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From Perception to Adaptation to Climate Change: Farm-Level Evidence from Pakistan

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From Perception to Adaptation to Climate Change: Farm-Level Evidence from Pakistan

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ABSTRACT

The economic costs of climate change are principally dependent on extent of adaptation to the changing climate. This study explores how farmers with different socioeconomic characteristics and land endowments perceive long term changes in climate and, correspondingly, how do they update their farming practices? We contend that different socio-economic endowments, social interactions and exposure to and source of information may shape significant differences in climate change perceptions and the corresponding adaptation strategies of the farmer(s). The analyses are based on data from Climate Change Impact Survey [CCIS (2013)] wherein 3430 farmers were interviewed from farming communities of Pakistan. Applying Exploratory Data Analysis (EDA) and Heckman's Treatment Effect model, we find the evidence that climate change perceptions and resulting adaptation strategies vary across gender, size of land holdings and the land ownership status and that the difference is significant statistically. The results further indicate that family size, access to credit, land holdings size, government extension and farm experience are significant determinants of farm level adaptation. Farmers with small land holdings and those who are tenant are found more responsive to climate change through effectual adaptations.

Keywords: Perceptions; Adaptations; Economic Costs; Climate Chang; Agriculture; Farm Size; Land Ownership Status; Pakistan; Heckman Model

I. INTRODUCTION

Global climate change is one of the most critical challenges that the international community faces at present. Climate change and its variability indicates severe risk to lives and livelihoods, particularly for the world's poorest and the most vulnerable populations due to its adverse consequences on human health, food security, economic activities, natural resources and physical infrastructure [IPCC (2007); Huq, *et al*. (2006)]. Of all the sectors of any economy, agriculture being the main source of providing livelihoods to majority of the rural households, is extremely vulnerable to climate change. The extent of vulnerability depends, along with exposure and sensitivity, upon adaptive capacity of a household. Due to this reason, voluminous literatures on climate change and agriculture focuses on the issue of adaptation and the consensus is emerging that level of adaptation is very low in developing countries, and hence the developing countries are badly affected by the negative impacts of climate change [IFAD (2010)].

Pakistan, like many other developing countries, is considered to be more vulnerable to the impacts of climate change. Climate change is considered as one of the potential threats for agriculture sector and livestock universally and in Pakistan specifically. Changes in climatic conditions do have adverse effects on the agriculture sector, livestock production, human health and, consequently, on Pakistan's economy. These changes hit poor and populous regions dependent on rain-fed agriculture austerely and consequently pose a challenge to develop a climate change response mechanisms.

As there is limited scope of mitigation for developing countries because of lower share in carbon emissions, effectual adaptation serves as the key to success in combating adverse effects of climate change. However, less attention has been paid to the issue of adaptation to climate change in Pakistan. The scope of the research that links climate change to agriculture is very limited in Pakistan and so is the farmers' perception regarding climate change and adaptation practices. To-date, studies on climate change and agriculture in Pakistan have been entirely limited to impacts of climate change on particular

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The first author is presently Research Fellow at Sustainable Development Policy Institute (SDPI), Islamabad while the second author is PhD scholar at Pakistan Institute of Development Economics (PIDE), Islamabad. This paper is an outcome of the project funded by IDRC and implemented by PIDE. The work on this paper was undertaken when the first author was at PIDE as Senior Research Fellow in the project. Authors are thankful to project and data collecting team(s) at PIDE.

crops or sectors.[1] To the best of our knowledge, only Abid, *et al*. (2014) studied the farmers' perceptions and their adaptive behaviour in Pakistan. According to this study, people are aware about the climate change and farm households make adjustments to adapt their agriculture in response to climate change. But this study is limited to the districts of the Punjab province only and does not provide a representative sample for Pakistan.

Against this backdrop, broadly speaking, this study investigates adaptation methods adopted by the farm household and the driver thereof. The analysis revolves around the argument that different socioeconomic endowments, social interactions and exposure to information sources may shape the climate change perceptions varying by gender, land ownership status and size of land holdings. These differences in formation of climate change perceptions are then transmitted to the difference in adaptation strategies. The main objective of this study is to explore how farmers with different socioeconomic and land endowments perceive long term changes in climate and, based on the perceived changes, how do they alter their farming practices to minimise the climate change related damage. The following is a structure detail for the rest of the paper:

Section 2 details data and methodology while descriptive and empirical results are discussed in Section 3. Finally, Section 4 concludes the paper and recommends policies for improving the existing adaptation practices.

2. DATA AND METHODOLOGY

The current study is based on Climate Change Impact Survey [CCIS (2013)] wherein 3432 farmers were interviewed from farming communities of three provinces (Punjab, Sindh, KPK) of Pakistan[2]. The Pakistan Institute of Development Economics (PIDE) in sponsorship with the IDRC carried out this survey in 16 districts[3] of the above mentioned provinces. In order to investigate and to analyse the factors that affect the farmers' perception and adaptation to climate change in Pakistan. We apply Treatment Effect *model* which undertakes estimations simultaneously for adapters and non-adapters and also is a form of switching regression [Madala (1983)].[4] Noticeably, adaptation to climate

[1]Hanif, *et al*. (2010), Ashfaq, *et al*. (2011), Javed, *et al*. (2014) and Ahmad, *et al*. (2014a and 2014b).

[2]Baluchistan (the fourth province of Pakistan) is not surveyed due to some security issues.

[3]Attock, Bahawalpur, Bhakkar, Chakwal, Charsadda, D.I. Khan, Hafizabad, Haripur, Jhang, Kohat, Larkana, Mirpurkhas, Nawab Shah, Sanghar, Sialkot and Vehari.

[4]In existing literature, many of the researchers such as Benedicta, *et al*. (2010), Apata, *et al*. (2009), Yesuf (2008), Mabe, *et al*. (2014) applied logit and Probit model to investigate the factors that affect the adaptation while some others, Sofoluwe and Baruwa (2011), Obayelu, *et al*. (2014), Owombo, *et al*. (2014) used the multinomial logit model. Multivariate Probit model is also used by Nhemachena and Hassan (2007), Nhemachena, *et al.* (2014) to explore the determinants of adaptation. Maddison (2006), Okonya, *et al*. (2013), Deressa, *et al*. (2010), Sofoluwe, *et al*. (2011) applied the conventional Heckman two step selection model to analyse the factors of adaptation.

change is a two-step procedure. Firstly, it involves perceiving the changes in climatic conditions and then, on the basis of perceptions, taking the decision whether to adapt or not by considering a specific adaptation strategy. This leads towards the problem of selection bias because only those who perceive climate change will adapt whereas it is required to make inferences about the adaptation made by the agricultural population as a whole. So, we use Treatment Effect model to solve the problem of selection bias.[5] Further, failing to counter unobservable determining the perception, may result in over or underestimation of the impact [Green (2003)]. Conventional Heckman models just give the solution of selection bias but they do not give counterfactual analysis directly. It is for this reason Treatment Effect is preferred over conventional Heckman Two-Step procedure.

2.1. Model Specification

2.1.1. *Selection Equation*

The Hekman's model includes two equations namely selection and outcome equation wherein the selection equation is used to capture the selection bias while outcome equation is the specification of interest. Perception is taken as dependent variable in the selection equation. Respondents are classified into two categories, farmers who perceived the changes in the climatic conditions and the farmers who did not.

Similar to the Heckman model, Probit model for sample selection equation is estimated to incorporate unobservable characteristics. Selection bias is observed through inverse mills ratio (λ) which automatically entered as an independent variable in outcome equation. This is one of the main advantages of applying the Treatment Effect model as compared to the Heckman approach. It is also noted that Treatment Effect model handles treatment effect score and selection bias simultaneously [Green (2012)].

Sample selection equation can be written as follows;

$$d_i = x_i\alpha + \mu_i$$

Where, $d_i > 0$ and 0 otherwise

$$\text{Prob}\,(d_i = 1 \mid x_i) = \phi(x_i\alpha) \text{ and}$$
$$\text{Prob}\left(d_i = 0 \mid x_i\right) = 1 - \phi(x_i\alpha)$$

The dependent variable is in binary form as farmers who perceived changes took the value 1 (perceived=1) otherwise zero and d_i could be estimated when $d_i = 1$ if $d_i > 0$ and for $d_i = 0$ otherwise. This can be

[5]Table A in appendix provides the information on socioeconomic characteristics of adapter and non-adapters

explained also in term of conditionality of adaptation on perception. The vector of explanatory variable which includes age of household head, education, farm experience, ecological zones dummies etc. is represented by x_i. Furthermore, α is a vector of coefficients and μ_i is an error term. Given selection bias and that *'d'* is an endogenous variable, the evaluation task is to use the observed variables to estimate the regression coefficient β. Lambda or inverse mills ratio which captures the problem of selection bias is calculated as:

$$\lambda = \phi(x_i/1 - \phi(x_i\ \alpha)).$$

Here, ϕ is a density function and α shows the normal distribution.

2.1.2. *Outcome Equation*

Outcome equation, carrying the variable of interest or policy as dependent variable, can be written as follows:

$$z_i = y_i\beta + d\alpha + \varepsilon_i$$

Where z_i is adaptation to climate change variable while y_i denotes the vector of explanatory variables such as age of household head, education, marginal farmers, medium farmers, large farmers, access to credit, livestock index. β is set of parameters and d is a dummy variable of perception coming directly from selection equation which is known as treatment effect score in outcome equation. It gives counterfactual analysis or significant differences of treated and non-treated households. ε_i is an expression of error term of outcome equation.

2.2. Description of Variables

Our main concern is to discuss the factors influencing the adaptation strategies of the farmers in Pakistan. Adaptations to climate change in the outcome equation are conditional upon the sample selection equation. In this model, the dependent variable is adaptation to climate change which is generated by using the Likert scale that takes into account all the strategies adopted by farmers.[6] Constructing the dummy of adaptation variable gives equal weights to farmers irrespective of the number of adaptation strategies undertaken. It is a revealing fact that multiple adaptation strategies adopted simultaneously may have different impact than that originated by any single adaptation strategy. Likert scale gives the average representation of the total numbers of strategies adopted (as ratio to the total strategies available) by farmers and captures the interactive impact of multiple adaptations mutually

[6]Constructing the dummy of adaptation variable gives the value one even if more than one strategy is adopted by farmer but Likert scale gives the average representation of the total strategies adopted by farmers.

reinforcing the climate changes combating capacity. Likert scale, is constructed as follow:

Adaptation=number of strategies adopted by a farmer/total number of strategies

The main independent variables include household characteristics, farm characteristics, and institutional factors which shape the behaviour to adaptation and choice of particular adaptation strategies. These variables were selected on the basis of previous studies,[7] include age, education, family size, non-farm income, farm experience, access to credit, livestock ownership, government extensions, temperature, precipitation, etc. Tables 1 and 2 provide a description of the model variables for the Treatment Effect model. The dependent variables are perception and adaptation. The explanatory variables for selection include different households and socio economic factors that affect the farmers' awareness to climate change.

Table 1

Description of Model Variables for the Selection Equation of the Treatment Effect Model

Dependent Variable		
Perception of Climate Change (takes value of one if perceived and zero otherwise)	1/0	
Independent Variables		
Description	Mean	Std. Deviation
Age (Continuous)	48.21	13.088
Education (Continuous)	5.62	4.891
Farming experience (Continuous)	24.92	13.002
Social_Index (Continuous)	0.02721	0.020721

It is important to remind here that Table 1 provides the descriptive analysis for only continuous variables as *Mean* and *standard deviation* are meaningless for categorical variables.[8] Framers in our sample have an average age of 48 years suggesting a good amount of farming experience which is also further reconfirmed by average experience of almost 25 years. Both these indicators have significance in the context of formation of perception regarding climate change i.e. changes over more than 20 years. Age of the farmer characterises his experience in farming and it is more likely, the older the farmer is, the more he is aware about the past and present climatic conditions over his

[7]Benedicta, *et al*. (2010), Apata, *et al*. (2009), Yesuf (2008), Mabe, *et al*. (2014), Sofoluwe and Baruwa (2011), Obayelu, *et al*. (2014), Owombo, *et al*. (2014), Nhemachena and Hassan (2007), Nhemachena, *et al.* (2014), Maddison (2006), Okonya, *et al*. (2013), Deressa, *et al*. (2010), Sofoluwe, *et al*. (2011).

[8]Details on categorical variables are reported in frequency distribution analysis.

life spans. Education is measured through completed years in school. On average, every farmer in our study passed primary education level. The more educated the farmer is, the more likely he will adopt different strategies in an effective way. Farm experience shows the total number of years that a farmer has spent making decisions about farming. A farmer is better informed about the changes in temperature and precipitation if farming experience is high. Farming experience helps in employing adaptation measures to reduce the negative effects of climate change on agricultural activities. If the entire land is owned by the famer then it is more likely that he will adapt different measures as result of changes in climate. Household size represents the total number of members in a household and is assumed to represent the labour input to the farm.

Table 2, provides description of the explanatory variables included in outcome equation. Again, as explained above, mean and standard deviation is not reported for categorical variable.

Table 2

Description of Model Variables for the Outcome Equation of the Treatment Effect Model

Dependent Variable	Farmers that have adapted	
Adaptation of Climate Change (Continuous)	Likert Scale	
Independent Variables		
Description	Mean	Std. Deviation
Age (Continuous)	48.21	13.088
Education (Continuous)	5.62	4.891
Family Size (Continuous)	8.5	4.098
Non-farm income (D=1, otherwise 0)	–	–
Owner (D=1, otherwise 0)	–	–
Owner Cum Tenant(D=1, otherwise 0)	–	–
Tenant (D=1, otherwise 0)	–	–
Index livestock (Continuous)	4.3112	5.82906
Loan from formal sources (D=1, otherwise 0)	–	–
Loan from informal sources (D=1, otherwise 0)	–	–
No Loan Access (D=1, otherwise 0)	–	–
Marginal farmers (D=1, otherwise 0)	–	–
Small farmers (D=1, otherwise 0)	–	–
Medium farmers (D=1, otherwise 0)	–	–
Large farmers (D=1, otherwise 0)	–	–
Government Extension (D=1, otherwise 0)	–	–
Temperature(Continuous)	24.2611	3.6929
Precipitation(Continuous)	45.463	23.8051

Note: As explained above *mean* and *std. deviation* for categorical variables are meaningless and not reported.

A large family size on average is observed for farming households. This is common in families working in agriculture sector across the country. Livestock holding by the farmers serves as a store of value[9]. For this study, live

[9]They provide traction and manure to enhance the fertility of soil.

stock index is generated by assigning different weights to live stocks depending upon their forms. For this purpose, conversion factor for various livestock species were used to compute cow adult equivalent score. The specific weights for various livestock species according to their age and sex are taken and then are multiplied by number of animals holding.[10] Rather than taking farm size as continuous variable, we purposefully decompose the variable in categorical variable. The rationale behind it is the different social dynamics attached with the farmers holding large, medium and marginal size in terms of their income, on farm/off farm income ratio, sources of information, access to loans and extensions services etc. These factors shape the nature and number of adaptations to a significant extent. Non-farm income is associated with the activities other than farming. The higher the level of non-farm income the less risk averse the farmer will be and is assumed to have more access towards information.

Awareness of the farmers to climate change is measured through media. In this study, dummy for information received from electronic media i.e. radio, newspaper and TV=1 and zero otherwise. Principal component analysis is used to construct social index. This index is based on the number of times the assistance is received by the farmers in land preparation, planting crops, harvesting, farm implements, providing seeds, food grains, etc.

Provision of credit is a source of relaxing financial constraints faced by the farmers. Farmers can easily adopt different copping strategies relating to crops if they have an access to credit and this can help in reducing the negative impact of climate change. This variable is categorised in two groups, formal source of borrowing and informal source of borrowing. Formal sources of borrowings include banks and other loan providing government organisations whereas informal sources consist of friends, relatives, money lenders, etc.

Dummy variable for government extension is generated on the basis extension services in cropping pattern, irrigation, fruit and vegetable growing, planting methods, intercropping and new improved varieties.

3. RESULTS AND DISCUSSION

3.1. Farmers' Perceptions

We begin with the Exploratory Data analysis. The analysis primarily revolves around the argument that a significant difference in perceptions formation and the nature of adaptation across gender, land ownership status and farm size exists. The rationale for undertaking the analysis in these directions is that a successful climate change policy must consider these

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[10]Based on, Baseline Survey (2000) for the development of livestock in *Cholistan*, Table B in appendix provides the weights allocated against each type of livestock.

dimensions separately and a general rule-for-all will not work. As it is evident from table 3, significant differences in perceptions regarding different climate change indicators prevail across gender. Percentage of the respondents who perceived no change in summer season among the males is 4.5 while in case of females, it is 2.0 (less than half) highlighting the difference in perception making across the gender. The plausible explanation behind this difference may be the different level of social index for female-headed households, and interaction and exposure to information/awareness sources. Similarly, 5.7 percent female respondents perceived winter season is less cool today as compared to 20 years back while the percentage is 8.7 for the male respondents. These differences may shape the nature of perceptions and the resulting adaptations significantly. Importantly, of the 9 indicators, a significant difference exists for 6 indicators.

Table 3

Farmer Perceptions of long-term Temperature & Precipitations (Over Last 20–30 Years) by Gender

		Percentage of Respondents		
S. No.	Variables	Male Respondent	Female Respondent	P-Value
1	Summer Season is More Hot	84	88.9	0.00
2	Summer Season is Less Hot	11.4	9.1	0.001
3	Summer Season is Same	4.5	2.0	0.00
4	Winter Season is More Cool	43.7	51.6	0.00
5	Winter Season is Less Cool	47.6	42.2	0.00
6	Winter Season is Same	8.7	5.7	0.00
7	Overall Rainfall has Increased	33.7	31.9	0.136
8	Overall Rainfall has Deceased	59.4	62.8	0.003
9	No Change in Overall Rain	4.3	3.8	0.224

Note: p-value are obtained by applying chi-squares test for independence to discover if there is a relationship between two categorical variables.

We now convert to our argument on difference in perception by land ownership status. Owners and tenants belonging to different classes may carry different socio-economic characteristics which in turn may result in difference of perception of temperature and precipitation based on different education level, social networking, access to sources of information including government extensions and formal and informal connections in the society/surroundings. Table 4 below reports the perception of temperature and rainfall between owners and tenants. Our argument is supported by the evidence as shown in the table 4 wherein double of the tenants than owners think that overall rainfall has decreased. Similar differences can be observed for perception on summer being less hot at present as compared to 20 years ago and on the decrease of overall rainfall. Among the nine variables, four variables indicate significant differences in perception of changes in seasons.

Table 4

Farmers' Perceptions of long-term Temperature and Precipitations (over last 20-30 years) by land Ownership Status

		Percentage of Respondents		
S. No.	Variables	Owner	Tenant	P-Value
1	Summer Season is More Hot	87.6	75.8	0.00
2	Summer Season is Less Hot	8.3	19	0.00
3	Summer Season is Same	4.1	5.2	0.208
4	Winter Season is More Cool	44.7	46.8	0.304
5	Winter Season is Less Cool	46.5	45.5	0.624
6	Winter Season is Same	8.8	7.7	0.337
7	Overall Rainfall has Increased	25.3	51.4	0.00
8	Overall Rainfall has Deceased	68	42.2	0.00
9	No Change in Overall Rain	4.3	4.1	0.78

Note: p-value are obtained by applying chi-squares test for independence to discover if there is a relationship between two categorical variables.

3.2. Adaptation Measures by Farmers in the Face of Changing Climate

The perception set the very basis of adaptation and the difference thereof can be transmitted to the strategies adapted. This is evident in the analysis of adaptation strategies. When asked if these farmers had undertaken any adaptation methods in response to the perceived changes in climate, 89.7 percent of the total respondents responded affirmatively that they had opted at least one adaptation method while the remaining 10.3 percent had not adapted any. (Table 5). The figures presented in table 5 clearly suggest that reduction in livestock is the strategy opted by the highest percentage of respondents. Mulching, on the contrary, had been opted by the least number of farmers i.e. 3.8.

Table 5

Adaptation Measures Taken by Farm Households to Adapt to Climate Change[11]

S. No.	Adaptive Strategies	Percentage of Farmers who Adopted the Strategy
1	Introduced a New Crop	14.8
2	Grow Low Input Crops	16.7
3	Grow Crops Requiring Less Water	23.7
4	Introduced Intercropping	8.3
5	Changed Crop Rotation	12.6
6	Started Planting Trees as Hedge	26.1
7	Reduced Livestock Animals	43.0
8	Improved Food Storage Facility	20.5
9	Laser Levelling to Save water	9.8
10	Mulching	3.8
11	Cropping Diversification	4.6
12	Manuring	31.8
13	Ridging	36.2
14	Others	11.4

[11]Crop wise breakup of adaptation strategies is available in Appendix.

We argue that the difference in nature of adaptation strategies opted comes from different perceptions regarding climate change crafted by socioeconomic backgrounds of the farmers. Following the difference in perceptions regarding different climatic indicators, we set to analyse the extent to which they transmit to difference in adaptation strategies. Table 6 reports percentage of owners and tenants who adopted different measures to combat the changes in climate. It is evident from Table 6 that there are significant differences in intercropping, crop rotation, food storage facility, manuring and ridging as adaptation measures taken by owners and tenants. The most notable feature of table 6 is the significant difference in almost all the strategies across the land ownership status. The differences in adaptation strategies undertaken may also emerge from the nature of tenancy; fixed rent, shared cropping etc. even if both owner and tenant form similar perceptions, the execution of the adaptation may vary depending for instance on the availability of financial resources.

Table 6

Adaptation Measures Taken by Farm Households by Land Ownership Status[12]

S. No.	Adaptive Strategies	Percentage of Farmers who Adopted the Strategy		
		Owner	Tenant	P-value
1	Introduced a New Crop	13	18.8	0.00
2	Grow Low Input Crops	17.5	16.2	0.428
3	Introduced Intercropping	5.8	15.4	0.00
4	Changed Crop Rotation	10	18.3	0.00
5	Started Planting Trees as Hedge	28.9	19.7	0.00
6	Reduced Livestock Animals	41	46.6	0.007
7	Improved Food Storage Facility	23.9	14.8	0.00
8	Laser levelling to save water	9.3	8.2	0.357
9	Mulching	3.4	5.3	0.016
10	Cropping Diversification	3.4	4.7	0.091
11	Manuring	36	19.2	0 .00
12	Shifting Cultivation	1.2	2.7	0.005
13	Ridging	30.1	45	0.00
14	Built a Water Harvesting Scheme	1.2	2.2	0.048

Note: p-value are obtained by applying chi-squares test for independence to discover if there is a relationship between two categorical variables.

Further, the size of the farm may set the bases of adaptation strategies in terms of the nature of strategy and the resources (adaptive capacity) level. However, significant differences were found in adaptation measures according to farm size

[12]Table D in appendix provides crop wise strategies by landownership status.

(Table 7). A significant difference was observed for adaptation strategies including, *introducing a new crop, growing low input crops, planting trees as hedge, laser levelling to save water, mulching, cropping diversification* and *ridging*. These differences in adaptation strategies are driven by different socioeconomic backgrounds, different initial endowments, different cash and food crops ratio and the share of total crop consumed for domestic purposes. This may however be noted that these results may underestimate the actual differences due to the fact that majority of the farmers (53.8 percent) interviewed in the survey hold a very small portion of the land (less than 6.25 acres). Cumulatively, approximately 80 percent farmers hold a farm smaller than 12.5 acres and percentage of the farmers who owned a large portion of land is only 6.7 percent.

Table 7

Adaptation Measures by Farm Households by Farm Size

Strategies/Farmers	Marginal Farmers (area <= 6.25 acres)	Small Farmers (<12.5 acres)	Medium Farmers (12.5 to 25)	Large Farmers (>25 acres)	P-Values
Introduced a New Crop	13.32	17.91	14.83	16.89	0.023
Grow Low Input Crops	14.88	18.39	18.04	23.74	0.003
Grow Crops Requiring Less Water	23.19	23.22	24.25	30.14	0.231
Introduced Intercropping	8.64	9.36	6.21	5.48	0.123
Changed Crop Rotation	12.18	14.1	13.03	10.96	0.484
Started Planting Trees as Hedge	24.35	28.83	25.25	32.11	0.03
Reduced Livestock Animals	43.32	44.43	40.88	38.36	0.442
Improved Food Storage Facility	19.37	19.93	22.69	26.48	0.075
Laser levelling to Save Water	7.5	11.03	14.46	14.61	0
Mulching	3.75	4.27	4.82	0.46	0.066
Liming	2.77	3.08	2.21	1.38	0.626
Cropping Diversification	3.6	4.51	7.43	6.85	0.003
Manuring	32.03	30.13	32.67	33.79	0.676
Green Manuring	2.13	2.02	2.81	4.57	0.195
Ridging	33.75	41.04	36.55	37.9	0.002
N (%age) of farmers against farm size	53.8	24.7	14.6	6.7	-

Note: p-value are obtained by applying chi-squares test for independence to discover if there is a relationship between two categorical variables.

3.3. Treatment Effect Model: Results and Discussion

In this section, we extend the analysis to identify the drivers of adaptation strategies using Heckman's Treatment effect model. A significance of inverse mills ratio in model indicates the existence of selection bias. Social network, information through media and agro ecological settings are found to be affecting the perception of climate change. The findings revealed that most of the explanatory variables except education, non-farm income and livestock are significantly affecting the adaptation.

We turn to adaptation equation in which we are primarily interested. The results in Table 8 are suggestive that increasing household size increases the

Table 8

Results of the Treatment Effect Model

Number of obs	3429					
Wald chi2(18)	267.51					
Prob > chi2	0.00					
	Outcome Equation			Selection Equation		
	Coef.	z	P>z	Coef.	z	P>z
Age_Male	0.000363	2.62	0.009*	-0.00059	-0.14	0.888
Edu_Male	0.000221	0.57	0.566	0.005901	0.73	0.467
FamilySize	0.001337	3.21	0.001*			
Nonfarm Income	-0.00647	-1.85	0.064***			
Owner	-0.01523	-3.51	0.000*			
Owner-CumTenant	-0.00923	-1.68	0.094***			
Livestock	0.000191	0.63	0.531			
Loan Formal Sources	0.042407	7.71	0.000*			
Loan Informa Sources	0.027262	5.39	0.000*			
Small Farmers	0.009507	2.33	0.020**			
Medium Farmers	0.004319	0.85	0.393			
Large Farmers	0.006635	0.91	0.364			
GovernmentExt	0.016915	5.01	0.000*			
Temperature	-0.01128	-10.71	0.000*			
Precipitation	-0.0014	-8.99	0.000*			
Constant	0.233952	4.63	0.000*			
Farm_Exp				0.004495	1.08	0.281
Social_Index				4.989597	2.38	0.017**
Media_Info				0.342505	2.8	0.005*
Punjab				0.573986	6.55	0.000*
Sindh				0.464603	4.21	0.000*
Constant				0.464603	4.21	0.000*
Perception	0.185455	3.76	0.000*			
Inverse Mills Ratio	-0.0655	-2.86	0.004*			

*, **, ***, indicate significant at 1%, 5% and 10% level of significance respectively.

likelihood of adaptation. The positive coefficient of family size implies that larger families have probability to adapt to climate change higher than the smaller families. Large family size, in agriculture, represents the high labour endowment and this may increase the adaptation capacity and options given the fact that farming in Pakistan is mostly labour intensive and farmers are likely to engage in labour intensive adaptation strategies. The choice of labour intensive adaptation strategies may also be driven by the smaller cost (monetary terms) incurred in following such adaptation measures. These results are in line with the study of Gbetibouo (2009) who established that family household size enhances the farmer's adaptive capacity.

Tenancy status indicates farmers' land tenure. Three categories of this variable are included that are *owner*, *owner-cum-tenant* and *tenant*. In this study, tenancy status (owner and owner-cum tenancy) has a negative sign for most of the adaptation measures which indicates that tenants are more likely to adapt their farming practices according to the perceived climate changes as compared to the owners and owner-cum-tenants. It can be observed (table 8) that if farmer is owner, his probability of adaptation is lower as compared to tenant. Higher likelihood of adaptation for tenants may be due to the reason that tenants are more conscious about their farm income as compared to owners as tenant has to pay the rent of land. Hence, they want to maintain their income above total cost as compared to owners. Partially, a higher dependency on the farm income may also motivate the tenants to adapt to the climate change.

Further, farmers' decision to adapt to climate change is influenced by access to credit. If a farmer has access to credit, then he is having a higher probability of adapting to climate change as compared to the farmers who have no access to credit. More financial resources help the farmer to change their farming practices in response to changes in climate change. These results are in line with the findings of Hassan and Nhemachena (2008) who found access to credit plays a critical role in helping farmers to adapt to climate change. Similarly, higher likelihood of adaptation is found for small farmers as compared to marginal farmers.

Given the arguments raised in the study, it is important to note that farm size enters as a statistically significant predictor of adaptation to climate change and the farmers with small land holdings are 2.3 times more likely to adapt to climate change as compared to the large farm size holders. Plausible explanation may exclude hands-on agriculture which may increase the recognition of changing climate and, consequently the adaptation accordingly. Also, the dependency on farm-income or limited farm holdings pushes the farmers to update farming practices to combat climate change in order to maintain sustained on-farm income as livelihood. Further, lower amounts of financial resources required for adaptation when the land holdings are smaller may also contribute positively towards the adaptation to climate change. Finally, the small landholdings may have been an outcome of the divide of the land endowments in *"large family"* which enhances the likelihood of labour intensive adaptation strategies.

Exposure to information on climate change and access to government extension increases the likelihood of adaptation. The results are consistent with findings of Deressa, *et al*. (2009) and Hassan and Nhemachena (2008). Households facing higher annual mean temperature are more likely to adapt to climate change through the adoption of different practices. It is predicted that with more warming, farmers will adapt more strategies to cope with increased temperature. The coefficient of this variable is found to be significant but with the opposite sign. The results specify that decreasing precipitation significantly increases the likelihood of using different adaptation measures such as soil conservation, changing crop varieties, changing planting dates, irrigating etc. but increasing precipitation does the opposite.

4. CONCLUSION

This study is based on micro-level analysis of farmers' adaptation to climate change for three provinces of Pakistan. This study attempts to answer the question that how adaptation decisions of farmers are influenced by household and farm characteristics, and also by institutional and other socio-economic factors. The evidence suggests that most of the farmers are well aware that temperature is increasing and the level of precipitation is declining. Importantly, a significant difference across the gender and land ownership status is observed in the formation of perception. The landownership status and the size of land holdings shape the decision for adaptation strategies significantly. Controlled for the selection bias, the results of the Treatment Effect model indicate that age, family size, access to credit, land holdings, government extension, and farm experience are significant determinants of farmers' farm level adaptation options. In the light of the above results, it is suggested that recommendations/suggestions related to climate change forecasting, changes in agriculture production cycles and appropriate adaptation strategies should be disseminated through effective communication channels. The government should increase the provision of extension services. Interactions between farmers and extension officers should be promoted. The government, through extension services, can encourage the farmers to exchange information about their farming experiences so that the experiences gained by experienced farmers may be shared with others. It is indicated by the results that affordability of credit is important in adapting to climate change; so that the government might priorities the availability of credit through the formal channels as this enables the farmers to secure farm inputs on time. More income will increase the purchase power of the farmers and they will be able to buy fertilisers and early yielding crop seed. Owners of the large size land holdings need to be motivated for effectual adaptation. Most importantly, climate change policy must particularly focus on tenants and the farmers with small land holdings as efficient source of successful adaptation to climate change and the capacity of both these groups must be further strengthened through increasing their access to extension services and small loans. Finally, the awareness policy should be framed considering the gender and landownership status to earn higher efficiency for the climate change policy.

APPENDIX

Table A

Types of Climate Change Induced Disasters Encountered by Farmers during Last 10-20 Years

S. No.	Climate Change Induced Disaster	Percentage of Respondents Affected: Most Severely Effected	Severely Effected	Badly Effected	Somewhat Effected	Minor Effected	Missing
1	Droughts	7.1	15.6	22.4	21.2	30.9	2.7
2	Floods	5.3	7.8	12.8	16.3	53.6	3.7
3	Too Much Rains	5.5	13.4	25.4	30.2	24.5	0.9
4	Early Rains	1.8	7.1	24.5	35.0	28.9	2.5
5	Late Rains	6.3	12.4	29.9	29.3	20.0	2.0
6	Extreme Cold	2.4	13.6	22.1	28.8	32.9	1.8
7	Extreme Heat	20.6	22.6	24.6	21.6	9.4	1.2
8	Wind Storm in Winter	1.5	6.9	14.2	25.0	48.9	3.4
9	Wind Storm in Summer	5.1	10.3	18.4	25.3	38.3	2.5
10	Fog	1.0	4.7	15.3	29.6	47.4	1.8
11	Frost	4.0	8.8	15.6	26.4	43.0	2.0
12	Hailstorms	5.7	8.0	9.6	22.5	50.6	3.5

Table B

Perception of temperature (1, 0) and Adaptation (1, 0)

	Perceiver & Adaptor	Perceiver but Non-Adaptor	Non-Perceiver but Adaptor
Perception (Temperature)	87.3	9.3	3.4
Perception (Precipitation)	85.5	8.9	5.6
Perception (Temperature & Precipitation)	83.4	8.2	8.4

Table C

Characteristics of Adaptor and Non-adaptor Farmers

Education	No Education	Primary	Matric	Above Matric
Female Adaptor	89.28	91.08	91.57	94.87
Female Non-Adaptor	10.72	8.92	8.43	5.13
Male Adaptor	11.21	7.25	11.24	8.91
Male Non-Adaptor	88.79	92.75	88.76	91.09
Farm Size	Small Farmers	Medium Farmers	Large Farmers	
Adaptor	91.02	91.43	93.15	
Non-Adaptor	8.98	8.57	6.85	
Tenancy	owner	Owner-cum tenant		
Adaptor	89.68	92.13		
Non-Adaptor	10.32	7.87		
Access to Credit	Formal	Informal	No Access	
Adaptor	92.04	89.87	83.86	
Non-Adaptor	7.96	10.13	16.14	
Access to Information(Media)	No Access to Information	Have Access to Information		
Adaptor	90.98	83.51		
Non-Adaptor	9.02	16.49		
Non-Farm Income	No Non-Farm Income	Have Non-Farm Income		
Adaptor	89.02	90.50		
Non-Adaptor	10.98	9.50		
Farm Experience	No Experience	Experienced Farmers		
Adaptor	81.58	89.84		
Non-Adaptor	18.42	10.16		

Table D

Crop Specific Strategies to |Mitigate the Effects of Climate Change (Overall Farmers)

	Crops						
Coping Strategies	Wheat	IRRI Rice	Basmati Rice	Sugar Cane	Cotton	Maize	Gram
Sowing Early	27.7	24.6	43.6	27.0	30.3	20.7	10.7
Sowing Late	22.2	24.6	15.9	8.6	19.5	2.9	5.5
Same	47.2	32.9	32.2	57.6	41.2	66.4	79.7
Used More Seed	75.5	52.2	77.3	65.3	68.8	55.1	59.1
Used More Fertiliser	74.1	58.5	83.9	73.9	72.0	78.1	8.2
Used More Irrigation	41.0	46.1	74.5	53.5	44.6	35.0	2.7
Used Less Irrigation	18.6	11.9	9.2	13.1	15.1	19.7	42.3
Planted Drought Tolerant Variety	20.3	20.3	13.7	19.7	15.9	22.5	45.0
Changed Time of Irrigation	27.2	28.6	40.7	33.2	32.6	10.0	4.1
Started making Ridges	8.3	7.6	18.9	68.1	64.7	21.5	2.1
Planted Shorted Cycle Variety	22.0	33.2	18.3	12.3	27.5	26.0	9.6
Planted Longer Cycle Variety	6.1	18.2	2.2	19.6	16.0	3.1	3.1
Kept Area Same	69.0	61.5	54.4	54.2	61.3	65.0	74.0
Increased Growing Area	11.8	7.8	18.1	21.6	9.4	13.7	0.6
Reduced Growing Area	10.3	9.4	13.2	16.1	15.5	10.4	12.0
Stop Growing	3.8	1.0	6.0	0.7	0.5	0.6	-
Planted Flood Tolerant Variety	9.6	16.7	4.8	13.4	9.2	12.7	0.7

Table E

Crop Specific Strategies to Mitigate the Effects of Climate Change (Owner & Tenant)

	Crops							
	Wheat		IRRI Rice		Basmati Rice		Sugar Cane	
Coping Strategies	Owner	Tenant	Owner	Tenant	Owner	Tenant	Owner	Tenant
Sowing Early	28.0	28.5	24.8	18.5	47.0	42.9	25.6	31.1
Sowing Late	20.2	24.8	16.1	32.1	15.7	7.1	7.1	11.8
Same	49.2	42.1	40.3	34.0	27.5	38.1	60.8	48.1
Used More Seed	76.5	69.1	54.4	44.4	79.0	76.2	67.9	63.2
Used More Fertiliser	73.5	70.4	60.4	52.5	84.3	76.2	73.6	70.3
Used More Irrigation	40.2	35.7	53.0	34.6	76.3	59.5	59.7	45.3
Used Less Irrigation	19.3	17.5	12.1	15.4	7.1	14.3	10.8	11.8
Planted Drought Tolerant Variety	22.8	21.0	25.5	19.8	14.2	14.3	23.0	20.8
Changed Time of Irrigation	25.0	27.6	26.8	30.9	37.9	42.9	37.8	25.0
Started making Ridges	7.9	9.2	8.7	6.2	21.0	16.7	73.0	56.1
Planted Shorted Cycle Variety	20.5	24.7	28.9	34.6	15.7	21.4	8.2	22.2
Planted Longer Cycle Variety	4.6	11.0	20.8	22.2	2.4	-	20.5	18.4
Kept Area Same	71.4	68.6	61.7	66.7	56.2	54.8	53.7	59.0
Increased Growing Area	10.8	10.3	5.4	8.6	14.5	26.2	20.5	20.3
Reduced Growing Area	9.8	10.3	10.1	8.0	13.6	4.8	18.5	9.9
Stop Growing	4.3	1.3	2.0	-	5.9	2.4	0.6	1.4
Planted Flood Tolerant Variety	7.2	17.2	12.1	22.8	4.1	11.9	11.9	18.4

Continued—

Table E (*Continued*)

Coping Strategies	Crops: Cotton Owner	Cotton Tenant	Maize Owner	Maize Tenant	Gram Owner	Gram Tenant
Sowing Early	29.8	33.6	17.3	28.0	10.1	11.4
Sowing Late	20.2	18.3	2.3	3.5	6.0	2.9
Same	44.3	38.3	73.0	54.5	80.2	80.0
Used More Seed	73.0	64.0	60.6	44.8	62.2	48.6
Used More Fertiliser	76.6	64.6	76.9	80.4	8.8	5.7
Used More Irrigation	46.5	40.4	31.9	35.7	2.3	2.9
Used Less Irrigation	14.9	15.6	17.3	23.1	42.4	45.7
Planted Drought Tolerant Variety	18.3	18.6	24.8	22.4	42.9	51.4
Changed Time of Irrigation	34.2	31.9	9.8	10.5	2.3	5.7
Started making Ridges	66.7	69.0	14.7	30.1	2.8	-
Planted Shorted Cycle Variety	26.4	30.4	23.1	32.9	9.7	8.6
Planted Longer Cycle Variety	19.7	12.4	2.3	4.2	2.3	8.6
Kept Area Same	65.4	63.7	71.7	55.2	74.2	77.1
Increased Growing Area	8.3	9.1	12.4	15.4	7.4	14.3
Reduced Growing Area	16.0	11.8	8.1	14.0	13.8	2.9
Stop Growing	0.5	0.6	0.3	0.7	-	-
Planted Flood Tolerant Variety	8.0	12.7	10.1	18.9	0.5	2.9

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This series of papers is an outcome of a joint research project of PIDE and IDRC. Transnational financing of developmental projects by donor agencies has emerged to be a notable phenomenon around the globe. Amongst others, International Development and Research Centre (IDRC) Canada remains one of the leading agencies providing funds for multifaceted developmental projects being implemented in developing countries. The project ***"Climate Change Agriculture and Food Security in Pakistan: Adaptation Options and Strategies"*** is one such an endeavor of PIDE and IDRC. Broadly speaking, the project aims at exploring responses of crop yields to changing climate and analyzing the adaptation efforts undertaken by farmers. The issue of climate change bears a special importance for Pakistan's economy being heavily dependent on agriculture sector both in terms of its contribution to GDP and employment. This project involves two strands of empirical undertakings: i) studies based on districts-level panel; and ii) studies based on Rapid Rural Appraisal (RRA) and household level survey data. The outcomes of the studies based on panel and cross-sectional data are being reported in working paper series of the project whereas findings of RRA have been published as a policy brief. However, for information of readers, the salient upshots of RRA are summarized in the following.

The evidence from RRA is suggestive that the farming communities in various regions of Pakistan widely perceive that climate is changing and is adapting accordingly through undertaking a wide range of adaptation strategies. Some of the adaptations in rainfed areas include use of deep tillage for rainwater harvesting and preserving moisture, building of small check dams, shifting away from shallow rooted to deep rooted crops, and delayed sowing of wheat and mustard by 15-30 days etc. While adaptations in irrigated agriculture include, in major, increased installation of tube-wells, increased area under low-delta/low-input requiring crops like canola and mustard as alternative to wheat in water scarce areas and substitution of other crop (guar seed and cotton crops being replaced with mungbean in low intensity zone), delayed wheat sowing by 15-21 days, and sowing of cotton on ridges to manage water scarcity etc.

Surprisingly, however, notwithstanding the changing climate, the research institutions and extension department still keep recommending completion of wheat sowing by 20th of November irrespective of regional climate variations. The sowing of rice nursery before 20th of May is prohibited according to the Punjab Agricultural Pest Ordinance, 1959 in order to control multiplication of harmful pests on early sown rice nurseries. Further, canal closure schedules do not match with the adaptation needs of farmers confronting climate changes (especially wheat in Punjab and rice in Sindh. The farmers have an urgent need of support from agricultural research and extension as well as other government departments to enhance their adaptive capacities.

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