Impact of Adaptations to Climate Change on Farm Income: A Case Study of Rice-Wheat Cropping System of Pakistan

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List of Acronyms/Abbreviation

CCIS	Climate Change Impact Survey
ESTEM	Endogenous Switching Treatment Effect Model
IPCC	Intergovernmental Panel on Climate Change
TFCC	Task Force on Climate Change
GDP	Gross Domestic Product
PPI	Pakistan Press International
TFP	Total Factor Productivity
IPWRA	Inverse-Probability-Weighted-Regression-Adjusted
IDRC	International Development Research Centre
ATE	Average Treatment Effect
ATET	Average Treatment Effect on Treated
POM	Potential Outcome Means

Abstract

The paramount aim of this study is to explore the influence of adaptations to climate change on farm income in rice-wheat zone. The study analyses a sample of 643 farmers from Climate Change Impact Survey (CCIS, 2013) conducted by PIDE with the collaboration of IDRC. This sample contains three districts of rice-wheat zone i.e. Sialkot, Hafiz Abad (Punjab), and Larkana (Sindh). For empirical purpose, Endogenous Switching Treatment Effect Model (ESTEM) has been used to conduct counterfactual analysis. The results of the study are suggestive that adaptations have positive and significant impacts on farm income. Adapters are found benefiting in most of the strategies than non-adapters whereas counterfactual indicates that if adapters become non-adapters, they bear loss and yield lower returns as compared to being remained adapters. Furthermore, education, access to credit market, and saving, and climatic variables such as long run averages of temperature and precipitations are found having significant impacts on farm income. The results obtained from treatment equations are suggestive that education, experience, social networking, and government extensions are found important determinants of decision to adapt climate changes. As a recommendations study suggests that farmers should adopt adaptation strategies and government should take step to enhance adaptive capacity of small and marginal farmers with strengthening role of extension department and awareness about changing climate.

CHAPTER 1

Introduction

One of the biggest challenges the world facing today is Climate change. According to Intergovernmental Panel on Climate Chang (IPCC), change in climate occurs due to natural and anthropogenic activities and this change remains for a long period of time. Due to anthropogenic activities climate change impacts have been observed from melting snow to rising sea level and precipitation to changing patterns of weather. These include: 1) global temperature rise—most of the temperature increases observed since 1970s, and 20 hottest years occurred since 1980; 2) declining Arctic sea ice—both in depth and size; and 3) sea level rise—risen almost 17cm during the last century (IPCC, 2007).

Climate change is considered to be significantly impacting production of global agriculture, because agricultural productivity is mainly dependent on climate. Therefore, weather patterns highly affect crop production. Climatic changes are exerting additional pressure on the food supply system of the world and is reducing yield at lower latitude and is however having positive impact on crop's yields at higher latitude (IPCC, 2007).

Changing climate has threatened productivity of agriculture sector, making it vulnerable both economically and physically to climate unevenness and change. Productivity is being affected by a number of climate change variables including rainfall patterns, temperature hike, changes in sowing and harvesting dates, water availability and land suitability. All these factors can change yield and agricultural productivity (Kaiser and Drennen, 1993).

Climatic changes will have far reaching implications on food security of the countries through reduction in crop productivity and adverse impacts on livestock health, mainly caused by extreme events of floods, droughts and cyclones (TFCC, 2010). Some regions will benefit from climate change while certain other regions will be adversely affected. Most of the developing economies depend on agriculture sector—the main contributor in GDP, and the adverse impact of climate change may lead to a large-scale human suffering in rural populations (Mertz *et al*., 2009).

According to the recent IPCC assessment report, agricultural production in South Asia could fall up to 30 percent by 2050 if no action is taken to combat the effects of increasing temperatures and hydrologic disruption (IPCC, 2007). For South Asia, the average annual mean warming by 2020 is projected to be between 1.0°C and 1.4°C, while it would be between 2.23 to 2.87°C by 2050. The temperature may rise by 3-4°C towards the end of the 21st century. Since temperatures in South Asian continent already approaching the critical levels during the pre-monsoon season, further increment will reduce yields of all crops including rice significantly.

Like other developing countries, climate change in Pakistan is a serious concern with its tremendous environmental, social and economic impacts. Pakistan is at 8th place among the countries which are highly vulnerable to the adverse impacts of climate change (PPI 2014)[1]. Pakistan is also included in World Bank's list of 12 highly exposed countries to climate change

[1]Pakistan Press International report on Climate Change

(Shakoor *et al*., 2011). Such a high degree of vulnerability of the country to climate change is due to resource, technological and institutional constraints.

The agriculture sector plays a vital role in Pakistan's economy. It is the second largest sector—contributing over 21 percent to GDP, and is the largest employer—absorbing over 43 percent of the country's total labour force. The total population of Pakistan is approximately 188.2 million with 40 percent living below the poverty line; any disturbance to agriculture patterns is likely to have ruinous effects for population of country (Shams ul Mulk *et al*. 2010).

Rice-wheat cropping system has a long history in Asia. This system has been practiced in China since 700 AD and in Pakistani Punjab since 1920 (Javed *et al*., 2010). Rice-wheat is one of the important cropping systems of Pakistan and its major portion (57%) falls in the Punjab. The rice-wheat area of Punjab mainly covers Gujranwala, Sheikhupura and Sialkot districts with some parts of Gujrat and Lahore Districts as well. Typically *Kallar* belt is the genuine homeland of 'Basmati' rice, a source of fame to Pakistan. The pleasant and sweet fragrant Basmati rice, a specialty of Pakistani Punjab, has the quality of elongation when cooked and the fluffiness that makes it unique in the world. The Punjab was one of the earliest beneficiaries of the Green Revolution with the introduction of modern varieties of wheat and rice in the 1960s (Byerlee and Siddiq 1994).

Farmers of the rice area are growing rice since centuries and they have continued the tradition despite emerging technical difficulties and socio-economic barriers. Basmati rice is grown for farm household consumption, domestic market and for export purposes. The bulk of wheat, the staple food of the country's population, is also produced in rice-wheat system of the Punjab. There exists a high gap between the potential and actual yields received by the farmers for both rice and wheat crops in the study area. The main causes of the problem are institutional, technical, climatic and socio-economic in nature, limiting the rice-wheat productivity (Mann *et al.* 2004).

Unfortunately, the problem of soil degradation is prominent in the wheat-rice belt, causing yields to decline or stagnate because of continued cereal mono-cropping for long [Byerlee and Siddiq (1994); Hobbs and Morris (1996)]. Soil organic matter is also declining. New weeds, pests, and diseases are creating more problems. Irrigation water is becoming increasingly scarce. As a consequence the sustainability of the system has become a serious issue. Ali and Byerlee (2000) also reported negative productivity growth in rice-wheat system of Punjab, Pakistan. The resource degradation was considered to be the major cause behind poor productivity performance in rice-wheat system. Pingali and Heisey (2001) argued that productivity of rice-wheat cropping system is not sustainable mainly because of degrading land resources in the system. Ahmad (2001) also reports lowest TFP of rice-wheat zone among other cropping systems in Punjab, Pakistan. The low TFP growth rate in this system was mainly caused by the degrading lands.

Recently, the issue of climate change has emerged as one of the serious threats to agriculture and food security. As mentioned earlier, the productivity of the rice-wheat system has either stagnated or declined because of degrading land resources in the system. Now the question being asked in this study is that 'whether the climate change has anything to do with the low productivity in the system' and 'what is the role of adaptation to climate change in moderating the climate change impacts'?.

To abate the negative impacts of climate change, adaptation have a pivotal role to play. Adaptive measures are much helpful to offset the potential negative impacts and reinforce the benefits associated with climate change (IPCC, 2001).

Adaptations in agriculture can be defined as changes in human systems with respect to actual or expected climatic changes. Adaptations are policy options to abate the negative effects of climate changes (Kurukulasuriya and Mendelsohn, 2008), and maintain or enhance the productivity of agriculture (IPCC, 2001). Adaptations include autonomous (taken by individuals or single farmer or organisations) as well as planned adaptations (taken by specific climatic related organisations at local, national or international levels) (Tubiello and Rosenweigh, 2008).

Changing crop varieties, planting trees, soil conservation, irrigation strategies, livestock and crop diversification, early and late planting, soil conservation and adjusting the quantity and timing of fertilizer use are the most common adaptations practices in agriculture (Bradshaw *et al*. 2004). Three factors play vital role for adaptation choices: household characteristics, social capital and institutional factors. Household characteristics consist of age, gender, education, farm size, household size, farm size, farming experience and wealth. Institutional factors include climatic information, access to credit, access to extension services, off farm employment opportunities and land tenure (Bryan *et al*. 2009). The main hurdles to adjustments include lack of information, water shortages and lack of access to credit and land (Bryan *et al*. 2009).

1.1 Significance of the study

The present intensive cropping of the rice-wheat system in vogue was not the tradition, instead one crop a year was cultivated. About three decades ago rice-wheat sequential cropping system began to take-off. With synthetic fertilizers, tubewell installation for irrigation and short duration varieties, made it possible to grow two crops in a year (Mann *et al.* 2004). Due to existing infrastructure and climatic conditions, rice and wheat crops get immense importance in the livelihood options for farmers of the rice-wheat zone in Pakistan. Recently, research on adaptations to climate change has gained attention of the researchers in the context of Pakistan

[Dehlvi, *et al*. (2015); Iqbal, *et al.* (2015); Ahmed *et al.* (2015)] where impacts of adaptation strategies on wheat productivity and food security were investigated. To our knowledge, no study is available on exploration of relationship between impact on farm income in rice wheat region and adaptation strategies with respect to climate change by the farmers of rice-wheat zones. Therefore, it is important to find out the impacts of climate change and adaptation on farm income received from all cultivating crops in rice-wheat region. Further, this study shall also conduct counterfactual analysis in case of adapters.

1.2 Research Questions

What is the impact of Climate Change on Farm income in Rice-Wheat Cropping Zone of Pakistan? And,

What is the impact of Adaptations to Climate Change on Farm Income of the Rice-Wheat Cropping Zones of Pakistan?

1.3 Objectives of Study

The prime aim of this study is to analyse the impacts of adaptations to climate change on farm income in rice-wheat region. Following are the specific objectives of the study;

1. To identify major adaptation strategies adopted by the farmers in rice-wheat zone and determinants of these adaptations.
2. To investigate the impacts of climatic factors and adaptations to climate change on the net farm income in rice-wheat region.
3. To conduct counterfactual in the case of adapters and non-adapters.
4. Suggest some policy implications based on results of the study.

1.4 Hypothesis of the Study

Following are the hypothesis of the study:

H_0: Climate Change has no impact on Farm income of rice-wheat system.

H_1: Climate Change has impact on Farm income of rice-wheat system.

H_0: Farmers are not adopting any strategy for adaptation in rice-wheat zone.

H_1: Farmers are adopting any strategy for adaptation in rice-wheat zone.

H_0: Adaptation to climate change has no impact on net farm income.

H_1: Adaptation to climate change has impact on net farm income

H_0: There is no difference in case of adapters and non-adapters.

H_1: There is difference in case of adapters and non-adapters.

1.5 Organization of the Study

Study would comprise of five chapters. Subsequent to introduction of the study in chapter 1, some important studies will be reviewed in chapter 2 whereas chapter 3 will cover discussion on data, variable construction, and empirical model. Discussion on empirical results would be given in chapter 4 and finally conclusion of the study and some policy recommendations would be presented in chapter 5.

CHAPTER 2

Literature Review

In this chapter mainly two types of studies are included: the first focuses on the impact of climate change on agriculture; and the second deals with impacts of adaptation to climate change on agriculture. This chapter also includes different models and approaches which have been employed to analyse the impact of climate change and adaptation impacts on agriculture.

2.1 Impact of Climate Change on Agriculture

Gbetibouo (2004) investigated the impact of climate change on South Africa's field crops by using Ricardian model. He also explored possible future impacts of further changes in the climate on wheat, sugarcane, sunflower, maize, sorghum, groundnut and soybean. Results of the study showed that production of field crops was sensitive to marginal changes in temperature as compared to changes in precipitation. Rise in temperature has a positive effect on net revenue whereas the effect of decrease in rainfall has a negative impact on net revenue.

Kurukulasuriya *et al* (2008) employed Ricardian Approach to assess the impact of climate change on net revenues of crops using survey data collected from 9064 farmers belonging to 11 African countries. The results are suggestive that a 10 percent increase in temperature will lead to a 13 percent decline in net revenue. They found that net revenues are more sensitive to changes in temperature than changes in precipitation.

Hassan *et al* (2010) used the Ricardian method to see the impact of climate change on the net revenue of rice fields under dry land and irrigation conditions in Nigeria. From 20 rice producing *states* of Nigeria 1200 farmers were interviewed. The results showed that increase in temperature in dry land farms will reduce net revenue while net revenue rises with the increase in temperature on irrigated farms. Precipitation had similar effects on rice net revenue. The results clearly showed that irrigation as a significant techniques used by the famers to adapt to climate change.

Shakoor *et al* (2011) explored the impact of climate change on agriculture of arid region employing Ricardian approach using farm survey data collected from 10 tehsils of three districts of arid region in Punjab province of Pakistan. The results depicted that there is negative relationship between increase of temperature and net revenues. It was revealed that an increase of one percent in temperature would reduce net revenue by PKR 4,180 per annum.

Fofana I (2011) studied the effects of climatic changes on income and agricultural productivity in Tunisia, Africa. Through different climate scenarios, the possible future climates were designed. Combines two levels of decreasing precipitation (10 and 20 percent) and three levels of temperature increase (1° , 2°and 3° centigrade) and doubling of Carbon dioxides (350 to 700 parts per million) concentration in atmosphere. The farming system of production is replicated through a biometric model; that is, one that couples a cropping system model and economic model run sequentially. Results showed that due to changes in precipitation, farm productivity decrease by 15 to 20 percent, and with the increase in temperature 1°C farm income decline by 5 to 20 percent. Income and farm productivity severely affected, as the climate warms up 2°C to 3°C by 35 to 55 percent and 45 to 70 percent respectively. As far as adaptation is concerned simple adaptations like, more irrigation and fertilization, these were compensating just for 1°C rise in temperature.

Cai *et al* (2012) estimated the effect of weather variations on corn yields. This study used balanced panel data regarding 985 corn producing districts in U.S for the period 2002-2006. Monthly temperature and precipitation data during growing season was taken for empirical estimation. The results of the study showed that the relationship between weather and corn yield has large spatial variability. In warmer regions temperature have negative effect on corn yield and in cooler region temperature have positive effect on corn yield. The spatial pattern of precipitation effects was more complicated since it is expected to be largely affected by local irrigation systems. The results of the OLS regression model showed that corn yields were negatively related to both precipitation and temperature.

2.2 Adaptations and Climate Change

Yesuf *et al* (2008) measured the impact of climate change on food production in low-income developing countries and investigate the determinants of adaptation to climate change and implication of these strategies on farm productivity. Primary data of rainfall and temperature were used and found that climate change and adaptation to climate change have significant effect on food production in low-income developing countries. Extension services, access to credit and information to future climate change, affected adaptations positively and significantly.

Di Falco *et al.* (2009) investigated adaptations impact on food productivity and major adaptation strategies to climate change along the Nile Basin in Ethiopia. Primary data consisted upon 1000 farm households were collected. To control unobserved endogeneity and heterogeneity stage least square and Pseudo fix effect models were used. They identified the 3 adopted strategies from that farmer household's survey which were changing crops, planting trees and adopting soil conservation. They found that adaptations have significant and positive role in the food production.

Acquah (2011) Conducted a study in Ghana, focused on, what is farmer's perception to climate change, how they response to climate change by their adaptation strategies and what are the barriers to their adaptation process. A standard questionnaire survey was conducted from 100 farmers randomly, and descriptive statistics were the analytical technique. Results showed that majority of farmers perceived decrease in rainfall and increase in temperature. In adaptation to climate change 86 percent switched to different crop varieties, 91 percent of the farmers change planting dates and 72 percent implemented soil conservation techniques to offset climatic effects. Main barriers to adaptation process were lack of credit and insufficient access to inputs.

Di Falco *et al.*, (2011) studied does adaptation to climate change provide food security? They employed Ricardian model on primary data of Nile Basin, Ethiopia. This study relied on primary survey consisted of 1000 farm households along the Nile Basin in Ethiopia in 2005. With this they also observed factors which lead households to take decision regarding adaptations and adaptations impacts on the food productivity. Credit access, information of climate change and extension services was found to be important factors for adaptations. They found three results from the study, first adapters households had the routinely different characteristics from the households that did not adapt. Second, climate change adaptations are helpful to increase food productivity, when they investigate this result for two different groups of farm households, adapters and non adapters. Third, adapters households had some important characteristics that make them more food secure as compare to non adapters even without adoption of adaptations strategies.

Gbreegziabher *et al*. (2011) assessed the economic impact of climate change on agriculture employing computable general equilibrium model in Ethopia. Climate change impacts on agriculture were based on the Ricardian Model results where, current and future production of agriculture was regressed as function of precipitation and temperature. They found that climate change effects on agriculture would be relatively friendly until 2030 then worsen substantially. Their counterfeit results showed that, over a 50-year period, the projected reduction in agricultural productivity may lead to 30 percent less average income, compared with the possible outcome in the absence of climate change. Adaptations to climate change by farmers and government's agricultural policies would play crucial role in Ethiopia's future agriculture.

Di Falco *et al* (2012) estimated the impact of climate change on agriculture in low income countries: Household level evidence from the Nile Basin, Ethiopia. The economic implications of climate change were estimated by using both farm productivity and a Ricardian framework. Data were drawn from about 1,000 farms producing cereal crops in the Nile Basin of Ethiopia. The thin plate spline method of spatial interpolation was used to predict household specific rainfall and temperature values using meteorological station data collected for 30 years across the regions. They estimated that climate change adaptation has a significant impact on both farm productivity and farm net revenues. They complemented the analysis by providing an estimation of the determinants of adaptation. Extension services (both formal and farmer to farmer), as well as access to credit and information on future climate changes were key drivers of adaptation.

Nantui *et al* (2012) studied the adaptive capacities and adaptive strategies of farmers to climate change on rice production in northern Ghana. Farmer adaptive capacities were categorized into high, moderate and low adaptive capacities. To quantify the impact of adaptive capacities of farmers Double Logarithmic regression model of Cobb-Douglas production was used. They find out that high adaptive farmers obtain nine more bags of 50 kg bag of paddy rice than the lower adaptive capacities. They also suggested that Rice farmers should be empowered through better extension services to attain high adaptive capacities.

Dehlvi *et al* (2015) investigated that whether there are productive benefits for farmers who adapt to climate change in Pakistan. Total 1,422 households were surveyed. Endogenous switching model was employed. Effect of on farm adaptation strategies were estimated for three crops: rice, wheat and cotton grown across Punjab and Sindh. The results showed that farmers who actually adapted gained benefits for wheat and cotton but not significantly different from zero for rice. The large estimated gains for non-adapters however, pointed to the existence of barriers to the adoption of these strategies. Policies aimed to reducing these barriers would be likely to both increase short term production of households and enabled them to better prepare for the potential impacts of climate change.

Ahmad *et al* (2015) has found the effects of adaptations to climate change on food security and evidences are collected from different agro-ecological zones of Pakistan. The data of 3,298 farmers who were found as food crop growers, and they were selected from 16 randomly selected districts of Pakistan. They undertook doubly-robust Inverse-Probability-Weighted Regression-Adjusted (IPWRA) to estimate the impacts of different crop related adaptations on food security of farm households. The pragmatic findings were suggestive that households which adapted climatic changes were appeared as significantly more food secure than that of non-adapters. According to the study education of male decision maker (head of household), non farm income, loan availability, and access to Govt. agricultural extension services are the main determinants of adaptations.

Iqbal *et al* (2015) has evaluated the impacts of different crop related adaptations to climate change on wheat productivity, and their evidences were composed from different agro-ecological zones of Pakistan. They used data of 3100 food crop growers from 16 randomly selected districts of Pakistan. The study has employed the information taken from CCIS (2012-

13), and it executed Treatment Effect Model. Results showed that adaptation strategies like, delayed sowing, varietal change and input intensification positively affect net revenue if they adopted separately or with other strategies. Evidence also found that climatic factors such as temperature in Jan-Feb, and temperature in Nov-December months, and similarly precipitations (March-April) and their deviations have significant impacts on net revenues gained from wheat productivity, and furthermore, the findings of the study are indicative of the positive and highly significant influences of adaptations on wheat productivity, and it implied that adapters were appeared as beneficiary from adoptions of crop related adaptations.

Literature suggests climate change have far reaching effects on the agriculture sector and food security. Developing Countries would experience more devastating impacts on the agriculture and ultimately on food security. Literature also suggests: mitigation and adaptation to offset the climatic effects on agriculture. Extensive attention has been paid on the adaptation strategies in the developing world. So, undergone study is being conducting considering the importance of adaptation to offset climatic effects in agriculture sector.

Above reviewed literature suggests that most of the studies cover impact of climate change on agriculture but still less attention has been paid to documented studies regarding adaptations in the context of Pakistan. Only few studies [(Ahmad *et al* (2015); Dehlvi *et al* (2015); Iqbal *et al* (2015)] have made endeavour to capture impacts of adaptation to climate change on food security and wheat productivity but to knowledge no study is available on adaptation and farm income in rice-wheat zone of Pakistan.

CHAPTER 3

Data, Variables and Analytical Model

3.1 Data

The study would use data of Climate Change Impact Survey (CCIS, 2013) conducted by PIDE and sponsored by IDRC. The survey data contains information of 3430 farm households located in 16 districts[2] of Pakistan. The survey information covers socio-economic, farm activities, perception, and adaptation to climate change. It is first comprehensive survey regarding agriculture and climate change from three provinces of Pakistan i.e. Punjab, KPK, and Sindh.

The main subject of the study is to compute farm income of farmers in rice-wheat region and analyse the impact of adaptations to climate change on farm income. Therefore, we would pick information regarding concerned households. The study would focus on 643 farm households located in rice-wheat region of Punjab out of total sample 3,430 farm households in Pakistan. To calculate their farm income, study would take into account all crops which are significantly contributing in farm income.

3.2 Theoretical Model

Evaluation of climate change impacts can be done through various approaches, such as simulation model, production function model and Recardian model. This study would use Recardian approach because main concern of the study is to find out the impact of adaptation to climate change on net farm income. Brief overview of simulation model and production function model and comprehensive overview of Recardian model is given below:

[2] Bahawalpur, Jhang, Vehari, Sialkot, Hafiz Abad, Bhakkar, Chakwal, Attock, Larkana, Sanghar, Nawab Shah, MirpurKhas, Charsada, Kohat, Haripur, and D.I.Khan.

3.2.1 Crop Growth Simulation Models

The crop growth simulation approach of measuring climate impacts can be divided into the crop suitability approach and the production function approach. The crop suitability approach assesses the suitability of various land types and biophysical attributes for crop production. By including as one determinant of agricultural land suitability, this model can be used to predict the impact of climate change on agricultural outputs and cropping systems (Du Toit *et al*. 2001).

The more commonly used approach of the two is the production function approach. This method uses a crop model that has been calibrated from careful controlled agro economic experiments (Adams 1989). The same farming methods are employed across various climates and no adaptation is included. This ensures that all differences in yield are only a result of the climate variables. The changes in yields obtained are then entered into economic models that predict aggregate crop outputs and prices (Mendelsohn 2000). This approach has been employed in a number of studies, e.g. Decker *et al*. (1986) and Rosenzweig and Parry (1994).

The production function approach has the advantage that it gives dependable predictions of Climate effects on yields since the link between the two is generated through controlled experiments. This method of climate impact assessment, however, has its own drawbacks. Its most critical weakness is the failure to include farmer adaptation in the modelling process. Mendelsohn *et al*. (1994) reported that this method over estimates the negative impacts. The failure to account for adaptation in the production function approach prompted researchers to opt for a hedonic approach as a superior method. This approach, pioneered by Mendelsohn *et al. (*1994) involves econometric procedures and it has come to be famously known as the Ricardian approach. This approach is comprehensively addressed below because it forms a basis for the current study. This study would follow this approach because the main concern of this study is to identify the impacts of adaptation to climate change on rice productivity.

3.2.2 The Ricardian Approach

The Ricardian method is based on the framework originally introduced by David Ricardo, and further developed by researchers like Palmquist (1989). They noted that every parcel of land has a large number of characteristics that vary across different areas. The parcel owner can change some of the characteristics like fertility and drainage erosion control in response to information and incentives while others like soil type, soil depth, climate and terrain cannot be practically modified.

Equation 3.1 below summarises the factors that influence output

$$g(y, x(h, w), z) = 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(3.1)$$

Where, y is crop output, x is production inputs e.g. fertilizer, pesticides, seed, hired labour, transport among others, z is land characteristics (climate and soil characteristics), h is farmer characteristics that influence production, w is market characteristics (e.g. distance to markets and access to all weather roads).

According to Ricardo (1815), land rents reflect the net revenue value of farmland and the farmland net revenue in turn reflects the net productivity and the costs of agricultural production.

This is illustrated in the net revenue equation below;

$$Y = \Sigma p_a \; y_a(x(h, w), z) - \Sigma p_x \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \; (3.2)$$

Whereby similar elements take up the meaning represented in Equation 1 and the rest include Y is net revenue, p_a is price of outputs and p_x is price of input x.

The Equation 3.2 above therefore implies that the productive value of a particular land characteristic like climate can be inferred by observing its significance in determining farm net revenue (Maddison *et al*. 2007). Being rational agents, farmers are assumed to maximize profits given the farm characteristics and market prices by using land in declining order of fertility which relies on climate and soil quality (Currie 1981). They put most profitable agricultural activity to the most suitable parcel and the least profitable one to the least suitable parcel (Polsky 2004). As a result, productivity of a particular parcel of land will be reflected in market value of its output, which also means that variation in climate across space directs variation in land productivity (Mendelsohn *et al.* 1994).

It is this setting that allows the estimation of a reasonable link between climate and net revenue through a multivariate regression model (Polsky 2004). Holding other factors constant, the estimated climate variable coefficients indicate its effect on agricultural productivity. The Ricardian methodology makes use of cross sectional observations with varying climate and Edaphic factors to estimate climate impact on agricultural productivity. By regressing farm net revenue on climate variables, soil variables and other control variables, the approach can derive climate's impact on productivity (Gbetibouo& Hassan 2004). Mendelsohn and Dinar (2003) reports a nonlinear relationship between productivity and the climate variables because there exist a production threshold for each crop in response to temperature and precipitation. This gives rise to the econometric relationship below,

$$Y = a_0 + a_i F + y_n k + \sigma_m h + \varepsilon \quad \text{……………………………………………………………} \quad (3.3)$$

Where Y is net revenue, a_0 is constant term, F is vector of climate variables and their squared terms, k is vector of soil characteristics, h is vector of household characteristics, and ε denotes error term

As noted earlier, this approach turns out to be superior to the production function approach because it incorporates private adaptation by farmers. Adaptation can be in the form of changing crop mix, planting dates, harvesting dates, irrigation and many other agronomic practices. These changes appear in form of increased costs to farmers and they are further reflected in the net revenue obtained. By using net revenue instead of yield as the dependent variable, farmer adaptation is adequately considered (Deressa 2007).

The Ricardian approach is not without faults. One of its major weaknesses is the implication of the homo economics assumption of a perfectly rational profit maximizing economic agent; a very important foundation of the approach (Sieberhuner 2000). According to Polsky (2004), the assumption implies that farmers can instantaneously identify climate change, assess all changes it generates in markets and then adequately adjust their land use practices to allow for utility maximization under the prevailing conditions. One implication of this assumption is that farmers can access all adaptation technologies at any given time (Mendelsohn *et al.* 1994).

Russell *et al.* (1970) reported that there exist a number of financial and political obstacles which could prevent such adaptation especially in areas with great competition for more profitable use of resources. Blaut (1977) adds to say that farmers will not necessarily adopt a technology that scientists think they should even if this is developed to solve their problem. As a result of this extreme adaptation supposition, Ricardian climate change impacts on net revenue are systematically biased to be too low (Polsky 2004).

Closely linked to the limitation above is that the approach considers only current adaptation in the analysis and this excludes future changes in agricultural practices as a result of modifications in technology. Another limitation of the method is its failure to include price effects in the model. According to Cline (1996) it leads to an under estimation of the climate impacts when climate change increases aggregate supply and an overestimation for the case where aggregate supply is decreased. The bias in estimated impacts is a result of price effects due to changes in aggregate supply.

Di Falco *et al.* (2011) incorporated adaptation directly into the Equation 3.4 which gets following form in general.

$$Y = \beta X + \delta A_i + U_i \qquad (3.4)$$

Where Y is net revenue, X is vector of socioeconomic and climatic factors, and A_i is set of different adaptation strategies which are adopted by farmers to reduce the negative impacts of climate change. β and δ are the parameters of X and A.

In Equitation 3.4, A_i is an endogenous binary variable (i.e. A=1 if farmer is adapting climate changes, and otherwise A=0) and it causes sample selection bias due to endogenity occurs. There are some unobservable socioeconomic factors which are needed to observe.

3.3 Econometric Model

Existing literature suggests different econometric approaches such as conventional Heckman models, multinomial Logit/Probit models, binary endogenous switching regression, and multinomial Switching Regression models, Inverse-Probability-Weighted Regression Adjustment (IPWRA) [Nhemachena and Hassan (2007); Di Falco *et al*.(2011, 2014); Dehlvi*et al*

(2015); Ahmad *et al.* (2015)]. This study would use binary switching regression model [i.e. as employed by Di Falco *et al.* (2011)].

3.3.1 Binary Endogenous Switching Regression Model

Binary endogenous switching regression model is extension of Heckman model. This is used to deal with statistical selection bias problem which may occur due to the endogenous binary variable such as decision to adapt climate changes. Like Heckman model, it also follows two step procedures to deal with selection bias. It differs from conventional Heckman model on the bases of following reasons.

1) The endogenous switching regression model follows two outcome equations for adapters and non-adapters, separately.
2) A counterfactual analysis can be made (i.e. differences in outcome variable between adapters and non-adapters, if adapters becomes non-adapters or vice versa)
3) It estimates simultaneously three equations such as outcome equations for both adapters and non-adapters, separately and treatment or selection equation.

3.3.2 Specification of the Model

The main aim of this study is to identify the impacts of adaptation to climate change on farm income in rice wheat region of rice growers. Therefore, Ricardian approach will be used to estimate net revenue (overall net farm income). Equation 3.4 is outcome equation where overall net farm income is outcome variable (dependent variable). It will be estimated by using binary endogenous switching regression model via two way procedure.

In 1st stage, we use selection model for climate change adaptation, to implement climate change adaptation strategies if it generates net benefits. Let A* be the latent variable that capture the expected benefits from the adaptation choice with respect to not adapting.

$$A_i^* = Z_i\alpha + \eta \text{ with } A_i = \begin{cases} 1 \text{ If } A_i^* > 0 \\ 0 \text{ otherwise} \end{cases} \quad \text{…………………………………… (3.5a)}$$

In above equation, A_i^* will be observed if $A_i > 0$ (A_i=1) and 0 otherwise. The vector Z represents the variables (socioeconomic and climatic factors) that affect the expected benefits of adaptation where treatment or selection equation (determinants of decision to adapt) will be estimated.

It has been argued that single output production function does not capture the possibility of switching crops, and therefore the estimated impact of climate change on production is biased (Mendelsohn, 1994). The adaptation decision to adapt or not is voluntary and may be based on individual self-selection. Treatment /Selection equation would be specifically gets following form.

$$A_i^* = \alpha_0 + \alpha_1 age\ of\ male\ HHH + \alpha_2 age\ square + \alpha_3 EDU\ of\ male + \alpha_4 EDU\ of\ female + \alpha_5 family\ size + \alpha_6 farm\ implements + \alpha_7 Punjab\ dummy + \alpha_8 Distanceextensionmarket + {} + \alpha_9 weatherinformation + \alpha_{10} socialnetworking + \eta_i \quad \text{………………………………………………………… (3.5b)}$$

Above equation will identify determinants of adaptation to climate change where dependent variable is adaptation which would be a binary variable, whereas, socioeconomic factors such as age and age square for experience, education of the farm male and female household head, distance to extension market, and weather information, provincial dummy for

Punjab, whereas, in the 2^{nd} stage we modelled the effect of adaptation on net farm income in rice wheat region along with other climatic and socio-economic factors.

To account for the selection biase, adopt an endogenous switching regression model of crop productivity where farmers face two regimes: to adapt; and not to adapt, which are given below.

Outcome Equation for Adapters

Regime 1: $Y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i}$ if $A_i = 1$ ………………………………………………… (3.6a)

Outcome Equation for Non-Adapters

Regime 2: $Y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i}$ if $A_i = 0$………………………………………………..... (3.6b)

Where Y_i is the farm income in rice wheat region per acre in regime 1 and 2 and X_i represent the vector of socio-economic factors, and climatic factor for both regimes and outcome equation in general form will be as specified for both adapters and non-adapters.

$y_i = \delta_0 + \delta_1 Age + \delta_2 edu + \delta_3\ owner + \delta_4 small\ farmers + \delta_5 marginal\ farmers +$
$\delta_6 credit + \delta_7 soilfertility + \delta_8 A +$ δ_9RiceA/cult+ δ_{10}nonfarm income + δ_{11}
Punjab+δ_{12}savings +δ_{13}temperature kharif+δ_{14}temperature rabi+δ_{15}precipitation
Kharif+δ_{16}precipitation rabi +δ_{17}kharif temp devi+δ_{18}rabi temp devi+δ_{19}kharif precip
devi+δ_{20}Rabi precip devi + ε_i ……………………………………………………….. (3.6c)

Equation (3.6c) is an outcome equation for overall net farm income for both adapters and non-adapters. Where, y_i is outcome variable whereas 'Age' shows age of household head, and EDU denotes for education of male, and savings, owner and marginal and small farmers, and access to credit market are other household variables. ‘A’ is adaptation to climate change i.e. changing sowing time, varietal change, soil and water conservation, and input intensification. Ratio of rice area to total area is used in the model to evaluate the impact continued rice cultivation on overall farm/land productivity, whereas ε_i is error term.

3.3.3 Counterfactual Analysis

This study also focuses on finding out the differences in expected gains (net farm income in rice wheat region) between adapters and non-adapters, and counterfactual cases as well. The endogenous switching regression model will be helpful to meet aforementioned differences. It provides: 1) expected gains from farm productivity for adapters; 2) expected gains for non-adapters, in counterfactual case; 3) expected gains for adapted households if they become non-adapters; and 4) finally expected gains for non-adapters if they become adapters.

To calculate above mentioned cases, study would estimate three major cases of treatment effects as suggested by Di Falco et al. (2011) and Ahmed et al. (2015), which are: a) Average Treatment Effect (ATE); b) Potential Outcome Means; and c) Average Treatment Effect on Treated (ATET) that will give us counterfactual case for adapters and vice versa. These are specified as follows.

1) **Average Treatment Effect (ATE):** ATE is the average effect of treatment in the population which is calculated as ATE = E (y_{1i} - y_{0i}) where y_1 is the outcome (net revenue attained from rice productivity) if the strategy adopted and y_o is the outcome for the same household in the case of being non-adapter.
2) **Potential Outcome Means (POM):** it is the average potential outcome for the treatment level for both adapters and non-adapters.

3) **Average Treatment Effect on Treated (ATET):** ATET is the average treatment effects of those who actually received the treatment (t=1) and is written as ATET = E (y_{1i} - y_{0i} | t=1) which gives the counterfactual analysis for actual adapters if they become non-adapters.

3.4 Definition of variables

This section covers the description of variables which are to be used in our empirical model binary endogenous switching regression model.

Age of Household Head: Age of the household head is a continuous variable recorded in years. Its expected effect is positive to decision to adapt.

Age Square of Male Decision Maker: square of age variable has been taken to observe the existence of non-linearity, and Di falco and Veronesi (2013) have used age square as proxy of experience as well. Therefore, this study has used this variable in treatment equation to see its impacts on the likelihood to adapt climatic changes.

Education of Male Decision Maker: Education is continuous variable and where completed years of the education of male decision maker have been used in both outcome and treatment equations separately. According to literature it affect positively to the decision to adapt.

Education of Female Decision Maker (Wife of Male Decision Maker): In Climate Change Impact Survey (CCIS, 2012-13), wife of male decision maker is said to be a female decision maker, therefore, this study has employed education of female decision maker to observe its impacts on decision to adapt climate changes. It is a continuous variable where numbers of total completed years of education are taken of female decision makers. It is expected it affect positively.

Tenancy Status: Tenancy status is measured in binary variable form where farmers are categorized into owner, owner-cum-tenant, and tenant. Tenant farmers and owner-cum-tenant will be kept as base category, whereas, a dummy variable of owner has been introduced in the model where it takes 1 if farmer is owner, and otherwise zero. Owner will have more ability to adapt so, it's expected affect will be positive.

Total Operational Area and Farmers Categories: Total operational area in acres has been used and it is a continuous variable. Further farmers are divided into four major categories on the basis of their land size i.e. marginal farmers, small farmers, medium farmers, and large farmers. A farmer is called marginal farmer if he/she has land less than 6.1 acres; She/he is called small farmers if holds below 12.5 acre; Medium farmer is if he/she holds more than 12.5 and below than 25 acres; and large farmer is hold up above 25 acres. These categories are measured in the form of dummy variable as used by Ahmad et al (2015) in their study. it is expected that A marginal and small farmers will have less net farm income and it negatively affect to the decision to adapt.

Soil Fertility: Soil fertility has been categorized into three categories such as poor fertility, average fertility, and good fertility. Actually this variable is based on farmer's perception where he is asked how much your area is good, bad or average fertile. CCIS (2012-13) contains its information in percentage for each category of soil fertility out of total area (in percentage). This study employs good fertility (in percentage) in outcome model to observe its impacts on net farm income, whereas, poor fertility, and average fertility are kept as reference categories as used by Ahmed *et al* (2015) and Iqbal *et al* (2015) in their studies.

Non-Farm Income: It is defined as income of farming family other than farm income such as income from private and public services, business and enterprises, and some other sources. A dummy variable has been used as: d=1 for non-farm income; otherwise zero. It is expected that Non-farm income will affect positively regarding decision to adapt.

Access to Credit Market: Access to credit market has been divided on the basis of two groups' i.e. formal source of loaning, and informal source of credit. Formal source consists on loan from banking and formal institutions. This variable is again a dummy form: where 1 is for having access to any of the formal or informal sources of credit, otherwise zero. It is expected that access to credit market will affect positively regarding decision to adopt adaptation strategies.

Social Networking: It is measured by dividing total number of times help receive with total number of times help given by households. Social networking will affect positively.

Adaptation Strategies: This study mainly deals with adaptation strategies. We focus on four major adaptation strategies including sowing time change, input intensification—use of more irrigation, seed and fertilizers, varietal change, water and soil conservation. It is commonly observed that farmers are adopting more than one strategy simultaneously which means these are not mutually exclusive. To make them mutually exclusive, various combinations were made. All these adaptation strategies are in binary variable form. Literature strongly suggests that adaptation strategies have positive effect on net farm income.

Weather Information: weather information has been divided into three major groups which are information from media, informal sources, and 'do not know' category. All these categories are in binary variable form where we introduce media source of weather information in model.

According to literature updated farmers take decision regarding adaptation so; its expected result is positive.

Government Extension: it is measured in the form of dummy variable if farmers have received help and assistance from government during adaptation and any shock regarding agriculture is assigned 1 otherwise zero. Literature strongly suggests that government extension affect positively in decision to adaptation.

Climatic Factors: 20 years long run averages of monthly temperature and precipitation are used, and further, deviations from mean are also used. Temperature and Precipitation variables are used as last 20 years mean in Kharif and Rabi season to see the impact of climate change on farm income. We have also used deviations of temperature and precipitation for the data year from their respective long term means to capture weather shocks in Rabi and Kharif Seasons. Climatic factors may affect positively or negatively to the net-farm income.

Rice Area/ Total Cultivated Area: Ratio of rice area cultivation with the total area of cultivation.

Farm Implements: If farmers possess any of tractor, thresher, and complementary machinery of tractor then binary variable takes 1, and otherwise zero.

Extension Distance from Village: It is a continuous variable and is measured in total distance of extension office from village in kilometres. In literature increasing distance affect negatively to the decision to adapt generally.

Savings Management: Savings is another variable that is supposed to influence on adaptation to climate changes positively. This includes personal savings and seed stocks kept for next season. This is dummy variable and takes a value of 1 and 0. If households consumed up all types of saving then it will have vale 1, otherwise 0. It is expected that Savings affect positively to the decision to adapt.

Provincial Dummy: A dummy variable has been generated for the province Punjab—if Punjab the variables take value of 1, otherwise zero (for Sindh).

Chapter 04

Results and Discussion

This chapter discusses descriptive statistics of the variables and the results of estimated Endogenous Switching Treatment Effect Model (ESTEM). The ESTEM provides two outcome equations—adapters and non-adapters. The ESTEM is estimated separately for three combinations of adaptation strategies.

4.1 Descriptive Analysis

This section discusses the frequency tables and summary of continuous variables being used in this study. Following are the descriptive statistics such as mean, standard deviation, minimum and maximum value of the socio-economic characteristics of the farmers about age, earnings, education, family size, fertility of the land, social networking, extension distance, wheat, rice area and their ratio to the total land etc.

Table 4.1 indicates that average age of the male decision maker is found about 48 years ranging between 18-90 years. The statistics regarding the education of male and female decision makers are suggestive that average education of male decision makers are almost 6 completed years which is above primary and below middle class whereas average education of female decision makers are found below primary (2 completed years of education) which shows that in rice-wheat zone female decision makers are poorly educated as compared to the male decision makers.

Table 4.1: Summary of the Socioeconomic, and Farm related Characteristics						
Variables	**Observations**	**Mean**	**S.D.**	**Min.**	**Max.**	**Unit**
Net Farm income	643	48506.69	32726.51	200	135127.50	Rupees
Male Education	643	6.37	4.93	0	16	Year
Female Education	638	2.09	3.70	0	14	Year
Family Size	643	7.33	2.93	2	20	Number
Operational Area	643	10.15	19.68	0.50	400	Acre
Rice ratio area	643	0.39	0.17	0	1	Ratio
Rice Area	643	7.99	18.77	0	390	Acre
Wheat area	643	7.93	18.47	0	380	Acre
Wheat ratio area	643	0.39	0.14	0	1	Ratio
Bad Fertility	643	19.20	31.82	0	100	Percentage
Average Fertility	643	50.67	33.57	0	100	Percentage
Good Fertility	643	30.13	40.83	0	100	Percentage
Social Networking	641	0.94	0.32	0.14	3.33	Index
Extension Distance	643	7.44	5.23	0	22	Kilometer
Age of Male HHH	643	48.42	12.73	18	90	Year

Author's own calculations from CCIS (2013)

Average family size is found as 7-8 persons ranging between 2-20 persons in a family in selected sample districts of rice-wheat zone.

Farming related variables indicate that farmers are holding almost 10 acres average operational area with huge range from a minimum of 0.50 acres to a maximum of 400 acres. This variation is understandable because in this study our sample is from Punjab and Sindh provinces. About 8 (80%) acres per farm are found under rice in kharif and the same area is then under wheat in

Rabi season. These statistics are suggestive that in rice-wheat zone, rice and wheat crops are widely grown (see Table 4.1). Furthermore, out of total cultivated area almost 20 percent has poor or bad quality soils, whereas 50 percent is average quality and 30 percent is said to be of good quality. On average farmers are earning almost Rs.49,000 per acre as net farm income ranging between Rs.200 to Rs.135127.

Table 4.2 categorises of income earning groups. It can be seen clearly that almost 9 percent households are earning less than or equal to 25000 rupees per acre net farm income, almost 17 percent households are earning below or equal to 50000 rupees whereas almost 31 percent households are earning annually 50000-70000 rupees per acre of cultivated area; and 8 percent of the household are earning more than Rs.100000/acre (Table 4.2).

Table 4.2: Frequency of Net Farm Income Groups

Income Groups*	**Frequency**	**Percent**	**Cumulative**
Less than 25000	61	9.49	9.49
25000-40000	114	17.73	27.22
40000-50000	112	17.42	44.63
50000-70000	201	31.26	75.89
70000-100000	101	15.71	91.6
More than 100000	54	8.4	100
Total	**643**	**100**	_

*Unit of income is Pakistan Rupees.

Table 4.3 reports the statistics of adaptation strategies—which are mutually exclusive. Generally majority of the farmers are found adopting four major types of adaptation strategies such as: 1) input intensification; 2) varietal change; 3) changing sowing and harvesting time; and 4) water and soil conservation strategy. It is commonly observed that farmers adapt more than one strategy. For the sake of analysis to avoid this problem, we generated fifteen mutually exclusive combinations and the results are reported in Table 4.3. It is evident that three combinations C-

123, C-134, and C-1234 are the prominent combination of strategies. Due to mutually exclusive in nature, number of adapters in each strategy varies significantly, and are quite low in numbers. The C-123—combining input intensification, varietal change and changing sowing time, is adapted by 117 farmers; C-134—covering input intensification, changing sowing time and water and soil conservation, is adapted by 138 farmers; whereas C-1234—including input intensification, varietal change, changing sowing time and water and soil conservation, is adapted by 93 farmers. The C-13 combination is adapted by only 90 farmers. Stand-alone adaptation strategies (C-1, C-2, C-3, and C-4) are adapted by a very few farmers.

Table 4.3: Frequency of Adaptation Strategies

Strategies	Frequency	Percentage
C-1	19	2.95
C-2	8	1.24
C-3	13	2.02
C-4	4	0.62
C-12	22	3.42
C-13	90	14
C-14	16	2.49
C-23	45	7
C-24	4	0.62
C-34	7	1.09
C-123	117	18.20
C-234	14	2.18
C-134	138	21.46
C-124	14	2.18
C-1234	93	14.46

Note: numbers attached with first column from left side are:
1> Input intensification
2>Varietal change
3> Changing sowing and harvesting time
4>Water and soil conservation strategy

4.2 Endogenous Switching (Treatment Effect) Regression: The Results

The major objective of this study is to identify the impacts of adaptations to climate change on net farm income per acre in rice-wheat zone. The results of endogenous switching treatment effect model are discussed in this section.

4.2.1 Impact of Adaptations to Climate Change on Net Farm Income

Endogenous switching treatment effect model gives estimated treatment effects and counterfactual as well. The estimated effects of adaptation strategies on net farm income are presented in Table 4.4. Only three combinations of strategies are estimated which are C-123,C-134 and C-1234. These combinations of strategies were found to be the most popular in the rice-wheat zone.

The results suggest that C-123 yields negative ATE which is the difference between potential outcome means of adapters ($POM_{1)}$ and potential outcome means of non-adapters (POM_o). It is evident from Table 4.4 that POM_0=57872.8 and POM_1=17068.49 which makes ATE=-40804.31. It indicates that those farmers which are adapting C-123 are earning less profit than non-adapters of this combination. This result shows that this combination is not beneficial for adapters, and the non-adapters of this combination remain profitable. Counterfactual of the adapters of this strategy shows that if all adapters become non-adapters then they may yield less profit as compared to staying adapters. The positive sign of ATET shows that if adapters stay as adapters, they would earn Rs.3881 each more than being non-adapters. It implies that overall impact of this combination has been revealed positive but returns are not as higher as actual non-adapters are yielding.

The results for C-134 and C-1234 indicate highly positive and significant impacts on farm income. Contrary to C-123, adapters of C-134 and C-1234 combinations are found yielding higher net farm income as compared to non-adapters. Moreover, counterfactuals in these cases of adapters suggest that if adapters of these two combinations become non-adapters, they have to bear loss and these results are statistically significant. Counterfactuals are reported in Table 4.4 where POM_0 is potential outcome mean for non-adapters (which are actually adapters), and ATET is difference of the POM_0 and POM of adapters amongst sub-population of adapters. Table 4.4 also suggests that C-1234 is better profit yielding (75614.6 rupees) combination among the three estimated in the study.

Hence, we have found positive and significant impacts of adaptations to climate change on farm income of adapters in rice-wheat zone. Only non-adapters of the combination (C-123) have been found more profiteering than adapters of this combination. These positive impacts of adaptations compare well with the findings of existing literature [Di Falco et al (2011); Ahmad et al (2015); Iqbal et al (2015); Dehlvi et al (2015)].

Table 4.4: Impact of Adaptations to Climate Change on Net Farm Income (per acre)

	Treatment Effects for Both Adapters and Non-Adapters			**Treatment Effects within Group of Adapters**	
Strategies	**ATE**	**POM_0**	**POM_1**	**ATET (1 Vs 0)**	**POM_0**
C-123	-40804.31**	57872.8	17068.49***	3881.395*	55692.27***
C-134	54514.04***	4677.393***	59191.44*	3286.583**	62860.24***
C-1234	75614.6*	54994.49***	130609.1***	54834*	40839.97*

*Note: ***, ** and *shows the level of significance at 1%, 5%, 10%.*
C-123= Combination of input intensification, varietal change, changing sowing time
C-134= Combination of input intensification, changing sowing time, water and soil conservation
C-1234= Combination of input intensification, varietal change, changing sowing time, water and soil conservation
ATE= Average Treatment Effect
POM_0=Potential Outcome Mean for Non-Adapters
POM_1= Potential Outcome Mean for Adapters
ATET= Average Treatment Effect on Treated

4.2.2 Socioeconomic Determinants of Net Farm Income: Outcome Equations

This section will discuss findings obtained from outcome equations for both adapters and non-adapters separately where socioeconomic determinants of farm income are observed. Table 4.5 presents results of outcome equations of three models for C-123, C-134, and C-1234.

Age of the male household decision maker have no significant impacts on net farm income in all three estimated models. Education of the male decision maker has been found positive and significant in models of C-123, and C-1234. These positive impacts are for non-adapters in C-123, and for adapters in C-1234. It implies that education of male decision makers brings about increase in farm income of adapters and non-adapters as well. Non-farm income has positive impacts on farm income but these impacts are significant only for the adapters of C-134. These results are consistent with the findings of Di Falco et al (2011).

We introduced good fertility of soil in model whereas average and bad fertility categories are kept as reference category. The estimated results suggest that good fertility of soil has statistically insignificant impacts for both adapters and non-adapters in all three models. Dummy variable of owner has been found statistically insignificant in all three models. Further estimated results indicate that marginal and small farmers are found earning lesser income as compare to medium and large farmers. These negative impacts of marginal and small farmers are statistically significant almost in all models for both adapters and non-adapters. These results are consistent with the findings of Di Falco et al (2011) and Ahmad et al (2015).

Ratio of rice area to total area has been used in all three models, and the results indicate that it has positive and significant impact on net farm income in adapters equations—of Models C-123 and C-1234, while found having insignificant but negative impact in case of C-134. In non-adapters models the proportion of rice area variable has shown negative but statically non-significant impact on net farm income. These results highlight the fact that non-adapters to climate change would be at a risk of losing net farm income per acre if they continue to increase area under rice. However, if farmers adapt to changes in climate, they would significantly gain by growing rice (see Table 4.5). Interestingly, when the climatic variables are excluded from the estimation of models, the impact of ‘rice area ratio variable becomes negative and significant for non-adapters in all three models (see Table 4.6). The impact remains however positive but magnitudes of the coefficients of ‘rice area ratio’ variables reduced significantly in adapters’ models. These results imply that climate change and continuously growing rice both have system’s productivity dampening effects in rice-wheat systems of Pakistan. However, these effects can be moderated by adapting agricultural farming to climate change (Table 4.6).

Table 4.5: Estimated Outcome Equations for Adapters and Non-Adapters (Determinants of Net Farm income in Rice-Wheat Zone)						
Variables	**C-123**		**C-134**		**C-1234**	
	Adapters	**Non Adapters**	**Adapters**	**Non Adapters**	**Adapters**	**Non Adapters**
Age of Male	-301.09	-116.24	-288.94	-100.30	47.69	-192.33
Education of Male	522.76	527.79**	673.43	391.90	614.37**	342.76
Good Fertility of Soil	-109.59	-6.45	-42.28	--2.78	68.25	-17.02
Non-farm income	6374.32	1128.04	4206.73*	1262.14	-1520.85	3109.71
Loan Access	768.77	3809.50*	1130.13**	4783.15	7832.48	2016.20
Marginal Farmer	-6070.93	-16774.09***	-10987.95	-13465.95***	2810.84	-15668.21***
Small Farmers	5631.87	-12600.4***	-18949.9**	-4966.89	-1547.07	-10279.03**
Owner	5721.94	-903.24	-7089.50	1641.60	-1824.58	891.91
Rice/Total Area	7652.27**	4536.85	-13628.04	9518.79	65409.32***	2482.24
Saving	16104.97***	4745.09*	10220.89*	4090.09	-2007.55	5900.61**
Punjab	-113633.8	-21953.21	37554.41	-60988.07***	48934.2	-34640.54
20 year Average Temperature Kharif	12329.23	34151.12***	29636.97*	30147.78***	22068.51	32145.48***
20 year Average Temperature Rabi	-37518.4*	-47858.02***	-43863.07*	-49880.89***	-16442.87	-47926.84***
Deviation Temperature Kharif	-14756.89	-38793.49***	-82979.16	-30141.9***	-4965.35	-38275.94***
Deviation Temperature Rabi	18174.74	47404.78***	73731.24*	39716.3***	15475.12	44696.11***
20 year Average Precipitation Kharif	1275.64**	250.28	1508.61	344.89	-210.05	353.88
20 year Average Precipitation Rabi	899.76**	-899.17	-4465.38*	-1277.99*	1410.02	-1147.92
Deviation Precipitation Kharif	-513.72	561.59	968.55	320.75	-1682.89	442.50
Deviation Precipitation Rabi	899.76	270.23	906.92	362.7	450.14	405.23
Constant	6221.71	-939.29	5059.78	-143.98	7469.39	-335.426

Table 4.6:Estimated Outcome Equations when Climatic Variables Dropped						
Variables	**C-123**		**C-134**		**C-1234**	
	Adapters	**Non Adapters**	**Adapters**	**Non Adapters**	**Adapters**	**Non Adapters**
Age of Male	-206.84	-183.30	-420.12**	-136.73	-28.18	-226.24
Education of Male	373.35	610.79**	636.03	655.22**	1043.84*	491.63*
Good Fertility of Soil	-35.38	36.43	-43.60	37.028	76.75	26.80
Non-farm income	6897.00	1846.23	4176.62	1520.67	-171.00	2830.32
Loan Access	-2073.90	3562.41	2818.11	3121.91	4806.94	1751.79
Marginal Farmer	-491.40	-17932.32***	-11528.58	-13731.75***	-231.53	-16353.67***
Small Farmers	6737.42	-12765.7***	-20417.98***	-4835.59	-2439.38	-9895.66*
Owner	5495.65	-1685.08	-6104.41	1296.79	-4170.24	698.24
Rice/Total Area	28470.44	-2863.24*	-16664.14	-10885.05**	57452.36***	-149.90**
Saving	15783.84***	5173.48*	10583.85**	4779.71*	-1870.10	6566.14***
Punjab	23155.37***	17260.88***	26263.82***	21750.32***	24168.43***	17950.46***
Constant	3151.57	-1034.02**	10732.89	-6867.91	5948.86***	1698.21

The results in Table 4.5 further reveal that access to credit and having precious saving would have some positive impacts on increasing the farm profitability. These results are consistent with the findings of Di Falco et al. (2011) and Ahmad et al. (2015).

The results reported in Tables 4.5 and 4.6 further highlight the fact that farm productivities/net farm incomes per unit of land in Punjab are not statistically different from its prevalence in Sindh when controlled for impacts of climate change indicators. However, we found productivity in Punjab significantly higher than Sindh if the model is not controlled for climate related variables that implies that climate related adverse impacts are much stronger in Sindh than in Punjab.

Long run averages and deviations of temperature and precipitation have been introduced in the model to find out their impacts on the net farm income. Their impacts vary across the rabi season, and kharif season. The estimated results show that climatic factors (temperature and precipitations and their deviations) have some significant impacts on net farm income in the rice wheat zone in Pakistan. Table 4.5 indicates that long run average temperature in kharif season has positive impacts on the net farm income whereas, long run deviations of respective season have negative impacts and all these impacts are statistically significant. As far as average Rabi temperature is concerned, it negatively impacts farm income and its deviations have positive and significant effects on the net farm income.

Moreover, the impacts of long run average precipitation and its deviations have positive impacts on the net farm income of adapters of C-123 but in rests of models, its effects are found statistically insignificant. But deviations in precipitation have negative and significant impacts on the farm income of adapters and non-adapters of C-134.

4.2.3 Determinants of Adaptations to Climate Change (Estimated Treatment Equations)

Table 4.7: Determinants of Adaptations to Climate Change

Variables	C-123	C-134	C-1234
Age	.0129344	-.0046112	.0298226
Age square	-.0001013	.0000678**	-.0002734
Education	-.0181049	-.0054849	.0077538*
Female education	-.003704	.0085536	.0176252
Family Size	-.0214519*	-.0267532	-.0016343
Social Networking	.7047951	.4989424***	.2087296***
Extension Distance	-.0008496	-.0020514	-.0325239
Farm Implements	-.0179038	-.0655246	.371037*
Govt. Extension	-.4155668*	.7709943**	.080683*
Weather information from Media	.1857595**	-.9665387	.0526905*
Punjab	-.2329116	1.052384***	-.2261281
Constant	5.15	-38.65	-23.26***

From endogenous switching treatment effect models, we obtained three estimated treatment effects where determinants of adaptation to climate change have been estimated. Treatment variables (C-123, C134, and C-1234) are regressed on age, age square, male and female education, family size, social networking, extension distance, government extension, source of weather information, and provincial dummy of Punjab province.

Table 4.7 suggests that age of male household head has been found statistically insignificant in all models but its square term has positive and significant impacts only in adapting C-134. It implies that nonlinearity among adapters of C-134 prevails, and it is proxy for experience as and Difalco and Veronesi (2013) have used age square as proxy of experience, intuitively these finding suggest that higher experienced households are more likely to adapt (C-134). These results are consistent with findings of Difalco and Veronesi (2013) and Di Falco (2014).

Education of male head is found having positive and statistically impacts only on decision to adapt C-1234 but education of female decision makers have been found statistically insignificant. It implies that other things remaining same, educated male heads are more likely to adapt climate changes. These impacts are found consistent with the findings of Di Falco et al. (2011) and Ahmad et al. (2015).

Social networking which is a ratio of number of time help receives and number of time help given has been found positively and significantly affecting decision to adapt to climatic changes. Furthermore, dummy variable of farm implements such as possession of tractors, thresher, etc. has been having positive impacts and significant on decision to adapt but these positive impacts are only in C-1234. These two variables enhance adaptive capacity of the farmers which ultimately leave positive and significant impact on adaptation.

The results further indicate that households who receive government extensions services are more likely to adapt to climatic changes. Households receiving information through media are more likely to adapt to climate changes as compared to those who rely on conventional medium. Furthermore, dummy variable for Punjab province has positive impacts on decision to adapt which implies that Punjab province is more likely to adapt as compared to Sindh.

4.3 Limitations of the Study

The major limitation of the study is coverage of limited districts of rice-wheat zone of Pakistan because our data set (CCIS, 2012-13) where only three districts are chosen from rice-wheat zone of the Pakistan (i.e. Sialkot, Hafizabad, Larkana. Moreover, we just focused on the farm income received from major contributing crops (i.e. wheat, rice, sugarcane, and maize etc.) but income received from other farm sources are not included due to unavailability of data. Scope of the study can be enhanced for further study by dealing aforementioned limitations of the study.

Chapter 5

Conclusion and Policy Recommendations

5.1 Conclusion

The major objective of this study was to identify the impacts of adaptation to climate change on farm income in rice-wheat zone. Sample of 643 farm households in districts of rice-wheat zone (Sialkot, Hafiz Abad, and Larkana)was taken from a larger household survey conducted by the Pakistan Institute of Development Economics in collaboration with IDRC, Canada, in three provinces of Pakistan—Punjab, Sindh and KPK.

This study employs endogenous switching treatment effect model to find out determinants of farm income, factors in decision to adapt, and counterfactual analysis. Four major categories of adaptation strategies include; input intensification (C1); varietal change (C2); changing sowing time (C3); and water and soil conservation were considered (C4). It is commonly observed that farmers adapt more than one strategy at a time. Therefore, we generated fifteen mutually exclusive combinations of the adaptation strategies.

Only three models were estimated because of less number of observations. The results suggest that the adaptations to climate change have positive and significant impacts on farm income in rice-wheat zone. The results generally imply that adaptation to climate change proved beneficial for farming communities. Furthermore, the counterfactual analysis suggests that if adapters become non-adapters, they have to bear loss.

Results of outcome equations suggest that education, access to credit and having savings at hand are found positively and significantly affecting farm income. The results further indicate that ‘continued growing rice’ at farm in the presence of changes occurring in climate would reduce farm income/profitability through reducing farm productivity. However, if farm households adapt to climate changes, they could reap higher farm productivity through reduced adverse impacts of climate change.

The results of treatment equation indicate that education and experience of farmers positively and significantly influence the decision making to adapt to climate changes. Moreover, social networking which is a ratio of number of time help receives and number of time help given has been found positively and significantly affecting decision to adapt to climatic changes. Furthermore, the ownership of farm implements also positively impact decision making to adapt. These two variables enhance adaptive capacity of the farmers which ultimately leave positive and significant impact on adaptation. Punjab province has appeared yielding higher farm income because its farmers are more likely to adapt climatic changes.

5.2 Policy Recommendation

The results suggest that adaptations to climate change have positive and significant impacts on farm income in rice-wheat zone. The results further reveal that without following the water and soil conservation strategy, no combination would be beneficial to moderate the impacts of climate change. On the basis of results following policy recommendations are put forward.

- Farmers are advised to follow water and soil conservation strategies besides other adaptations to climate change.
- There is need to enhance awareness about climate changes and its negative impacts, importance of adaptations so that farmer adapt to climatic changes.
- The government extension departments should play an active role in creating awareness among the farm communities and also advise them about the adaptations.
- Government must take some steps to enhance adaptive capacity of marginal and small farmers because they earn significantly low profits.

Way Forward

This study focuses on the adaptation to climate change in rice-wheat zone particularly. It is addition to literature regarding adaptations in said zone particularly in agriculture sector generally. But its domain was limited in two ways: it focuses on only three districts of rice-wheat zone and it calculates only crop income of the farmers. So this work can be extended to the whole rice-wheat zone and other agriculture sectors like horticulture and fisheries can be taken in board. With this, pattern of study can be applied to the every agro-ecological zone of Pakistan to check the comprehensive impacts of climate change on agriculture and role of adaptations to abate the adverse effects of climate change.

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