowing time (S-12)	Dummy=1 if the farm household only adapted changing cotton varieties and cotton sowing time as adaptation strategies, 0 otherwise
6	Changing cotton varieties and changed input use(S-13)	Dummy=1 if the farm household only adapted changing cotton varieties and water

		and soil conservation strategies as adaptation strategies,0 otherwise
7	Changing cotton varieties and water and soil conservation strategies (S-14)	Dummy=1 if the farm household only adapted delayed cotton sowing and water and soil conservation strategies , 0 otherwise
8	Delayed cotton sowing and changed input use(S-23)	Dummy=1 if the farm household only adapted change in cotton sowing time and changed inputs use as adaptation strategies, 0 otherwise
9	Delayed cotton sowing and changing water and soil conservation strategies (S-24)	Dummy=1 if the farm household only adapted change in cotton sowing time and water and soil conservation strategies as adaptation strategies, 0 otherwise
10	Changed inputs use and adopted water and soil conservation (S-34)	Dummy=1 if the farm household only adapted changed inputs and water and soil conservation strategies as adaptation strategies, 0 otherwise
11	Changing cotton varieties, delayed cotton sowing and changed inputs use (S-123)	Dummy=1 if the farm house hold only adapted changing cotton varieties, cotton sowing time and changed inputs use strategies as adaptation strategies,0 otherwise
12	Changing cotton varieties, delayed cotton sowing time and water and soil conservation strategies (S-124)	Dummy=1 if farm household only adapted changing cotton varieties, cotton sowing time and water and soil conservation strategies as adaptation strategies, 0 otherwise
13	Changing cotton varieties, changed inputs use and water and soil conservation strategies	Dummy=1 if farm household adapted changing cotton varieties, changed inputs use and water and soil conservation

	(S-134)	strategies as adaptation strategies, 0 otherwise
14	Delayed cotton sowing , changed inputs use and water and soil conservation strategies(S-234)	Dummy=1 if farm household adapted change in cotton sowing, changed inputs use and water and soil conservation strategies as adaptation strategies, 0 otherwise
15	Changing cotton varieties, delayed cotton sowing time, changing inputs use and water and soil conservation strategies(S-1234)	Dummy=1 if farm household adapted changing cotton varieties, cotton sowing time, changing inputs use and water and soil conservation strategies as adaptation strategies, 0 otherwise

The construction of certain variables listed above need more details and the same is presented in the following.

Net Revenue

The net revenue is defined as the difference of total revenues (cotton price x cotton yield) and variable costs per acre involved in production of cotton (seed, labor, fertilizer, rental cost of tractor and other machines, and pesticides/weedicides etc.)

Government Extension

If the farmer responded that government provides information services about cropping pattern, irrigation, soil quality, weed control, planting methods, crop residue incorporation, intercropping, new/improved varieties etc. the dummy variable (government extension)takes value equal to one and zero otherwise

Formal Information

If the farming household gets information about weather from formal sources like radio, newspaper, television and department of agriculture then the dummy formal information takes value of one and zero otherwise.

Temperature and Precipitation

The climatic variables (temperature and precipitation) were defined for each growth stage of cotton crop as the average over the period (months) representing that growth stage. The growth stages division comes from assumption of (Schlenker & Roberts, 2008) that the impact of temperature is comparative to plant growth is accumulative over the time and thus production is proportional to total growth. The effect of climate is preservative over the life length of plant. Crop production is generally sensitive to temperature and precipitation variation. Climatic factor effects the 60 percent production of cotton(Deshmukh and Lunge, 2012). Even though temperature norms values are usually not vary too much during cotton production season but optimum temperature does change for each growth stage. According to Tsiros (2008) cotton crop can be divided into growth stages according to the phenological properties of cotton crop. This study used the 20 year average (1994 to 2013) of temperature and precipitation and divided the cotton crop into four growth stages. The growth stages of cotton crop developed using the reaction of cotton (Gossypiumhirustum) to temperature change (K. Reddy et al., 1992).Growth stages of cotton crop consist of the following phenological stages.

Sowing and Germination Stage

Punjab and Sindh are the major producer provinces of cotton crop in Pakistan. Punjab and Sindh both have the characteristics of low precipitation and high temperature. In the growing and sowing temperature for cotton crop is nearly same. Cotton sowing usually starts from the May and at the highest peak in the second fortnight of the month. Cotton crop is not much responsive in 1st three days of sowing after that sensitivity of cotton increases up to certain limit.

Vegetative Growth Stage

Vegetative stage consist of the development of stem and augmentation of leave, this growth stage need the moderate temperature and humidity, high temperature and humidity will results in leaves flaking and pest attack on the plant. This stage extends from June to July. The conditions of climatic factors during these months have significant effect on production of cotton crop.

Flowering and Fruit Formation Stage

This stage is also important stage for attaining the high production of cotton crop which consists of flowering, boll formation and lint configuration. At this stage cotton needs a moderate temperature and less precipitation. In this stage plants are more prone to pest attacks. Increase in temperature and precipitation will result in flower and boll flecking adversely affecting the crop yields. This stage covers the months of August and September.

Boll Opening Stage

In this stage involve the procedure of boll opening and picking of the crop. Lint feature is highly effected by the temperature there fore at this stage crop generally requires modest temperature about 27 to 30 ^{0}C. Exposure of crop to high temperature normally causes the decline in the yarn length and thus overall value of crop. This stage mainly covers the month of October.

4.4: Econometric Model

This study has used treatment effect model to estimate the impacts of adaptation on net revenue or productivity of cotton farms in Pakistan. Decision to climate change adaptation and its implication in term of crop productivity can be modeled in setting of two equations frame work.

4.4.1: Specification of Treatment Effect Model

The researchers have added many improvements in the sample selection models since its development [Maddison (2006) and Tessoet.al(2012)].Greene (2003)referred these additions in sample selection models as "Hecket" Models. The most important development was the use of sample selection model to estimate the effect of treatments. The Treatment Effect Model (TEM) has advantage on sample selection model in two ways: 1) a binary variable representing the treatment situation (i.e. if adaptor is in treatment situation or non-treatment situation) is directly entered into regression equation and 2) outcome variable of regression equation is examined for both adapter and non-adapter. Importance of treatment effect model can be stated in two equations as in original Heckman sample selection model:

Outcome or Regression equation: $NR_i = X_i\beta + A_i\delta + \varepsilon_i$ (1)

Where i represents the i^th^ cotton farm; N*R* is dependent variable which is net revenue; X symbolize the vector of inputs (e.g., climatic variable, farmers characteristics, soil characteristics, and other socio-economic variables); β is the column vector of parameters; A is a dummy variable coming from selection/treatment equation and assigned value of 1 if $A_i^* > 0$ and $A_i = 0$ otherwise; δis coefficient of adaptation which is also known as Average Treatment Effect (ATE)[2], and it is suggestive average difference of outcome (net revenue) between adapters and non-adapters; and ε is the error term of outcome equation.

The treatment equation is specified as below

Treatment equation $$A_i^* = z_i\gamma + u_i \qquad (2)$$

With A=1 if $A_i^* > 0$ and $A_i = 0$ otherwise

And Prob $(A_i = 1 \mid z_i) = \varphi(z_i\gamma)$ and Prob $\left(A_i = 0 \mid z_i\right) = 1 - \varphi(z_i\gamma)$

In above equation, Z_i is vector of variables which have influence on cotton growers' decision to adapt to climate changes and includes variables such as age, education, family size, operational land area, access to loan, soil fertility, access to government extension, , and (formal and informal) sources of weather information; and γ is a vector of coefficients. The error terms ε_i and u_i are bivariate normal with mean zero and covariance matrix= $\begin{bmatrix} \sigma_\varepsilon & \rho \\ \rho & 1 \end{bmatrix}$

One important assumption of this endogenous binary treatment effect model is there must be joint correlation between error terms of both outcome equation and treatment equation because validity of this assumption confirms of being endogenous treatment effect model. This assumption will be tested by applying Wald chi-square (χ^2) independence test where null hypothesis is both error terms are independent. Rejection of null hypothesis will confirm that assumption of being endogenous holds.

The empirical outcome and treatment selection equations are specified in the following.

[2] It is measured by the difference of observed potential outcome (net revenue) means of treated (adapters) and non-treated (non-adapters).

Outcome equation

$$NR = \beta_0 + \beta_1 CA + \beta_2 LA + \beta_3 Age + \beta_4 Edu + \beta_5 FA + \beta_6 FG + \beta_7 TM_{20} + \beta_8 TJJ_{20}$$
$$+ \beta_9 TAS_{20} + \beta_{10} TO_{20} + \beta_{11} PM_{20} + \beta_{12} PJJ_{20} + \beta_{13} PAS_{20} + \beta_{14} PO_{20}$$
$$+ \beta_{15} devTM_{20} + \beta_{16} devTJJ_{20} + \beta_{17} devTAS_{20} + \beta_{18} devTO_{20}$$
$$+ \beta_{19} devPM_{20} + \beta_{20} devPJJ_{20} + \beta_{21} devPAS_{20} + \beta_{22} PO_{20}$$
$$+ \beta_{23} interM_{20} + \beta_{24} interJJ_{20} + \beta_{25} interAS_{20}$$
$$+ \beta_{26} interO_{20} + A_i \ldots. (4.1)$$

Treatment equation

$$A_i = \gamma_0 + \gamma_1 OP + \gamma_2 LA + \gamma_3 Edu + \gamma_4 Age + \gamma_5 FS + \gamma_6 OW + \gamma_7 FA + \gamma_8 FG + \gamma_9 GE$$
$$+ \gamma_{10} FI + \gamma_{11} TK \ldots (4.2)$$

The above equations were estimated for all standalone and portfolio strategies (15 mutually exclusive models). All variable is same for all models except A_i which represent different adaptation strategies.

Chapter 5

RESULTS AND DISCUSSION

Treatment Effect Model was estimated by using STATA 13. The dependent variable in outcome equation is net revenue per acre gained from cotton production. In total 15 models (for fifteen adaptation portfolios) were estimated. Out of these 15 mutually exclusive combinations only seven strategies (in isolation and in portfolios) are found having significant impact. These strategies include S-1, S-3, S-4, S-14, S-34, S-234 and S-1234. The strategies and the number of farmers who adopted those strategies are given below:

Table 5.1

Strategies and Number of Adopters

Strategies	Adopters	Strategies	Adopters
S-1	43	S-34	109
S-3	42	S-234	11
S-4	56	S-1234	159
S-14	41		

Hence, these seven strategies are used to describe the results and find the impact of adaptation of respective strategies on net revenue of cotton growers.

5.1: Impact of Adaptation on Net Revenue

The treatment score resultant of Treatment Effect Model tells about the impact of adaptation in response to climate change on net revenue of cotton growers either positive or negative. The results from treatment effect model indicate that all the seven models estimated are fitted good as shown by Wald chi-square statistics which are significant in all models. The results indicate that varietal change(S-1), input intensification(S-3), soil and water conservation (S-4) have a significant and positive impact on net revenue when adopted in isolation. The portfolio strategies S-14(varietal change and soils and water conservation), S-34 (input intensification and soil and water conservation), S-234 (change in sowing time, input intensification, and soil and water conservation) and S-1234 (all the adaptations) also have a positive and significant effect on net revenues earned from cotton production.

The treatment scores of all adopted strategies are given below that shows the increase in net revenue in PKR/acre.

Table 5.2

Strategies and Gain in Net Revenue (PKR/Acre):

Strategies	**Scores**	**Std. error**	**P-values**
(S-1)	29850.6	3375.70	0.000
(S-3)	41727.6	1862.89	0.000
(S-4)	21616.9	6668.04	0.000
(S-14)	34432.0	2545.83	0.000
(S-34)	25958.3	2357.26	0.000
(S-234)	27546.4	3913.38	0.000
(S-1234)	27764.0	2447.17	0.000

The results are suggestive that cotton growers gain in net revenue on average by adopting strategies (S-1, S-3, S-4, S-14, S-34, S-234 and S-1234). When strategies namely varietal change (S-1), input intensification (S-3) and soil and water conservation (S-4) have a significant and positive impact on net revenue when adopted in isolation and increases the net revenue by PKR29851/acre, PKR41728/acre, and PKR21617/acre on average respectively. On the other hand result also shows that when these strategies implemented as a part of portfolio combining varietal change and soil and water conservation (S-14) increases net revenue of farmer byPKR34432/acre on average. Similarly, combination of input intensification and soil and water conservation (S34) increases the net revenue of cotton growers by PKR25958/acre on average. The strategy (S-2) change in sowing time has no significant impact on net revenue when adopted in isolation but when implemented as a part of portfolio combining changing sowing time, input intensification and soil and water conservation(S-234) resulted in increase of the net revenues by PKR27546/acre on average. Similarly, S-2 as part of the strategy S-1234 is also beneficial for cotton growers. This strategy increased the net revenue of adoptersPKR27764/acre on average.

5.2: Impact of Climate Change on Net Revenue

The results of the outcome equation and the treatment/selection equation are listed in Table 5.3. Net revenue is the dependent variable in the outcome equation while the explanatory variables include adaptation dummy, climatic factors, and other socio-economic variables. The treatment or selection equation has farm and farmer characteristics and other socio-economic variables among the independent variables.

Table 5.3: The Direction and Significance of Various Variables Included in Outcome Equations and Treatment Equations. Dependent Variable: Net Revenue (PKR/acre)

Independent Variables	**Strategies**						
	(S-1)	**(S-3)**	**(S-4)**	**(S-14)**	**(S-34)**	**(S-234)**	**(S-1234)**
CA	40.0	62.2	43.1	38.1	20.9	42.4	51.9
LA	-4673.6***	-3266.3**	-3430.7***	-5389.9***	-3940.5***	-4846.0***	-7227.0***
Age	0.4	6.6	-10.8	-22.9	-36.8	2.5	-43.2
Edu	-18.6	-20.6	22.2	-25.1	-97.3	-9.4	-138.5
FA	3.3	12.1	-6.2	-2.5	-35.3	-1.3	-19.7
FG	12.0	28.4	13.7	18.5	30.9	24.7	19.4
TM_{20}	-979.3	-2771.9	-1611.2	-4729.9	-69.2	-4850.6	-6223.9
TJJ_{20}	10778.0**	11472.5**	11532.1**	14729.9***	9791.7**	9033.1**	8577.0*
TAS_{20}	-5572.1	-6621.3	-5889.2	-7859.1	-4403.5	-260.3	-1658.0
TO_{20}	16304.4***	14561.6***	15682.7***	15761.1***	15430.5***	14814.5***	14572.3***
PM_{20}	-39571.5**	-34683.6**	-39669.3**	-48174.1***	-37906.6**	-43315.9***	-48131.6***
PJJ_{20}	8723.7***	6899.2***	8271.6***	9489.9***	8428.0***	7448.4***	6807.1**
PAS_{20}	-2489.2	-1940.0	-2697.7	-4652.2	-1912.5	-1063.1	-1398.5
PO_{20}	6607.8	3938.8	6315.5	7209.3*	6834.2*	6155.7	6344.9
$devTM_{20}$	-1790.7	-2289.3	-2745.0	-1896.9	-2017.8	-2177.3	-2830.1
$devTJJ_{20}$	-1318.7	-56.1	63.1	683.8	-1452.0	16.0	747.0
$devTAS_{20}$	-2566.0	-2235.1	-2928.3*	-3928.6**	-2209.6	-3331.9*	-3178.9*
$devTO_{20}$	9666.4***	8474.1***	9548.1***	8374.7***	9225.9***	9435.9***	8709.6***
$devPM_{20}$	-1255.1	-1311.2	-994.1	-1092.3	-1423.2	-1118.8	-1092.0
$devPJJ_{20}$	208.2***	188.9***	218.6***	194.1***	217.0***	214.3***	203.4***
$devPAS_{20}$	-108.5	-127.7	-136.6	-143.4	-126.0	-170.3	-184.6
$devPO_{20}$	-2650.4**	-3361.5**	-2716.2**	-3551.4***	-2441.3*	-2649.8*	-2453.0*
$InterM_{20}$	1022.9**	886.8**	1027.3**	1241.5***	968.0**	1120.6***	1259.5***
$InterJJ_{20}$	-269.4***	-214.9**	-255.6***	-293.7***	-259.6***	-228.8	-212.2**
$InterAS_{20}$	141.8	116.9	147.5	214.5*	119.2	92.5	102.6
$InterO_{20}$	-339.7**	-264.6**	-329.9**	-395.9***	-339.6**	-322.5**	-319.4**
S_i	29850.6***	41727.6***	21616.9***	34432.0***	25958.3***	27546.4***	27764.0***
NR	29.8	41.7	21.6	34.4	25.9	27.5	27.7
Treatment equation	**(S-1)**	**(S-3)**	**(S-4)**	**(S-14)**	**(S-34)**	**(S-234)**	**(S-1234)**
OP	.001	.005**	-.004	.002	-.000	-.013	.002
LA	.103	-.117	-.325*	.679***	-.196	-.074	.499***
Edu	.017	-.011	-.015	.020	.011	-.010	.015
Age	.001	-.003	.004	.017***	.009**	-.013	.007**
FS	-.001	-.036*	.020	-.024*	-.036**	.006	-.013
OW	-.211	-.193**	-.344**	-.331***	.178	.057	-.005
FA	-.003	-.001	.002	.001	.009***	.001	.003*
FG	.002	-.000	.003	.001	-.001	-.001	.000
GE	.052	.098	-.225	.124	.296***	.584**	-.057
FI	.249*	.575***	.311	.471***	-.092	-.501**	-.013
TK	-.386**	-.131	-.677	-.274***	-.018	.046	-.321***

Note: ***, **,* **denote impact significant at 1%, 5%, 10% respectively.**

The results are suggestive that crop area, age, education, and fertility are less important variable in determination of net revenue from cotton production. The farm households who took loans realized significantly lower net revenues than their counterparts.

Climate change is beneficial for the crop or harmful is depend upon the growth stage of the plant (Doherty et al., 2003). According to agronomists cotton crop has a tap root system and characterize by tolerant water stress, by irrigation the effect of water stress can also be decreased.

On the basis of phenology of cotton crop the developmental stages the crop are divided in to four growth stages. The linear impact of conditions of climatic factors (temperature and precipitation) during these growth stages of cotton are reported in Table 5.3.This study also includes the deviation of temperature and precipitation as well as interaction terms of temperature and precipitation in order to respectively check the effect of climatic shocks and the joint impact of the climatic factors.

The first stage of cotton namely sowing and germination expands over month of May and during this stage the effect of temperature is found to be insignificant. The cotton crop does not respond to temperature during the first fortnight of crop and in 2^{nd}fortnight cotton crop becomes responsive to temperature (Sankaranarayanan, 2010).

The change in norm of precipitation for the month of May (first stage) is negatively related to net revenue from cotton production. The higher precipitation norm during May reduces the net revenues significantly.

Vegetative growth stage is a second phenological stage of cotton crop (square development and flower setting) and occurs during the months of June and July in Pakistan. This stage has vital impact on cotton productivity. These months are most important in determining the cotton yield. To achieve the optimal growth of plant the exposure of plant to most favorable temperature could make it able to photosynthesized more. When temperature increases cotton yield affect positively and similar to precipitation has a positive impact on cotton productivity because increase in day temperature might lift up the requirement of water (Imran, 2014). So, results indicate that positive impact of climatic factors (temperature and precipitation) and increase the net revenue of cotton growers. However, a significant and negative joint impact of the climatic factors on net revenue was found at this stage of cotton growth.

Third developmental stage of cotton stretches over the months of August and September in Pakistan. In this growth stage cotton plant reaches to boll setting, and lint development. Results show that the changes in long run norms of temperature and precipitation during this stage have an insignificant effect on net revenues from cotton production. On third growth stage the deviation of precipitation from long run mean has a negative and insignificant impact on net revenue of farm households. The joint effect of climatic factors (rainfall and temperature) is also insignificant for this stage crop development in all the models except S-14 in which a positive and significant joint effect of temperature and precipitation was observed.

Fourth stage in cotton development is boll opening which mostly covers the month of October. This stage consists of the opening of all bolls and crop is ready for being picked. The impact of rise in norm of the October temperature is positive because high temperature helps in maturing and opening of the bolls and make easy to harvest the crop. The impact of change in long run norm of precipitation for month of October has a positive and significant effect on net revenues for the S-14, and S-34 adaptation strategies (varietal change along with precision leveling and ridge sowing; and input intensification along with precision leveling and ridge sowing)and positive but insignificant for the other adaptation strategies. However, the deviation of precipitation from long run mean during

October adversely affects the net revenue. When other factors are controlled the joint impact of temperature and precipitation on net revenues for this stage is also negative because of yield losses due to pink boll formation and impaired quality of lint.

The results from the above four stages indicates that cotton react positively in response to temperature but impact of precipitation on yield of cotton vary according to the crop growth stage.

5.3: Determinants of Adaptation

Adaptation in response to climate change is among the independent variables in outcome equations however it not an exogenous variable and is determined by a number of other factors. The Treatment Effect Model was used to correct endogeniety problem and the estimates of resulting selection equation are also reported in Table 5.3. Empirical results show that the size of operational farm (operational area) has statistically insignificant impact on adaptation but has positive and significant impact on the adaptation of S-3(input intensification). The farm household having access to loans are more likely to adopt the adaptation strategies of S-1234(varietal change, change in sowing time, input intensification and soil and water conservation) and S-14 (varietal change and soil and water conservation) whereas they are less likely to adopt adaptation strategy of S-4(soil and water conservation).Similarly, the age of head of the farm household is also found a less important variable in decision making about adaptation but in the decision of adapting the S-14, S-34 and S-1234. However, education was observed as less important variable in determination of adaptation decisions. Family size of farm household negatively impacts the adaptation decision. The owners are found less likely to adopt the strategies S-14, S-4 and S-3than the tenants. The land fertility has significant impact on the adaptation decision of S-34 and S-1234. The access to government extension increases the likelihood of adopting S-34 and S-234 (combination portfolios) whereas those take information from electronic and print media are less likely to adopt adaptation strategy S-234 and more likely to adopt adaptation strategies S-1, S-3, S-4 (standalone strategies) and S-14.Similar results are also reported by Di Falco (2014). Those who use the traditional knowledge about the weather information are less likely to adopt the adaptation strategies S-1, S-4 and S-1234.

Chapter 6

CONCLUSION AND POLICY RECOMMENDATION

6.1 Concluding Remarks

This study aims at identifying the impacts of climatic factors (temperature and precipitation) and adaptations to climate change on net revenues received from the cotton productivity by using Ricardian Approach. Net revenue (outcome variable) is regressed on age and education of male decision makers, loan access, soil fertility, and climatic factors such as 20 year averages of monthly mean temperature and precipitation, and deviations and interaction terms of temperature and precipitation according to phonological stages of cotton. In treatment equation independent variables like age and education of male decision maker, family size, access to loan, soil fertility, access to government extension, and different sources of weather information are included.

This study identified four types of adaptation strategies [varietal change, sowing time change, input intensification, and water and soil conservation] adopted by the cotton growers but it is often observed that farmers are adopting simultaneously more than one strategies. To capture this issue we generated 15 mutually exclusive strategies, and out of those adaptation portfolios only seven strategies are regressed which have significant number of adapters i.e. S-34(input intensification and soil and water conservation), S-234(sowing time, input intensification, and soil and water conservation) and S-1234(combination of all the four adaptation strategies) have a significant and positive impact on net revenue. Further, S-1(varietal change) and S-3 (input intensification) also increase the net revenue of cotton growers when adopted in isolation.

The estimated results of outcome equation indicate that the average temperature during the1st stage namely sowing and germination (month of May) affect insignificantly because crop is unresponsive to temperature, precipitation has a positive impact on 1st stage. Temperature as well as precipitation has positive and significant impact on net revenue during the Second Stage (average of June- July). In 3rd stage temperature has negative impact on net revenue of cotton growers. In the 4th stage net revenue is increased by increasing temperature whereas precipitation has an adverse impact on productivity of cotton crop during the same stage of crop growth. From the above study findings following conclusion can be drawn. The climatic factors (temperature and precipitation) play a significant role in determining net revenue realized from cotton production. The increase in temperature shows to have either an insignificant effect (as in first and third stages of growth) or enhances cotton productivity significantly (second and fourth stages of crop growth). However, the effect of Precipitation on cotton productivity depends on the stage of crop being negative in the first stage and positive in the second stage. Further, the access to government extension and source of weather information are important determinant of adaptation decisions undertaken by the cotton growers. The extension services helps to get the information about new improved varieties, planting methods, soil quality, irrigation, cropping pattern and all that farmer need to cultivate and the formal information services provide the information about weather which helps to . The farmers using traditional knowledge about weather are less likely to adapt at to climate change.

6.2 Policy Recommendation

The adaptation decision in response to climate change increases the cotton productivity. Primarily this study intends to identify the impacts of adaptation on net gains received from cotton productivity. The estimated results are suggestive that adaptations to climate change have significant and positive impacts on net gains. Amongst all observed beneficial strategies, those farmers who are found adopting input intensification stand-alone (S-3) are gaining more profits as compared to other strategy adapters. Moreover government extension has been found important determinant which is affecting positively decision of the cotton growers to adapt. Hence, on the basis of these findings this study suggests following suggestions.

1- Cotton growers should be encouraged to adopt the stand-alone strategies for increasing their net revenues.
2- The access to government extension services need to enhance.
3- The study suggests revisiting of recommendations of regarding cotton production practices.
4- The encouragement of crop insurance as an adaptation strategy may prove useful exercise.

6.3 Limitations of the Study

Climate change is not just about the increase in temperature and variation in rain fall. Many other factors like humidity and frost affect the productivity of crop and lessen the net revenue of cotton growers but we have not the data of humidity and frost.

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Appendix:

Appendix-1a: Outcome Equations (Strategies 1, 3, 4)

Dependent Variable: Net Revenue per Acre

	Strategy-1		Strategy-3		Strategy-4	
variables	Coefficients	P>[Z]	Coefficients	P>[Z]	Coefficients	P>[Z]
Crop area	40.01	0.53	62.20	0.32	43.17	0.50
Loan access	-4673.6	0.004	-3266.30	0.05	-3430.77	0.04
Age	.416	0.992	6.61	0.87	-10.80	0.79
Education	-18.62	0.866	-20.64	0.85	22.25	0.83
Fertility average	3.34	0.872	12.13	0.56	-6.25	0.76
Fertility good	12.50	0.544	28.40	0.17	13.72	0.50
May_t_20year	-979.33	0.89	-2771.91	0.69	-1611.29	0.82
June_july_t_20year	10778.09	0.034	11472.52	0.01	11532.19	0.02
Aug_sep_t_20year	-5572.12	0.453	-6621.34	0.33	-5889.24	0.43
Oct_t_20year	16304.25	0.00	14561.66	0.00	15682.79	0.00
May_p_20year	-39571.51	0.01	-34683.63	0.03	-39669.37	0.01
June_july_p_20year	8723.70	0.00	6899.23	0.00	8271.63	0.00
Aug_sep._p_20year	-2489.24	0.49	-1940.00	0.56	-2697.78	0.46
Oct_p_20year	6607.81	0.10	3938.88	0.30	6315.55	0.12
May_t_20year deviation	-1790.7	0.39	-2289.35	0.25	-2745.00	0.19
June_july_t_20year deviation	-1318.77	0.60	-56.13	0.98	63.16	0.98
Aug_Sep._t_20year deviation	-2566.09	0.13	-2235.15	0.16	-2928.36	0.08
Oct_t_20year deviation	9666.43	0.00	8474.17	0.00	9548.15	0.00
May_p_20year deviation	-1255.11	0.46	-1311.24	0.41	-994.14	0.57
June_july_p_20year deviation	208.25	0.00	188.93	0.00	218.68	0.00
Aug_Sep_p_20year deviation	-108.59	0.40	-127.75	0.28	-136.65	0.30
Oct_p_20year deviation	-2650.46	0.05	-3361.54	0.01	-2716.26	0.04
InterM_20	1022.91	0.02	886.85	0.04	1027.31	0.02
InterJJ_20	-269.47	0.00	-214.95	0.00	-255.63	0.00
InterAS_20	141.84	0.25	116.94	0.30	147.51	0.23
InterO_20	-339.75	0.01	-264.62	0.05	-329.93	0.02
Only 1	29850.6	0.00	41727.68	0.00	21616.95	0.00
_cons	-691542.8	0.00	-548682	0.00	-659046.6	0.00

Appendix-1b: Treatment Equations (Strategies 1,3,4)

	Strategy-1		Strategy-3		Strategy-4	
Variables	Coefficients	P>[Z]	Coefficients	P>[Z]	Coefficients	P>[Z]
Operational area	.00105	0.83	.0051	0.449	-.0040	0.644
Loan access	.10394	0.59	-.1176	0.527	-.3256	0.682
Education	.01728	0.23	-.0111	0.792	-.0159	0.031
Age	.0014	0.79	-.00342	0.903	.0041	0.014
Family size	-.0011	0.94	-.0362	0.864	.0205	0.377
Ownership	-.2111	0.11	-.1937	0.640	-.3449	0.649
Fertility average	-.0034	0.17	-.0015	0.007	.0037	0.025
Fertility good	.0023	0.29	-.0003	0.059	.0020	0.006
Government ext.	.0521	0.67	.09815	0.807	-.2250	0.321
Formal information	.2494	0.08	.5751	0.001	.3114	0.047
Traditional know.	-.3862	0.02	-.1318	0.259	-.6773	0.000
_cons	-1.88	0.00	-1.325	0.000	-1.6252	0.000
Lambda	-13946.9		-17141.4		-10140	
Rho	-.8004		-.956951		-.59395	

Appendix-2a: Outcome Equations (Strategies 14, 34, 234)

Dependent Variable: Net Revenue per Acre

	Strategy-14		Strategy-34		Strategy-234	
Variables	Coefficients	P>[Z]	Coefficients	P>[Z]	Coefficients	P>[Z]
Crop area	38.14	0.55	20.90	0.75	42.45	0.50
Loan access	-5389.98	0.00	-3940.52	0.02	-4846.02	0.00
Age	-22.90	0.58	-36.88	0.39	2.56	0.94
Education	-25.13	0.82	-97.31	0.39	-9.43	0.93
Fertility average	-2.52	0.90	-35.31	0.10	-1.34	0.94
Fertility good	18.51	0.37	30.96	0.14	24.71	0.21
May_t_20year	-4729.97	0.50	-69.22	0.99	-4850.61	0.51
June_july_t_20year	14709.12	0.00	9791.72	0.05	9033.10	0.07
Aug_sep_t_20year	-7859.12	0.28	-4403.51	0.55	-260.38	0.97
Oct_t_20year	15761.16	0.00	15430.54	0.00	14814.59	0.00
May_p_20year	-48174.11	0.00	-37906.6	0.02	-43315.99	0.00
June_july_p_20year	9489.90	0.00	8428.03	0.00	7448.47	0.00
Aug_sep._p_20year	-4652.24	0.19	-1912.55	0.59	-1063.10	0.77
Oct_p_20year	7209.37	0.07	6834.21	0.08	6155.71	0.13
May_t_20year deviation	-1896.91	0.36	-2017.83	0.33	-2177.39	0.30
June_july_t_20yeardeviation	683.87	0.78	-1452.09	0.55	16.03	0.99
Aug_Sep._t_20year deviation	-39.28.64	0.02	-2209.64	0.19	-3331.98	0.05
Oct_t_20year deviation	8374.76	0.00	9225.98	0.00	9435.98	0.00
May_p_20year deviation	-1092.32	0.51	-1423.26	0.93	-1118.87	0.51
June_july_p_20year deviation	194.11	0.00	217.08	0.00	214.34	0.00
Aug_Sep_p_20year deviation	-143.40	0.26	-126.05	0.33	-170.33	0.19
Oct_p_20year deviation	-3551.41	0.00	-2441.38	0.06	-2646.86	0.05
InterM_20	1241.50	0.00	968.07	0.02	1120.62	0.01
InterJJ_20	-293.75	0.00	-259.61	0.00	-228.81	0.00
InterAS_20	214.56	0.07	119.29	0.33	92.57	0.45
InterO_20	-395.96	0.00	-339.68	0.01	-322.56	0.02
Only 1	34432.09	0.00	25958.37	0.00	27546.41	0.00
_cons	-583097	0.00	-695953.3	0.00	-608935.3	0.00
Sigma	17424.06		17912.5		17071.93	

Appendix-2b: Treatment Equations (Strategies 14, 34, 234)

	Strategy-14		Strategy-34		Strategy-234	
Variables	Coefficients	P>[Z]	Coefficients	P>[Z]	Coefficients	P>[Z]
Operational area	.0022	0.58	-.0007	0.84	-.0130	0.38
Loan access	.6793	0.00	-.1966	0.16	-.0744	0.80
Education	.0202	0.12	.0119	0.27	-.0107	0.62
Age	.0176	0.00	.0092	0.02	-.0136	0.17
Family size	-.0243	0.08	-.0366	0.01	.0061	0.82
Ownership	-.3317	0.00	.1786	0.15	.0575	0.80
Fertility average	.0017	0.47	.0091	0.00	.0012	0.74
Fertility good	.0017	0.47	-.0010	0.66	-.0019	0.62
Government ext.	.1240	0.25	.2966	0.00	.5846	0.01
Formal info.	.4712	0.00	-.0929	0.36	-.5018	0.01
Traditional know.	-.2740	0.02	-.0186	0.84	.0469	0.82
_cons	-3.3194	0.00	-2.119	0.00	-1.5038	0.02
Lambda	-155668.4		-14100.21		-14723.61	
Rho	-.88197		-.7803		-.872246	
Sigma	17651.77		18069.55		16880.11	

Appendix-3a: Outcome Equations (Strategy 1234)

Dependent Variable: Net Revenue per Acre

	Strategy-1234	
Variables	Coefficients	P>[Z]
Crop area	51.99	0.42
Loan access	-7227.09	0.00
Age	-43.25	33
Education	-138.544	0.24
Fertility average	-19.42	0.38
Fertility good	19.42	0.38
May_t_20year	-6223.91	0.38
June_july_t_20year	8577.06	0.09
Aug_sep_t_20year	-1658.08	0.82
Oct_t_20year	14572.38	0.00
May_p_20year	-48131.6	0.00
June_july_p_20year	6807.10	0.01
Aug_sep._p_20year	-1398.52	0.69
Oct_p_20year	6344.95	0.11
May_t_20year deviation	-2830.16	0.17
June_july_t_20year deviation	747.04	0.76
Aug_Sep._t_20year deviation	-3178.91	0.06
Oct_t_20year deviation	8709.66	0.00
May_p_20year deviation	-1092.04	0.51
June_july_p_20year deviation	203.45	0.00
Aug_Sep_p_20year deviation	-184.65	0.15
Oct_p_20year deviation	-2453.09	0.06
InterM_20	1259.50	0.00
InterJJ_20	-212.23	0.01
InterAS_20	102.61	0.39
InterO_20	-319.46	0.00
Only 1	27764.08	0.00
_cons	-479221.7	0.00

Appendix-3b: Treatment Equations (Strategy 1234)

	Strategy-1234	
Variables	Coefficients	P>[Z]
Operational area	.0026	0.040
Loan access	.4996	0.197
Education	.0152	0.300
Age	.0072	0.386
Family size	-.0138	0.066
Ownership	-.0059	0.932
Fertility average	.0033	0.167
Fertility good	.0009	0.109
Government ext.	-.0576	0.678
Formal info.	-.0139	0.921
Traditional know.	-.3218	0.000
_cons	-1.896	0.000
Lambda	-14965.77	
Rho	-.7902631	
Sigma	18937.71	