

**EQUITY AND EFFICACY IN FINANCING FARMERS CLIMATE ADAPTATION:  
EVIDENCE FROM AGRO-ECOLOGICAL ZONES OF PAKISTAN**

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## Abstract

*In agriculture sector, financing the climate change adaptation has emerged as central issue that is heavily dependent on availability of credit financing from Formal, Semi-formal and Informal lenders. But there has been limited access to the credit for adaptation because of the inefficient credit market, induced by the variation among farmers about socio-economic status and unavailability of collateral as security for loan. This study analyzes the inefficiency and inequity measures of capital market imperfection by utilizing the field data from various Agro-ecological zones of Pakistan. The findings based on Exploratory Data Analysis (EDA) evaluates that there is an evidence about the existence of imperfect (inefficiency) capital market in financing the farmer's climate change adaptations. Only 36% and 37% farmers have access to loan from Formal (Banks) and Semi-formal lenders (MFIs), respectively while 95% farmers have access to credit from Informal lenders which also support the inequity issue in credit market. The findings further suggests that 'average distance to lender' is 21.71 miles, indicating that borrowers have to travel from far-off areas to get credit which may strengthen the imperfection of capital market in allocating and financing loans to vulnerable farmers. Additionally, application processing fees is highest from Formal lenders (18.50 USD) as compared to Semi-formal (5.50 USD) and Informal lenders (3.00 USD). Additionally, around 70% farmers use 'Personal Security' as Collateral to get loan while they borrow from Informal lenders.*

*Results based on Probit model, Two Stage Least Square (2SLS) and Heckman Treatment Effect Model suggest that increase in 'duration of loan' from Formal and Informal lenders has ambiguous sign in determining the farmer's access to credit while increase in distance to lenders non-significantly reduces the farmers access to credit from Banks and MFIs. 'Farm size' and 'irrigation from canal' also reduces the farmer's access to credit from Banks and MFIs. 'Increase in collateral amount' helps to reduces the farmer's access to credit while this doesn't hold true for Informal lenders where their personal and group contacts have significant impact to improve the access to credit, strongly support to the capital market imperfection. Additionally, the evidence suggests that increase in cost (registration and trip to lenders) may reduce the access to Banks. Findings of EDA and Heckman Treatment Effect model also evaluates that more than 94% farmers spend the whole borrowing amount in adapting the climate change. Reduction in 'Access to credit' from MFI also reduces the choice for all types of adaptation strategies with significant implications. Increase in 'marginal farmers' reduces the farmer's capacity to adapt to climate change. Finally, 'ownership of land' is non-significantly related in reducing the adaptation investment as well as adaptation strategies. On policy grounds, awareness about MFIs among backward farmers is still scarce and there has been immense need for dissemination about the existence of MFIs for loan provision at scattered and far flung rural areas. In addition, market imperfection should be minimized through the direct provision of agriculture inputs at local market without the role of Informal lenders.*

**Keywords:** Imperfect Capital Market, Adaptation Finance, Agro-ecological zones, Heckman Treatment Effect model, Pakistan

## 1. Introduction

Severe turn in climatic conditions has been observed in all over the world and the decades of 80's and 90's have been known as the warmest period since the onset of mankind (Harrison and Pearce, 2000; Oreskes, 2006 and IPCC, 2007; 2014). These climatic stresses as well as risks, tied with sudden events of temperature and precipitation, ranging from heat waves to cool waves and drought to floods have adverse implication across various sectors of developing countries where agriculture is not an exception (Nicholson, 1994). The agriculture sector faces negative effects on yield mainly due to high climatic risk. Farmers in developing countries are unable to undertake mitigation options as effective tool to combat the global warming mainly due to the low share in carbon emission. They are left with to adapt to climate change as the only option to combat adversaries of changing climate. In this context, financing the adaptation has emerged as central issue wherein the strategies related to input changes have earned serious consideration.

This includes purchase of input material such as fertilizer, seeds and pesticides. Similar holds true for *technological related* (new innovative and highly productive agricultural tools such as laser leveler and tractor). These two major types are heavily dependent on availability of credit/finance as require plentiful resources. Farmers, in general and small holders in particular lack these resources required to finance these adaptations. Despite of that, other types of adaptation strategies that also demand huge financing include *variety related adaptations* (plantation of stress resilient or flood/drought tolerant varieties), *crop related adaptations* (purchase and introduce new crop, crop diversification, changed crop rotation, change in crop planting/sowing and harvesting date; and intercropping), and *irrigation related adaptations* (purchase of various water resources).

All these adaptations are expensive to fund and farmers have to face heavy financial dose to bear up the cost but benefits are widely scattered, covering the high loss in agriculture output and enhance the farmer's capacity to cope with natural events as well as climate risk. In most of the cases, poor farmers are left with lower adaptive capacity due to high pecuniary cost and less available resources that result in less use of modern technological resources, used for adaptations (Rosenzweig and Tubiello, 2007; Yesuf *et al.*, 2008). In order to cover-up loss in output or utilize adaptation strategies, they mostly have to rely on public or private institutions, where they can get loan to compensate or readjust their productivity.

In developing countries, there have been no sever scarcity of financial resources/institutions, including Micro and Macro credit banks (Formal lenders), non-governmental organizations (NGOs) and Microfinance Institutions-MFIs (Semi-formal lenders) and Informal lenders (money lenders, pawnbrokers, and traders)<sup>1</sup>. But these small lending groups remain unable to meet the targets of financing and allocating their budgets in line with the sustainable development objectives of Asian Development Banks (ADB, 2008) and Millennium Development Goals (MDG's). Also these institutions have manifold issues in financing farmer's adaptations. *Firstly*, there is strong evidence for the existence of public and private financing institutions but they are not so much resourceful to help the farmers in the provision of multiple type of financing opportunities for agriculture sector. *Secondly*, there are huge disparities in the allocation of loans (Pitt & Khandker, 1998; Ravallion, 2001; Montgomery & Weiss, 2005; and Berhane &

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<sup>1</sup> For detail see, World Bank (1997) and Matin *et al.* (2002)

Gardebroek, 2011) demonstrating the existence of inefficiencies in financing adaptations in agriculture. *Thirdly*, most of the farmers seem to be inefficient in utilizing these resources while purchasing agricultural technology and financing inputs. This inefficiency is induced by the variation among farmers about socio-economic status (Weir, 1999 and Meijer *et al.* (2015) while purchasing agricultural input such as fertilizer, seeds and pesticides.

In literature, credit market has two broad aspects for the equilibrium of loanable funds whereas first one comes through supply side of loanable funds. In credit market with asymmetric information, lender evaluates the borrowers' capacity through *i*) application scrutiny process by sorting potential borrowers (*the adverse selection effect*), *ii*) following the action of borrowers i.e, their ability as well as willing to repay the loan (*the incentive effect or moral hazard*). The selection of potential borrowers by excluding others marginalized segment and consequences about the probability to default can be widely viewed as imperfect capital market (Stiglitz and Weiss, 1981). Additionally, credit rationing by formal lenders is another indicator of market imperfection (Jappelli, 1990; Feder *et al.*, 1990; Barham *et al.*, 1996 and Zeller *et al.*, 2001). And monopoly power in credit market exercised by informal lenders also indicates the inefficiencies in the market (Bell *et al.*, 1997).

On demand side of loanable funds, borrowers need to get loan but there exist inefficiency in getting the loan from credit market which is induced by the heterogeneous characteristics about their socioeconomic factors, e.g. tenancy status, land/farm size, marital status, and unavailability of collateral in a form of expensive assets i.e. livestock, farm land, availability of guarantors, large transaction cost (Carter, 1988) and marginalized access to formal microcredit institutes as well as application processing cost (Conning, 1995; Kochar, 1997 and Mushinski, 1999). These micro factors endorse the imperfect capital market in financing the climate change adaptations.

Additionally, on supply side, credit constraint leads to (efficient) perfect capital market whereas lenders select most credible borrowers from a set of applicants through a variety of screening devices (Stiglitz and Weiss, 1981). But on demand side, particular unselected group of farmers face credit constraint due to socioeconomic factors, hence promoting the inequality in getting loan at credit market. Broadly speaking, this makes capital market imperfect and also induces the inefficiency that can be characterized as barrier in adapting to climate change.

In literature, these barriers are mainly consisting of *difficulty in access to availability and approach to bank/microfinance institutes, large transaction costs, regulatory restrictions, collateral in a form of expensive assets like house, bank deposits and guarantors in terms of land and cattle, interest rate ceiling for small farmers, high lending rate, diverging lending rates among farmers*, which substantiate imperfect capital market (inefficiency) in credit market (Abdallah, 2016). Further, the case of developing countries is obvious, where NGOs and MFIs (supplier of loanable funds) can potentially contribute to inequity issues in financing climate change adaptation that can be considered in terms of *absence of equal opportunities of funding for all recipients (dominant and rich farmers get more from bank or microcredit institutes as compared to poor farmers) and low willingness to financing to most vulnerable households*.

In addition to that, Pakistan is no exception where small farmers have fewer shares in land holding as compared to the large farmers<sup>2</sup>, mainly due to the cultural demand<sup>3</sup>, inheritance law and subject nature of the issue (Sivakumar and Stefanski, 2011 and Ahmad *et al.*, 2014a, 2014b). Further, biggest land owners often dominate in the allocation of funds by public institutions for purchase the agriculture inputs through credit financing. So, in order to address imperfect capital market in terms of inequities in credit financing at agriculture sector, the issue of informal credit market need to be explored where dominant segment offers loan to small landholders at exorbitant interest rate (Aleem, 1990).

This study analyzes the existence of imperfect capital market (inequity and inefficiency) in credit financing to farmers at Pakistan and evaluates the choice of adaptation strategy in the presence or absence of efficiency and equity in loan provision. Additionally, it also aims to identify the socio-economic determinants of clustering of availability of and access to credit opportunities. Finally, this study tries to scrutinize the alternate strategies that farmers adopt in the presence of asymmetric financial options. Against this back drop, there are two specific objectives of the study, whereas first one assesses the existence of Imperfect Capital Market<sup>4</sup> in credit financing to farmers, while second one analyzes the factors<sup>5</sup> that affect farmers' decision to invest in adaptation investment or adaptation strategies in the presence of perfect or imperfect capital market. In the lights of objectives, following research questions can be considered *i*) In Pakistan, capital market of credit financing to farmers is imperfect? *ii*) Opportunities and access to credit is clustered around socio-economic position of borrowers? *iii*) The choice and nature of adaptation strategy is contingent on availability of credit? Based on the findings of the study, policy options to enhance equitable and efficient adaptation finance can be suggested.

## 2. Literature Review

The issue of imperfect capital market has been the aspiration of many studies but there exists scarcity of literature that considers the issue along with adaptation to climate change. In literature, imperfect capital market of credit financing ensures the existence of moral hazard and asymmetric information among lenders and borrowers (Arnott and Stiglitz, 1988). This illusion in delivering information at imperfect capital market may lead the misconception among borrowers and lenders. Further, existence of imperfect capital market and asymmetric information indicates that banks prefer to distribute lending based on available collateral rather than expected profitability in market (Stiglitz and Weiss, 1981; Binks and Ennew, 1997). In extending the argument of imperfect capital market, Arnott, Greenwald and Stiglitz (1994) points out that adverse selection and moral hazard also constrained to “*Pareto Efficient*” and may promote inefficiency in system.

The literature on credit financing and adaptation of technology is abundant but there exist little evidence that highlights the imperfect capital market (inefficiencies and inequities) in credit financing and farmer's technological & input adaptation to climate change. Kelsey (2013) and

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<sup>2</sup> In Pakistan, average land-holding lies around 5-acres while it's exactly 5-acres at ‘Muzaffargarh’ district, which means that poor farmers have land holding less than 5-acres (SDPI, 2018).

<sup>3</sup> In Pakistan, poor families are more restricted to follow culture norms that may allow them to offer partition of land to offspring and grandchildren.

<sup>4</sup>See sub-section 3.1.2 for Demand and Supply for Loanable fund's perspective of inefficiency and inequity measures of imperfect capital market and also explained by Vectors  $X_{DL}$ ,  $X_{SL}$ ,  $Y_{DL}$ ,  $Y_{SL}$ , respectively.

<sup>5</sup>Inequity, inefficiency, agro-ecological zones and climatic vulnerability as well as socio economic factors

Abdallah (2016) discuss the inefficiencies in credit financing and farmers target to adapt to agricultural technologies but both studies couldn't address the inequities in credit financing with climate change vulnerability. Mohamed and Temu (2008) evaluate that household's characteristics are responsive for the adoption of technology. Kudi *et al.* (2011)<sup>6</sup> extend literature by incorporating the role of institutions and credit's access in evaluating adaptation of technology and agricultural input. Bircan and De Haas (2015) also broaden the scope of literature by considering the role of bank in credit financing to farmers and agriculture technology adaptation. In addition to that, constrained and unconstrained credit access has been addressed in literature for promoting the inefficiencies.

The literature on inequities arises in financing to communities have been abundant in public economics framework that is also applicable in the context of capital market for the supply of loanable funds but there exist little evidence for demand of loanable funds. Report of the Consultative Group to Assist the Poor (CGAP) 2006 evaluates that there is huge disparities in accessing the loan from financial sources and farmer's value chains finance exist around 10 percent of smallholders. Further, IFC (2011) highlights that most of the farmers don't have access to finance and inequities in financing arises, mainly due to fixed assets as collateral that cause to exclude large share of agriculture producer. These inequities can be explained in the context of demand for loanable funds at imperfect capital market.

The existing literature on agriculture adaptation is scarce on imperfect capital market, in general and for the demand of loanable funds of climate changes adaptation, in particular. There is hardly any study that analyzes the dimension of climate change vulnerability and credit constraint along with adaptation to climate change simultaneously. Simtowe *et al.* (2006) consider the issue and examine the technological adaptation in agriculture without credit inefficient market system but Kelsey (2013) undertakes the role of credit inefficiency in the presence of collateral and high interest rate that discourages the adaptation of new technology and reduces the farmer productivity.

In extending the literature, Abdallah (2016) incorporate the inefficient credit distribution in the presence of collateral and also highlight the inefficiencies in credit constraint and technology adaptation. All these highlighted studies have been absent to analyze the inefficiency and thereof imperfect capital market from demand side of loanable funds in the dimension of climate change vulnerability. Although there exists plenty of literature that analyze the imperfect capital market from supply side of loanable funds (Stiglitz and Weiss, 1981; Binks and Ennew, 1997; Arnott *et al.*, 1994) and also credit financing from Informal lenders in case of Pakistan (Aleem, 1990 and Irfan *et al.*, 1999). But all these studies could not consider the case of climate change vulnerable farmers as well as inefficiency arises from Formal and Informal credit institutions.

Against this back drop, this study attempts to fill the gap in literature in case of Pakistan by exploring following dimensions *i*) it analyzes the existence of inefficiency and Imperfect Capital Market from demand side of loanable funds, *ii*) It evaluates the work of Stiglitz and Weiss (1981) by exploring the phenomena of Imperfect Capital Market for supply side of loanable funds of climate change vulnerable areas and considering the response of Formal, Semi-formal and Informal money lenders. *iii*) It also extends the literature by exploring the demand of

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<sup>6</sup> See also Teklewold *et al.* (2013), Abdul-Hanan *et al.* (2014) and Beshir (2014)

loanable funds from Formal and Informal institutes in utilizing the adaptation finance *i.e.* incorporation and purchase of various adaptation strategies in agriculture as solution to climate change adaptation in Pakistan.

### **3. Theoretical and Empirical Methodology**

This section explains about the analytical framework in explaining the farmer's choice to credit along with farmers' socio-economic status and production capacity. Additionally, it also highlights the case of imperfect capital market in evaluating the demand for loanable funds. In last, the detailed methods about empirical analysis are also discussed.

#### **3.1. Analytical Framework**

##### **3.1.1 The Role of Inequity and Inefficiency in Credit Financing**

In loanable market, farmers demand for loan to finance the adaptation strategies and to mitigate the climate risk. In empirical literature, demand for loanable funds depends on social status and also determined by farmers' economic activities along with production capacity. These socio-economic activities are tied with farmer education level, housing characteristics as well as amenities, marital status, number of family members and dependents. Additionally, the production capacity of farmers is determined by farming experience, tenancy status, farm size and technological parameters. Based on all these fundamental characteristics and also considering the climate risk, farmers decide about the demands to get the loan from the loanable market.

In climate change adaptation finance literature, credit provision to farmers has been inefficient and inequitable which is also based on their socio-economic stats and production capacities. The inefficiency in credit financing has been evaluated as necessary component in hindrance to mitigate the climate shocks as well as adaptation to climate change. Further, this inefficiency (imperfect capital market) to demand for loanable funds in credit financing to farmers can be regarded as locomotive to decrease the agricultural productivity.

##### **3.1.2. Measures of Imperfect Capital Market: Choice of Study Variables**

The issue of imperfect capital market, indicated by inefficiency and inequity of credit financing to farmers is explored for empirical analysis. Various measures of both inefficiency and inequity are explored, in detail.

In evaluating the demand for loanable funds<sup>7</sup>, inefficiency measures include, *collateral in form of expensive assets like house, bank deposits, guarantors, land, cattle, future farm production*, (Abdallah, 2016), *and non-farm income as substitute for land as collateral* (Collier & Lal, 1986 and Hoffman & Heidhues, 1993), *regulatory restrictions, high transaction cost* (Gonzalez, 1981 and Matin *et al.*, 2002), *interest rate ceiling for small farmers, high (interest) lending rate, and diverging lending rates among farmers* (Bardhan & Udry, 1999 and Kelsay, 2013). Additionally, *personal characteristics of famers, socio economic status, i.e, education, tenancy status, land ownership status* (Feder, 1984), *farmers' livestock assets, and farmers' income* can be other factors explaining unequal distribution of credit opportunities [Henceforth,  $Vector-X_{DL}$ ].

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<sup>7</sup> Demand for loanable funds consider the borrower perspective, hence farmers here.

For supply of loanable funds (lender perspective), inefficiency measure in Formal credit market assumes ‘*screening cost (application scrutiny process)*’, ‘*the incentive effect or moral hazard (the ability as well as willing to repay the loan)*’, ‘*monitoring cost*’, ‘*adverse selection*’ and ‘*enforcement cost*’. Utilizing these measures for borrowers<sup>8</sup>, the proxy for ‘screening cost’ includes transaction cost of being selected such as “*application processing cost paid by farmers (application registration and trip to office cost)*”, and “*fees to get pass book*”<sup>9</sup> from Land Revenue Department as well as “*visit and time cost paid*” while borrowing. The proxies for ‘willing to repay’ can be captured by the “*change in allocation of time in farming activities after getting loan*”, “*loan based expenditure on non-agriculture products*”, “*access to irrigation*”, “*years of work experience*”, “*amount of money spent on social traditions*”, “*house repairing as well as construction*”, and “*children marriages*”. Further proxies can also take into account “*having more than one wives*”, “*number of dependents*”, “*too many children*” and also “*willing to borrow at very high interest rate*”, etc.

Another important component for ‘willing to repay’ is “*history of business/credit transaction*” and those who have long-term better transaction history are more likely to be financed by Informal lenders who charge exorbitant interest rate from farmers (Aleem, 1990, and Haugen, 2005). And these satisfied long-term borrowers also support to new borrowers for entering in credit market. In credit market, lender evaluates the application using various indicators such as *past history as well as dealing of farmers, applicant indebtedness as well as reputation in the market, applicant references and personal sureties from person known to lenders, lender experience in the market* (Aleem, 1990) and *Administrative cost of lending (overhead cost)* (Irfan et al., (1999) as well as *information cost* (Garcia-Marco and Ocana, 1999).

Other factors consider the ‘monitoring cost’ encompass “*the distance of the village from the lender location*”, “*how many times a credit officer visits the borrower before and after credit*” and “*cross check of pass book*” from land revenue department. Additionally, ‘adverse selection’ also captures “*amount of credit delivered to borrower as percentage of his/her total income*” while, ‘enforcement cost’ consist that “*either debtor follows rules and regulation to return back loan*”, “*attachment of any credit officer in evaluating loan return performance*”, “*local pressure to deliver credit back to Informal lender*”, “*legal pressure to repay the loan*” and “*use of law and enforcement agency (police) to get loan by Formal lenders*”. Despite of that, lenders also consider “*the risk to repay the loan by borrowers, and available guarantors*” [Henceforth, *Vector-X<sub>SL</sub>*].

As far as inequity measures in financing the climate change adaptation are concerned, demand for loanable funds consider the percentage of vulnerable farmers who have “*access to credit*”, and “*availability of credit through various source (i.e., the private banks, the government banks, the microcredit banks, NGOs, MFIs, the Informal Money lenders)*” and “*how much farmers receive from these Formal as well as Informal institutes*” [Henceforth, *Vector-Y<sub>DL</sub>*].

Additionally, inequity issues in supply for loanable funds considers “*the quantity of disbursement of microcredit i.e., equal funding for all recipients*”<sup>10</sup> irrespective of their tenancy

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<sup>8</sup> This study doesn’t evaluate the supply-side data of loanable market and use its proxies to evaluate the borrower’s perspective.

<sup>9</sup> In Pakistan, “*pass book*” is pre-requisite to apply for loan at formal institute such as Bank etc.

<sup>10</sup> “Egalitarianism” principal of equity (Persson and Remling, 2014; Stadelmann et al., 2013; Fu’ssel et al., 2012; and Grasso, 2010a, 2010b)



*and land ownership status*” as the rich farmers get more from Banks and MFIs, “*financing to most vulnerable households*<sup>11</sup>” (the poor have been most vulnerable to climate change but meager lending opportunities have been documented from both Formal and Informal lenders) and *the number of beneficiaries (how many vulnerable farmers are being credited)* are widely used instruments in literature. In addition to that, different socio-economic variables such as farmer age, gender, household size, and farm and off-farm income are also be incorporated for analysis [Henceforth, *Vector-Y<sub>SL</sub>*].

### 3.2. Empirical Methodology

Empirical methodology for the exploration of credit market imperfection and thereof its impact on the choice of adaptation strategy is explained. In order to analyze the credit market imperfection, access to credit is taken as dependent variable along with various socio-economic, farming and proxies for market information as explanatory variables. The issue of credit market inefficiency is evaluated by applying the probit model. Further, the endogeneity in credit market is handled through the implication of Two-stage least square (2SLS) and also Heckmen Treatment Effect Model. In last, the choice of adaptation strategy in the presence of credit market imperfection is also handled through Heckmen Treatment Effect Model.

#### 3.2.1. Bivariate Probit Model for Imperfect Capital Market of Credit Financing

In order to analyze the existence of imperfect capital market for credit financing to farmers, bivariate logistic regression model is analyzed. The dependent variable is taken equal to one if there is an access to credit and equal to zero if there is no access to credit for farmers.

Hence, dependent variable is binary variable with choice of access to credit or not,

$$Access = \beta'x_i + \varepsilon_i \quad (1)$$

$$Access = \begin{cases} 1 & \text{if } Access > 0 \\ 0 & \text{if } otherwise \end{cases} \quad (2)$$

Where  $\beta$ 's stand for coefficients of estimated parameters which are related with farmer socio-economic status, and imperfect capital market *i.e.* inefficiency and inequity parameters<sup>12</sup>. Logitisc model helps to develop quantitative background and also estimate the parameters of inefficiency and inequity. Additionally, independent variables such as personal characteristics, socio economic status, *i.e.* education, tenancy status, land ownership status, farmers' agriculture assets for collateral, farmers' income, whether or not farmers are living in the areas with extreme weather condition are also incorporated. This regression analysis also allows in proving the financial exclusion (or imperfection) hypothesis in the perspective of demand for loanable funds.

In extending the quantitative analysis, access to credit opportunities undertake the Bivariate regression analysis into three categories separately *e.g.*, access of credit from *i*) Formal institutes (Banks) *ii*) Semi-formal or quasi-formal lenders (community credit group or MFIs and NGOs) and *iii*) Informal money lenders. This issue is handled through the application of Probit model. Three equations are regressed separately to analyze the response of imperfect credit market.

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<sup>11</sup> “Prioritarianism” principal of equity (*see all references of foot note “5”*)

<sup>12</sup> For detail, see section 3.1.1.1 with Vector  $X_{DL}$ ,  $X_{SL}$ ,  $Y_{DL}$  and  $Y_{DL}$

The bivariate model is defined for access to credit (Greene 2003).

$$Y_i = \beta_i X_i + \varepsilon_{1i} \quad (3)$$

Where, ‘Y’ is binary variable, having the probability for access to credit =1 and 0 otherwise.  $X_i$  stand for set of exogenous variable effecting the access to credit and hence  $\beta_i$  is the vector of parameters that shows the estimated coefficients.

The access to credit is modeled as:

$$Y_i = \alpha_i X_i + \varepsilon_{2i} \quad (4)$$

Where Y is probability of having access to credit and  $X_i$  is set of exogenous variable while  $\alpha_i$  is the estimated parameters.

### 3.2.2 Two-Stage Least Square (2SLS)-Instrumental Variable

The determinant of *access to credit* depends on demand side factors but there is possibility for the dependence of *access to credit* on other (supply) factors including collateral, transaction cost, and information related variables etc. And these factors are also responsible for change in supply of loanable as well as demand for loanable funds. This possible relation of demand and supply side variable of loanable market can generate the econometric problem of endogeneity. The solution can be obtained by applying the two stage least square (2SLS) estimators which use the instrumental variable to get the unbiased coefficients.

### 3.2.3. Modeling Imperfect Capital Market and Climate Change Adaptation Strategy

In modeling the impact of imperfect capital market on the choice of adaptation strategy, the first stage deals with the absence or presence of efficiency and equity in getting the loan from public as well as non-public institutions (Formal institutes) and second stage deals with undertaking of appropriate adaptation strategy<sup>13</sup> along with other socioeconomic factors that may help to adapt to climate change and increase the agriculture productivity. In order to address this issue, Heckman Treatment effect model is used to estimate the efficiency and equity to obtain the loan in first stage and thereof, its impact on adaptation strategy, in second stage.

#### 3.2.3.1 Heckman Treatment Effect Model and Adaptation Choice

The existence of imperfect capital market in the presence of climate change and decision to adopt is a two stage process, wherein the first stage farmers observe inefficiency and inequity in getting the loan from Formal and Informal lenders and in second stage, the decision either to adapt or not is undertaken (Adesina 1995; Bryant *et al.*, 2000; Maddison, 2007; Deressa *et al.*, 2009; and Weber 2010). The second stage is known as “outcome stage” and considered as sub-sample of first stage that also called “selection stage”. It is evident that outcome stage takes only sub-sample of selection stage and it may possible that outcome sub-sample is non-random and different from those who didn’t observe inefficiency in credit market at first stage. The agents who observe inefficiency in credit financing and those who don’t observe inefficiency in credit financing are two different groups and modeling them as homogenous group can cause well known selection bias. Bias is due to the fact that while taking the full sample as homogenous

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<sup>13</sup> See above at Introduction section for detail discussion about adaptation strategies.

incorporates only observable factors as the determinants while in the process of making inefficiency in credit financing unobservable factors are also involved.

Sample selection bias in inefficiency in credit financing to adaptations is corrected using the implication of Heckman’s two-step selection procedure (Heckman, 1979). The Heckman two-step estimation helps in estimating the treatment effects when the treated sample is self-selected. In the very first step, the inefficiency in credit financing of farmers are evaluated and then outcome response is modeled based on given inefficiency behavior (Deressa *et al.*, 2009). In literature, Treatment effect model is preferred over the simple Heckman model as former one incorporates Treatment effect scores and controls selection bias, simultaneously (Heckman’s, 1974, 1976, 1979 and Greene, 2003) and these Heckman-type model are called “Heckit” models (Guo and Fraser, 2014)<sup>14</sup>.

The Heckman Treatment Effect model is followed which analyze the impact of imperfect capital market (inequity and inefficiency) on the choice of adaptation strategy<sup>15</sup>. In order to model the inefficiency in credit financing to adaptation, let assume that  $\Omega_{ik}$  is the vector of observations of  $i^{\text{th}}$  group of agriculture wheat growing farmers with  $k^{\text{th}}$  forms of inefficient and non-inefficient credit financing farmers due to climate change.

$$\Omega_{ik}^* = \gamma_3' X_{ik} + v_{ik} \quad (5)$$

Where  $\gamma_3'$  and  $v_{ik}$  are coefficient vectors of  $X_{ik}$  socio-economic characteristics and the disturbance term at selection equation. This equation can induce the problem of sample selection as many farmers observe inefficiency to credit financing farmers to climate change while others don’t. It is also possible that inefficient credit financing farmers to climate change choose between the adaptation and non-adaptation<sup>16</sup>. The famers who adopt  $\Omega_{ik}, k = M$  are observed only if they observed inefficiency in credit financing to climate change and also adopted to it. The farmers who don’t adopt are also observed ( $\Omega_{ik}, k = N$ ), given that they observe inefficiency in credit financing to farmers due to climate change. The two step procedure is non-random and takes into account this selection bias producing the unbiased estimates resultantly. In order to address selection bias, sample selection problem is introduced in adaptation equation. Where,

$$A_{i1} = \begin{cases} 0 & \text{if } A_{i1}^* \dots \leq 0 \\ 1 & \text{if } A_{i1}^* \dots \geq 0 \end{cases} \quad \text{Selection Equation} \quad (6)$$

Let assume that  $A_{i2}$  is the measure of adaptation versus non-adaptation as result of inefficiency in credit financing to climate change. It would be observed if  $A_{i2} = 1$  and farmers may adapt or not and if they observe inefficiency in credit market then it take value of 1 for adaptation and 0 for non-adaptation.

<sup>14</sup> pp.96, 97

<sup>15</sup> See section 3.1.1.1 for detail construction of all inefficiency and inequity related variables.

<sup>16</sup> The case can be argued for individual adaptation strategies

$$A_{i2} = \begin{cases} 0 & \text{if } A_{i2}^* \leq 0 \\ 1 & \text{if } A_{i2}^* \geq 0 \end{cases} \quad \text{Outcome Equation} \quad (7)$$

$\Omega_{iM}$  is only observed when  $A_{i1} = 1$  and  $A_{i2} = 1$  (inefficiency in credit market and adopt) while  $\Omega_{iN}$  is only evaluated when  $A_{i1} = 1$  and  $A_{i2} = 0$  (inefficiency in credit market but not adopt). For  $N$  random sample, the selectivity model with bivariate Probit selection model for farmer “ $i$ ” can be written as:

$$A_{i1} = \gamma_1' X_{i1} + \mu_{i1}, \quad A_{i1} = \begin{cases} 1 & \text{if } A_{i1}^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{Selection Equation} \quad (8)$$

$$A_{i2} = \gamma_2' X_{i2} + \mu_{i2}, \quad A_{i2} = \begin{cases} 1 & \text{if } A_{i2}^* > 0 \\ 0 & \text{otherwise} \end{cases} \quad \text{Outcome Equation} \quad (9)$$

Equation 8 and 9 are partially bivariate probit model(s) that give the first stage inefficiency in credit market as well as adapter and non-adapter in second stage, respectively. The partial situation relates with unobservable cases of decision between adaptation and non-adaptation bases on the phenomena that farmers did not observe inefficiency in credit market climate change<sup>17</sup>.

The determinant of *access to credit* depends on demand side factors but there is possibility for the dependence of *access to credit* on other factors including collateral, transaction cost, information relating variables or proxies etc. and these factors are also responsible for change in supply of loanable funds. This possible relation can generate the econometric problem of identification. The solution can be obtained in reduced-form equation if all factors of both demand and supply of loanable funds are introduced in this equation. For the proxies of supply side factors, Vector  $X_{SL}$  is incorporated in regression equation 6 and 7.

### 3.2.4 Exploratory Data Analysis: Imperfect Capital Market and Adaptation Investment

In spite of the regression analysis, the Exploratory Data Analysis (EDA)<sup>18</sup> is also performed to scrutinize the study objective. In performing qualitative analysis, the issue of adaptation investment in the presence of imperfect capital market is explored. And farmers’ assets, income, knowledge, climate change, etc. and credit relating variable are analyzed. The expected outcome of following answer is also worked-out, e.g. does credit help farmers to invest in adaptation activities? If yes, who obtain the credit? Further, how do farmers finance their climate adaptation activities? Either, income, savings, asset selling or credit helps to finance the adaptation strategies? Do they use the credit from the Banks to finance the adaptation strategies or they only use the credit for consumption, working capital, and repairing house?

In addition to analyze the demand-side of loanable market, the supply of loanable fund is also worked-out that analyze the issue of inefficiency and hence, imperfect capital market using the

<sup>17</sup> Rest of the part for Heckman Treatment Effect model is explained at ‘Appendix-C’

<sup>18</sup> EDA analyze data set by using and summarizing the main characteristics of data through statistical or non-statistical tools. Additionally, EDA encompasses “three of the main strategies of data analysis which are: *i*) graphical presentation, *ii*) Provision of flexibility in viewpoint and in facilities, *iii*) Intensive search for parsimony and simplicity” (Jones, 1986, Vol. IV, p. 558).

Exploratory Data Analysis. The data regarding this aspect is gathered through In-depth Interviews (IDIs) and Focus Group Discussion (FGDs) with Formal and Informal money lenders as well as farming communities, respectively. This framework is helpful to scrutinize the Microcredit banks and Microfinance Institutions (MFIs)<sup>19</sup> criteria in allocating/ credit to farmers, *i.e.*, screening cost, application scrutiny process of borrowers, adverse selection as well as moral hazard issues. This process also guides to explore the Informal financial market structure and existent credit availability there.

#### **4. Sampling and Data, Variables Description**

##### **4.1. Selection of Climate Change Vulnerable Areas/districts**

This study uses the similar cropping pattern to identify the issues in climate financing and adaptation investment in agriculture. For the selection of districts, *i*) only those districts are taken where wheat<sup>20</sup> is major crop of production, *ii*) vulnerability of all wheat growing districts are considered and most vulnerable districts are taken, *iii*) vulnerable districts are selected from at least four agro-ecological zones that may describe the diversity of climatic condition as well as agriculture productivity, *iv*) selected districts also lies in each province of Pakistan<sup>21</sup>, and *v*) the availability of rural Microcredit facilities<sup>22</sup> is also analyzed with the presence of Formal, Semi-formal and Informal credit institutions that have been working to facilities the farmers for the imbursement of loans.

In first stage for the selection of wheat growing districts, the work of Ahmad *et al.* (2014) is followed and 19 major wheat growing districts<sup>23</sup> are selected from Pakistan. The choice of these districts is based on meteorological observatory and the availability of district profile since 1981. These districts have been situated in all provinces of Pakistan with 13 districts in Punjab Province, 3 in Sindh, 2 in Khyber Pakhtunkhwa (KP) and 1 district in Baluchistan.

In second phase, selection of districts based on vulnerability index is guided by Khan and Salman (2012)<sup>24</sup> where they have constructed human vulnerability index to climate change for 103 districts of Pakistan. Khan and Salman (2012) further divide climate change vulnerability into 5 quintiles and also ranks their affects to natural calamities (climate change). Highest vulnerable districts (also mentioned in quintile 1 to 5) along with major wheat growing districts at Provincial and Agro-ecological wise is adjusted.<sup>25</sup> Further, selected districts are reported at Table 1 where choice was based on variety of Districts, Provinces and Agro-ecological Zones.

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<sup>19</sup> See section 5.2 for detail sampling discussion about formal and informal money lenders for In-Depth Interviews (IDIs).

<sup>20</sup> Wheat is grown as major crop on more land area as compared to other crops.

<sup>21</sup> Baluchistan is ignored due to security reason.

<sup>22</sup> Microcredit bank of Government, Zarai Taraqiati Bank Limited (ZTBL) with wide covering network scattering with 460 branches in more than 300 cities at all over the Pakistan while, National Rural Support Programme (NRSP) Microfinance Bank limited (non-profit organization/bank), working in 64 districts of Pakistan. In spite of that, there are large numbers of private Microfinance institutions are functional at Pakistan (see list of Domestic, Foreign Banks and DFIs at Pakistan's Economic Survey 2016-17)

<sup>23</sup> Pakistan has 144 districts (32 in Baluchistan, 26 in Khyber Pakhtunkhwa (KP), 36 in Punjab, 29 in Sindh, 1 in Islamabad Capital Territory, 10 in Azad Jammu and Kashmir, 10 in Gilgit-Baltistan) including 7 Tribal agencies and 6 Frontier regions with diverse agro-ecological condition.

<sup>24</sup> This study is better with respect to the sample selection and variety of districts in analyzing vulnerability as compared to Rehman and Salman (2013).

<sup>25</sup> See appendix A, Table 2

These districts ensure representative sample of various provinces as well as agro-ecological zone. These agro-ecological zones are developed on the basis of physiographic, soil type, agricultural land usages and climate condition (PARC, 1980; Muhammad, 1986 and Khan, 2005). In Province “Sindh”, there are 3 major wheat growing districts, where “Hyderabad” is moderately affected while “Sukkur” is severely affected due to natural calamities *i.e.* floods and also lies in vulnerable quintile with its presence at “Southern Irrigated Plain” and hence selected. In Province “Khyber Pakhtunkhwa (KP)” both of the districts, namely “Peshawar” and “Mardan” lies in same vulnerability quintile but former one is severely affected due to climate change. In this way, “Peshawar” which lies in “Northern Dry Mountains” Agro-ecological zone is selected.

In last, selection of 2 districts is worked out in Province “Punjab” due to its high share in agriculture productivity and population. “Rajanpur”, Muzaffargarh, D.G. Khan and Mianwali are severely affected districts due to climate change and also vulnerable while Rajanpur is ignored mainly due to security issues and its existance in already selected Agro-ecological zones of district “Sukkur”. District “Muzaffargarh” (vulnerable in Quintile 2) is ranked in highly vulnerable areas as compared to D.G. Khan (Quintile 3) and also lies at Agro-ecological zone of “Northern Irrigated Plain” and selected. While district “Mianwali” has similar characteristics but lies in Part of “Barani (rainfall)” and “Sandy Desert” agro-ecological zone with diverse climatic condition and hence, selected.

After working this sampling methodology, 4 districts present variety of climatic conditions as well as vulnerability to climate change including, *i*) Sukkur (Sindh), *ii*) Peshawar (KP) and *iii*) Muzaffargarh (Punjab) and *iv*) Mianwali (Punjab). One district is selected form each province except Punjab, mainly due to high share in agriculture productivity.

**Table: 1 Vulnerability Ranking and Selection of Districts**

Sr. No.	Province	Districts	Climate Change	Vulnerability Quintile*	Agro-ecological Zones
1	Punjab	Muzaffargarh	Severely Affected	2	Northern Irrigated Plain
2	Sindh	Sukkur	Severely Affected	3	Southern Irrigated Plain
3	Punjab	Mianwali	Severely Affected	4	Part of Barani (rainfall) and Sandy Desert
4	KP	Peshawar	Severely Affected	4	Northern Dry mountains

Source: Khan (2005) and Khan & Salman (2012)

\* Vulnerability Quintile is distribution of districts in five equally distributed quintiles with respect to their vulnerability (For Detail, see Table 1 of Khan & Salman, 2012)

## 4.2. Selection of Primary and Secondary Sampling Unit

The cluster (village) is primary sampling unit while the household is taken as secondary sampling unit. A complete and detailed list of all household within boundary (sample frame) is collected through satellite map, list of union councils in each village and also with the support of Pakistan Metrological Department (PMD). Multi-stage cluster sampling for data collection is adopted to get a representative sample.<sup>26</sup>

### 4.2.1. Sample Size

<sup>26</sup> In case the updated list is not available at household level, systematic sampling is adopted to draw sample.

The study focuses on farm household with agriculture as source of earning because it makes primary earning source of the rural population in Pakistan especially in the areas, under consideration. Major part of poor people in rural area depends on crop output for their survival and also for livelihood but most importantly these sources are highly vulnerable to climate change. A total of 400 households are selected from study area (100 from each district). Two (02) villages/wards are selected randomly from each of the districts that lie in the circumference of 10 km from the observatory point.<sup>27</sup> Then 50 observations from each (one) village is selected randomly and interviewed. These two villages don't have adjacent boundary which help to capture the variety of respondents with varying Microcredit facilities (through formal, semi-formal or informal sources). Additionally, selected respondents are those farmers who have taken loan from formal, semi-formal and informal lenders. Where formal lenders consist on Banks and Semi-formal lenders are Micro-finance institutes and Non-Governmental Organization (NGOs) whereas informal lenders are Commission agents, Arhti, Input supplier; shopkeepers and Landlords etc.

The household list is obtained from union council office, lies in the village and then households shall be picked randomly. In case the lists are not available, systematic sampling is adopted wherein very first households from the very first main street of the village (at entrance way) is picked up. In case the next falling household is not available, the house very front to this are interviewed. Both quantitative and qualitative tools of analysis and data collection are proposed as follows:

#### **4.2.2. Structured Questionnaire, FGDs and Key-Informant Interviews**

Structured questionnaire is used as a major tool for data collection. In order to meet survey objects, two questionnaires, *i*) Household questionnaire *ii*) Questionnaire (guide-line) for **a)** Focus group discussions (FGDs) and **b)** Key-Informant Interviews is designed to collect adequate information. Household questionnaire is structured questionnaire which comprises of all important indicators covering household information, credit availability and options of imperfect capital market scenario, the efficiency to use these loan, and equity to get these loan from institutions, concept of climate change issues, source of climate change adaptation, adaptation strategies and farmers access to get loan from institutions (private and public). In order to account the equity and efficiency issue, attitude & practices of community people about environmental issues is explored through FGDs.

Structured questionnaire is conducted on 400 households that help to analyze the study objectives. It is also supportive to evaluate the existence of imperfect capital market and choice of adaptation strategies in the presence and absence of inequity and inefficiency through the implication of logistic regression analysis.

Key-Informant Interviews (8 from Formal as well as Semi-formal money lender and 8 from Informal money lenders) are being conducted from Bank executives as well as credit officers of Bank/MFI's and Microcredit policy makers, and also informal money lenders. Further the distribution is explained as at least 4 officers (two senior operating officers and two at

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<sup>27</sup> Observatory point is Meteorological observation that is fixed to gather data of weather related variables. Additionally, given the circumference 10 km, it is hard to find large number of villages in the circle. Also a reasonable size of respondents is required to capture intra-district variation in response.

management level from any of two randomly selected districts) in the government agricultural banks, and 4 from MFIs (2 officers in the Microcredit banks and 2 in the Microfinance Institutions). Total 8 (eight) Informal money lenders are being interviewed with 1 (one)<sup>28</sup> from each village areas that may help to better explore the extent of imperfect capital market. They are also helpful to evaluate the credit criteria of banks and the policy in which they offer loan to small and large farmers. It further helps us to evaluate the inefficiencies and inequities arising from credit financing institutions.

Despite of that and also to evaluate the extent of imperfect capital market along with adaptation investment at community level, 4 (four) Focus group discussions (FGDs) are conducted from the all selected districts, this discussion is helpful to evaluate all difficulties that are faced by small to large farmers in getting loan from Microcredit institutions. It explores the access and approach to credit from MFIs institutions? It further evaluates their response for Formal and Informal institutions and how they use credit in allocating various adaptation strategies?

### **4.3. Description of Variables**

This section explains the description of variables, used in this study for Exploratory Data Analysis (EDA) and Heckman Treatment Effect Model of access to credit and adaptation finance. Table 2 explains the description of these variables for analysis.

Age and Family size are used in continuous form while education is categorized in 4 types, namely Not-attending schools, primary education, middle education, and secondary & above education. Farm size is important factor in determining the farmer's capacity to get loan from formal and informal lenders. Four different categories including, marginal, small, medium and large farmers are explained to analyze the economic characteristics. For irrigation, both canal and tube-well as sources of water are considered. Land status is imperative in determining the access to credit and adaptation investment, hence, it's both categories including owners and tenants are taken. Farmers, who are rich in the holding the agriculture tools such as tractor, harvester and thresher are considered to be rich in getting the agriculture productivity gains. Additionally, livestock is another factor that also strengthens the farming status through loan provision and facilitation. In the presence of climate change and vulnerabilities attached with it, climate information variables play vital role in adapting to climate change, and also for demand to credit. In this perspective, weather information through media and community is highlighted. Perception to climate change is also controlled in adaptation finance equation and also mentioned in Table 2.

Access to credit plays an important role in demanding credit for adaptation finance. But existent inequalities as well as inefficiencies in credit market can impede in adaptation investment. And this imperfection in capital market may arise due to unavailability of collateral by farmers at demand side of loanable market. Table-2 also presents the description of collateral held by farmers when they demand for loan from Bank, MFI's and Informal Lenders which are usually reflected in terms of availability of immovable property, personal and group security as

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<sup>28</sup> In some villages, it is very hard to find even one or more than one informal money lenders due to the Islamic nature of the region that strictly forbid loan on interest or sometime informal lenders don't show themselves publically.



**Table 2: Description of Variables (Access to credit and Adaptation Financing)**

<b>Dependent Variables</b>	
<b>Model 1</b>	<b>Model 2</b>
<b>a.</b> Access to Credit = 1 and 0 = otherwise <b>i)</b> Amount of Credit ( <i>continuous</i> ) from <i>ii)</i> Semi-formal and <i>iii)</i> Informal Institute	<b>a.</b> Adaptation Strategy = 1 and 0 = otherwise <b>b.</b> Area under Wheat cultivation ( <i>continuous</i> )
<b>Independent Variables</b>	<b>Definitions</b>
Age	Continuous with Mean 45
Family Size (Continuous)	Continuous with Mean 11.79
Never Attended School	=1 if he/she didn't attend school and 0 = otherwise
Primary Education	=1 if he/she got primary education (1-5) and 0 = otherwise
Middle Education	=1 if he/she got middle education (6-8) and 0 = otherwise
Secondary & Above Education	=1 if he/she got $\geq 9$ education and 0 = otherwise
Marginal Farmers	=1 if farmers have land area $\leq 6.25$ acre and 0 = otherwise
Small Farmers	=1 if farmers have land area $\leq 12.50$ & $> 6.25$ acre and 0 = otherwise
Medium Farmers	=1 if farmers have land area $\leq 25$ & $> 12.50$ acre and 0 = otherwise
Large Farmers	=1 if farmers have land area $> 25$ acre and 0 = otherwise
Non-Farm Income	=1 if he/she earn income from non-farm sources and 0= otherwise
Canal Irrigation	=1 if he/she get canal water for irrigation and 0= otherwise
Tube well Irrigation	=1 if he/she get Tube well water for irrigation and 0= otherwise
Tenancy Owner	=1 if he/she is owner of land and 0= otherwise
Tenancy Tenant	=1 if he/she is tenant of land and 0= otherwise
Agriculture Assets	=1 if he/she has one or more agriculture assets and 0= otherwise (Assets are Tractor, Trolley, and Harvester etc.)
Livestock Assets	=1 if he/she has one or more Livestock assets and 0= otherwise (Assets are Buffalo, Cow, Goat and Hens etc.)
Bank Collateral_property	=1 if he/she has Agriculture Land as Bank Collateral and 0 = otherwise
MFI Collateral-personal Security	=1 if he/she has Personal Security/Guarantee as MFI's Collateral and 0 = otherwise
MFI Collateral-Group Security	=1 if he/she has Group Security/Guarantee as MFI's Collateral and 0 = otherwise
Informal Lender-personal Security	=1 if he/she has Personal Security/Guarantee as Informal Lender's Collateral and 0 = otherwise
Informal Lender-group Security	=1 if he/she has Group Security/Guarantee as MFI's Collateral and 0 = otherwise
Distance of Bank/MFIs and Informal lenders from borrower place	Distance of lenders (Bank/MFIs/Informal lenders) from borrowers place ( <i>in miles</i> )
Duration of loan obtained from Bank/MFIs and Informal Lenders	Duration of loan obtained from Formal and Informal lenders ( <i>in months</i> )
Interest rate Information about Bank/MFIs and Informal lenders	=1 if farmer has information about interest rate from lenders and 0 = otherwise
Cost (Registration/trip to lenders)	Total cost of borrowing faced by farmer in paying registration and trip to lender ( <i>USD</i> )
Paying back whole amount to lenders (Bank/MFIs/Informal)	=1 if farmer has paid back whole borrowed amount (already taken) and 0 = otherwise.
Temperature <sup>29</sup>	6 years moving average of Temperature at village level (down-scaled data)
Precipitation	6 years moving average of Precipitation at village level (down-scaled data)
Weather Information- Media source	=1 if people has source of weather information through Media and 0 = otherwise
Weather Information- Community	=1 if people has source of weather information through Community and 0 = otherwise
Perception of winter rainy season	=1 if he/she perceive about the increase in winter rainy seasons and 0 = otherwise
Northern Irrigated-Agro Zone	=1 if he/she has farming activities at Agro-ecological zone of Northern Irrigated Plain and 0 = otherwise
Southern Irrigated-Agro Zone	=1 if he/she has farming activities at Agro-ecological zone of Southern Irrigated Plain and 0 = otherwise
Northern Mountains-Agro Zone	=1 if he/she has farming activities at Agro-ecological zone of Northern Dry Mountains and 0 = otherwise
Barani and Sandy Desert-Agro Zone	=1 if he/she has farming activities at Agro-ecological zone of parts of Barani and Sanday Desert and 0 = otherwise

<sup>29</sup> Source: PMD (2018)

guarantee. Existing research also highlights the distance of Bank, MFI's and Informal lenders from borrower location as important variable in accessing to credit. Further, Distance of Bank/MFIs and Informal Lenders from borrower place are also explained in miles. This is the distance of nearest lender (those who offer and give loan) from the respondent/farmers location. It means that some of the farmers may get loan from the nearest lenders, including Banks/MFIs/Informal lenders while others may get loan from the far-off lenders.

## 5. Results and Discussions

### 5.1. Findings of Exploratory Data Analysis (EDA)

This section explains the findings of field data for various Agro-ecological zones of Pakistan by using the EDA method. Table 3 explains the socioeconomic characteristics of 400 farmers for four districts. Highest and least age of credit obtaining farmer (80 and 20 year) is observed at 'Peshawar' and 'Sukkur' districts, respectively while rest of two districts have different ranges of age. Highest family size is observed to be 70 at Peshawar district which lies at "Northern Dry mountains"—agro-ecological zone of Pakistan. While highest average family size

**Table 3: Socio-Economic Characteristics of Farmers by Districts**

Variable	Complete Sample	Mianwali	Muzaffargarh	Sukkur	Peshawar	
Age (Years)	44.99	48.57	43.85	42.56	44.98	
	(80)	(75)	(65)	(80)	(80)	
	[12.90] {20}	[10.32] {23}	[11.08] {24}	[15.30] {20}	[13.68] {20}	
Family size	11.79	9.9	10.37	14.11	12.81	
	(70)	(45)	(36)	(45)	(70)	
	[7.42] {2}	[5.75] {2}	[5.53] {2}	[7.28] {4}	[9.65] {2}	
Education (percent of sample)	Never Attendant School	48.25	44	53	67	29
	Primary	18.50	15	22	4	33
	Middle	10.00	16	12	3	9
	Secondary & Above	23.00	25	13	26	28
Farm Size (percent of sample)	Marginal Farmer	66.50	53	70	73	70
	Small Farmer	21.75	26	16	23	22
	Medium Farmer	8.25	18	6	4	5
	Large Farmer	3.50	3	8	0	3

**Note:** ( ), [ ], and { } stand for maximum, standard deviation, and minimum values.

First 2 rows gives mean, max., std. deviation and min. values while rows consisting on Education and Farm size provide percentage of farmers in each category.

exists at Sukkur district and least family size exist at 'Mianwali' region. Percent of educated people in each category, including 'Never Attendant School', 'Primary education', 'Middle education' and 'Secondary & Above education' is taken and presented at Table 3 with highest percent of people in each districts as 67%, 22%, 16% and 28 % at 'Sukkur', 'Muzaffargarh', 'Mianwali' and 'Peshawar', respectively. In full sample, the highest percentage of most of the people holds for "Never Attendant School" which indicates that most of the farmers at Sukkur have not joined school ever. For farm size, 266 (66.50%) respondents at 'Sukkur' district are observed to be 'Marginal farmers' with land area less than 6.25 acre. 'Large farmers' with land size > 25 acre are observed to exist at 'Muzaffargarh' district while there is no evidence for large farmers at 'Sukkur'.

Table 3A extends the socio-economic characteristics of wheat-growing and credit borrowing farmers. It also analyzes the source of income from various major activities, including cultivation, agriculture, non-agriculture, services, business and live-stock etc. It's evident that income from cultivation and agriculture has the highest percentage in complete sample and also

in each district under sample analysis. Only 11% of complete sample have their income from non-agriculture sources including, services, business and livestock but least number of farmers have their source of income from livestock. ‘Muzaffargarh’ district has highest percent (15%) of those farmers who earn their income from non-agriculture sources. Table 3A also explains about percentage of income earned as well as consumed from non-agriculture sources. 42.53% income is earned from non-agriculture sources in complete sample whereas maximum income is earned from ‘Muzaffargarh’ district (43.16%) while least from ‘Mianwali’ (33.22%) which means that people from district ‘Mianwali’ has less option to explore income from non-agriculture sources. In similar way, consumption on non-agriculture sources is mostly used by the farmers of ‘Mianwali’ district. They are earning less from non-agriculture based resources but they are spent more on those resources and most of the income is financed by agriculture based sources.

**Table 3A: Source of Income and Consumption by Districts (in percentage)**

Variable	Complete Sample	Mianwali	Muzaffargarh	Sukkur	Peshawar	
Source of Income from	Cultivation	80.00	83.00	74.00	67.00	96.00
	Agriculture	67.25	78.00	57.00	68.00	66.00
	Non-agriculture	11.00	12.00	15.00	7.00	10.00
	Services	8.00	7.00	6.00	10.00	9.00
	Business	6.00	6.00	5.00	5.00	8.00
	Livestock	0.75	0.00	1.00	0.00	2.00
Income earned from non-agriculture sources (in percent)	42.53	33.22	43.16	39.50	50.52	
Consumption on non-agriculture items (in percent)	43.72	45.37	42.82	43.75	42.94	

**Note:** All values are given in percentage from its sample under analysis.

Table 4 explains farmer characteristics of ‘land area of wheat growing farmers’ and ‘market distance to lender from borrower location’. In full sample (400), mean land area is 7.63 acre with maximum land area size, 175 acre lies at ‘Muzaffargarh’, District and minimum land size is 0.49 acre at ‘Sukkur’ and ‘Peshawar’ District. Distance to lender (Banks, MFIs and Informal Lenders) from borrower location is explained for each district. Hence, it’s observed that average distance

**Table 4: Farming and loan Characteristics by Districts**

		Complete Sample	Mianwali	Muzaffargarh	Sukkur	Peshawar
Total Land Area acre (Wheat grower)		7.63	8.89	10.06	5.25	6.31
		(175)	(75)	(175)	(25)	(60)
		[12.53]	[9.72]	[21.02]	[4.17]	[8.02]
		{0.49}	{1}	{0.988}	{0.49}	{0.49}
Distance to Lender	Bank	17.02	14.40	14.75	14.33	21.71
		(30.0)	(30.0)	(28.0)	(20.0)	(30.0)
		[7.62]	[9.03]	[5.72]	[6.02]	[5.15]
		{1.0}	{1.0}	{10.0}	{8.0}	{12.0}
	MFIs	22.81	4.46	35.44	—	19.69
		(90)	(13.0)	(90.0)		(26.0)
[23.62]		[4.05]	[28.41]		[4.60]	
	{1.0}	{1.0}	{6.0}		{12.0}	
Informal Lender	21.31	3.88	9.76	52.15	11.90	
	(600)	(13.0)	(35.0)	(600)	(30.0)	
	[76.84]	[3.49]	[7.24]	[137.53]	[10.15]	
	{1.0}	{1.0}	{1.0}	{1.0}	{1.0}	
Off-farm income	Yes =1 No = 0  (percent)	24.75	20	28	29	22
Access to canal irrigation		67.50	20	53	99	98
Access to Tubewell irrigation		32.00	78	47	1	2
Number of Dependents						

**Note:** ( ), [ ], and { } stand for maximum, standard deviation, and minimum values.

First 2 rows gives mean, max., std. deviation and min. values while other rows provide percentage of farmers in each category.

(in miles) is least for ‘Sukkur’ while highest mean distance is explained by ‘Peshawar’ (21.71 miles). Borrowers of this region (Peshawar) have to travel far flung areas to get credit from Formal lenders that may strengthen the imperfection of capital market in allocating and financing loans to vulnerable farmers of this region. Borrowing farmers couldn’t approach to MFIs at ‘Sukkur’, District which further strengthen the argument of imperfect capital market in semi-formal lender perceptible. This is possible due to unawareness about MFIs among poor farmers, non-availability of MFIs facilities about credit financing, existence of MFIs at far flung areas and most importantly about the access and approach to Semi-formal credit market by farmers. It is imperative to note that the borrowers of same region have direct connection with Informal lenders with mean value of 52.15 miles and maximum value of 600 miles distance. It also means that climate change vulnerable farmers don’t have option to borrow from Formal or Semi-formal lenders and they decide to get loan from Informal lenders in spite of long distance. Additionally, unavailability of Banks and MFIs at closet areas and people preference to move for longest route to obtain loan from informal lenders substantiate for credit market imperfection.

Off-income can be used as collateral to get loan from Formal and Informal lenders and also support to agriculture activities in adapting to climate change. The least number of farmers having off-farm income is observed at ‘Mianwali’ District while there is no evidence for largest share for other districts. Access to irrigation through ‘canal’ and ‘Tube well’ water increase the farm productivity, strengthen lender confidence in disbursing loan to farmers and also willing to repay of debtors. 99% of farmers at ‘Sukkur’ region have less-expensive source “canal water” for irrigation but borrowers at ‘Mianwali’ have only 78% as Tubewell Water.

**Table 5: Access and Approach to Credit (in percentage)**

Variables		Complete Sample	Mianwali	Muzaffargarh	Sukkur	Peshawar
Access to Credit opportunities by	Bank	36.25	45.0	52.0	19.0	29.0
	MFIs	37.25	45.0	64.0	12.0	28.0
	<b>Informal Lenders</b>	<b>95.0</b>	<b>87.0</b>	<b>99.0</b>	<b>100</b>	<b>94.0</b>
Approach to Lenders (Formal and Informal)	Bank	49.0	63.0	63.0	25.0	45.0
	MFIs	45.2	60.0	70.0	16.0	35.0
	<b>Informal Lenders</b>	<b>96.0</b>	<b>87.0</b>	<b>99.0</b>	<b>100</b>	<b>98.0</b>
Awareness of Rural Credit facilities from	Bank	55.8	68.0	73.0	31.0	51.0
	MFIs	52.0	65.0	79.0	21.0	43.0
	<b>Informal Lenders</b>	<b>96.8</b>	<b>90.0</b>	<b>99.0</b>	<b>100</b>	<b>98.0</b>
Awareness about different services, provided by	Bank	63.4	47.4	82.4	56.6	68.7
	MFIs	59.1	44.2	86.4	42.8	51.6
	<b>Informal Lenders</b>	<b>96.9</b>	<b>89.9</b>	<b>100</b>	<b>100</b>	<b>98.0</b>

Source: Self data Collection and self-calculations

In order to evaluate the market imperfection, Access to credit opportunities by Bank, MFIs and Informal Lenders are explained at Table 5. As far as complete sample is concerned, only 145 (36.25%) farmers have access to credit from Banks as compared to 95% borrowers from Informal lenders. so, large sample size have easy access to credit from Informal lenders while they have less access to get credit from Formal (145 farmers) and Semi-formal lenders (149 farmers) that corroborate the credit market imperfection in financing to adapt to climate change. The similar behavior is documented across all districts where only 19% and 12% borrowers have access to credit from Formal and Semi-formal lenders. Highest number of farmers (52%) at ‘Muzaffargarh’ Districts has access to credit from Banks while 99 % have access to credit from Informal lenders which also strengthen credit market imperfection. In addition to that, ‘approach to lenders’ and ‘awareness to rural credit facilities’ are also reported for all types of lenders

across various districts. Again it has been observed that framers have meager approach to Formal and Semi-Formal lenders but they have easy approach to Informal lenders.

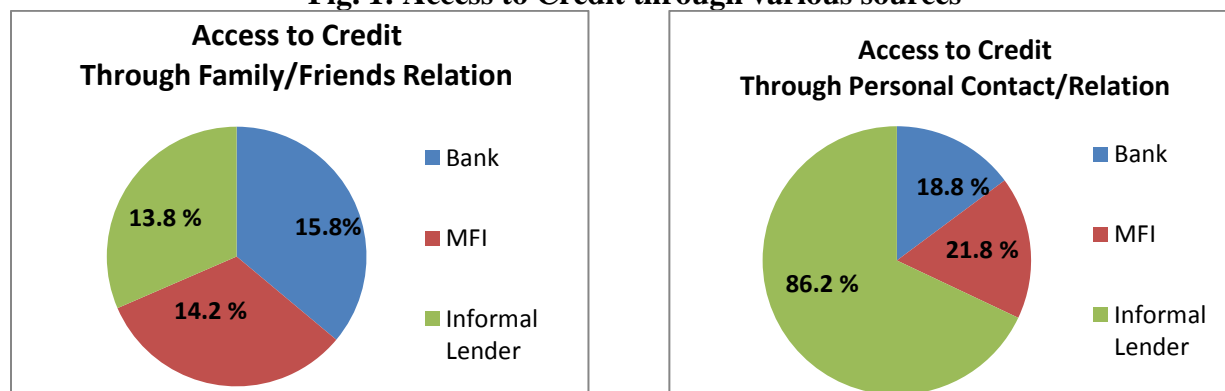
‘Limited access of farmers to Banks’ alone doesn’t indicate the capital market imperfection rather it’s based on the application scrutiny process which depends on the easy availability and also requirement of collateral for Informal lenders while same requirements are not workable for Banks. Additionally, capital market imperfect hypothesis is strengthened using other market indicators, e.g., “Direct access to credit from Bank/MFIs and Informal Lenders”, “Awareness to Bank/MFIs and Informal Lenders”, and also “Approach to Bank/MFIs and Informal Lenders” etc. From Table 5, it is evident that large number of farmers has easy approach to all these indicators from Informal lenders rather than Banks.

**Table 6: Type of Security observed by Borrowers (by percentage of total)**

Securities	Bank	MFIs	Informal Lender
Agriculture Land (Immovable property)	8.2	2.0	5.2
Personal Security /guarantee	0.2	7.8	63.0
Group Security/guarantee	1.0	3.0	4.8

In order to explore further about market imperfection and access to credit from Formal, Semi-formal and Informal lenders, collateral for loan and various sources are explored at Table 6 and Fig.1. Farmers are observed to get credit from Formal and Informal lenders and their access to credit can be analyzed further through type of security used, while borrowing. Most of the farmers have less land holding and also meager land or immovable property for collateral (only 8.2%). Further, this hold trues for Semi-formal lenders where only 7.8% farmers has access to personal security (borrower own guarantee while borrowing from Informal lenders)<sup>30</sup> and only 3.0% to group security— week form of collateral.<sup>31</sup> This further creates inefficiency in getting credit from Formal and Semi-formal lenders. As far as loan from Informal lender is concerned, 63% borrowers use ‘personal security’ which is the easiest form of collateral in getting loan. This is only and easy source that farmers can use to obtain loan from market. Additionally, the availability of personal security as collateral is evident from Table 6 for credit market where

**Fig. 1: Access to Credit through various sources**



<sup>30</sup> Own guarantee can be sustained for future and current borrowing based on credit history or previous credit information of borrowers by lenders for lending.

<sup>31</sup> Group security is type of security, done by group or members for guarantee of one another while they borrow from lenders and it is usually used to get borrowing from MFIs and Informal lenders

maximum number of farmers borrows from Informal lenders which substantiates the market imperfection hypothesis.

In Fig.1, inefficiency in credit market is evaluated through sources of access to credit from Formal, Semi-formal and Informal lenders. Farmers are observed to get credit access through “family/friends relation” and also “personal contacts”. Farmers who get credit through Banks and MFIs use their own personal contact (18.8% and 21.8%, respectively) in accessing to credit. Additionally, borrowers also use personal contacts in accessing loan from Informal lenders while only 14.2% use friends/family contacts. Both of these sources are observed to have major share for access to credit while the role of “Mobile Credit Officer” (MCO) as source for access to credit has been absent that support to the credit market imperfection. It further indicates that Formal credit network of MCO’s have been absent and they are unable to meet the local market requirements regarding loan financing.

The description of all of above tables shows that Formal credit market provides scant access to credit opportunities while Informal credit market has been vibrant in the provision of loan to farmers which support to the credit market imperfection hypothesis. It is evident that Banks, MFIs and Informal lenders work on different business models to screen the borrowers where Banks take into consideration both collateral and marketing surplus to the farmers’ ability to repay while, Informal money lenders have close relation with farmers/borrowers and scrutinize their application based on credit history, personal relation and previous transaction in evaluating the farmers ability to repay the loan. But still the role of collateral is very essential in evaluating the application of borrowers. If farmers don’t have access to collateral and they are easily rule out to apply for loan by Formal lenders including Banks and some structure of MFIs. This week availability of collateral doesn’t make them powerful for the application of loan at Banks and also indirectly substantiates the credit market imperfection hypothesis. Additionally, farmers can’t use personal guarantee or group guarantee as collaterals in getting the loan from Banks while they can easily use these collaterals to apply for loan from Informal lenders which has been flexible in considering their applications and also offering them loan. So, the same collateral is not applicable for Formal lenders i.e., Banks while it is feasible and applicable for Informal lenders that support to the fundamental hypothesis of market imperfection.

**Table 7: Access to Credit and Farming Status (by percentage of total)**

	Marginal Farmer	Small Farmer	Medium Farmer	Large Farmer	Non-Farm Income	Canal Irrigation	Tube-well Irrigation	Owner	Tenant
<b>Access to Credit-Banks</b>	32.3 [32.2] (0.00)	39.1 [4.1] (0.042)	51.5 [0.30] (0.862)	57.1 [0.286] (0.593)	46.5 [0.495] (0.482)	32.96 [31.348] (0.00)	42.96 [2.531] (0.112)	40.00 [11.600] (0.001)	28.76 [13.164] (0.00)
<b>Access to Credit-MFI’s</b>	35.7 [21.7] (0.00)	39.1 [4.1] (0.042)	39.4 [1.49] (0.223)	50.0 [0.000] (1.00)	28.85 [26.638] (0.00)	56.37 [2.423] (0.12)	42.95 [2.960] (0.085)	69.12 [21.805] (0.00)	21.47 [48.490] (0.00)
<b>Access to Credit- Informal Lender</b>	93.6 [202.3] (0.00)	97.7 [79.1] (0.00)	96.96 [29.1] (0.00)	100 [----] (----)	24.47 [99.042] (0.00)	68.68 [53.063] (0.00)	91.4 [87.78] (0.00)	94.82 [233.103] (0.00)	18.815 [154.116] (0.00)

*Note: Chi-squares test is performed for association of variables where [ ] stands for value of chi-squares while ( ) stands for Asymptotic significance.*

The findings of capital market imperfection and inefficiency in credit market are further strengthened by developing the frequency percentage among socio-economic status, farming options and access to credit related variables. The significance is also checked by applying the

Chi-squares test for the association of variables. Table 7 reports the relation among Access to credit and farming status, using its various categories, including, Marginal, Small, Medium and Large farmers. Land holding farmers > 25 acre (large farmers) have highest access to credit from Bank (57.1%) and MFIs (50%) while marginal farmers significantly less access to credit from Banks, strongly supports the credit market imperfection at demand side. It further indicates that access to credit is scattered toward rich segment of society (large land holders) by Formal and Semi-formal lenders that may be existent due to the availability of land as collateral. For Informal land holders, access to credit is existent for across all land holdings, from Marginal to Large farmers.

Non-farm income can also determine the farmer ability for Access to credit and highest non-farm income holding farmers (46.5%) can use it for collateral and has greatest access to credit from Banks. Existent of Canal and Tube-well irrigation is effective to get loan from Informal lenders which doesn't have any link with collateral and enhance the opportunities for access to credit.

**Table 8: Access to Credit and Socio-Economic Background**

	Awareness Bank	Never attended School	Primary	Middle	Secondary & Higher	Agriculture Assets	Livestock Assets	Household Assets
Access to Credit-Banks	63.67 [16.68] (0.00)	28.89 [31.36] (0.00)	39.18 [3.45] (0.063)	42.50 [0.90] (0.343)	44.56 [1.08] (0.297)	60.37 [2.28] (0.131)	33.03 [25.45] (0.00)	37.36 [23.75] (0.00)
Access to Credit-MFI's	69.71 [32.32] (0.00)	28.86 [34.66] (0.00)	40.54 [2.64] (0.104)	52.5 [0.10] (0.752)	45.65 [0.69] (0.404)	50.94 [0.01] (0.891)	33.148 [24.11] (0.00)	39.24 [17.20] (0.00)
Access to Credit- Informal Lender	98.19 [359.50] (0.00)	96.9 [170.74] (0.00)	94.59 [58.86] (0.00)	90.0 [25.60] (0.00)	93.47 [69.56] (0.00)	90.56 [34.88] (0.00)	94.11 [172.05] (0.00)	94.62 [296.30] (0.00)

*Note: Chi-squares test is performed for association of variables where [ ] stands for value of chi-squares while ( ) stands for Asymptotic significance.*

Farmers who have awareness of Banks have also access to credit; again this effect has been strong to obtain credit from informal lenders. Farmers have highest access to credit, irrespective of their education status while the highest values go to "Never attended school". Assets (agriculture, livestock and households) have significantly highest and strong relation with Access to credit from Informal lenders while farmers with ownership of agriculture tools have relation with Access to credit from Banks (60.37%).

In order to further support the capital market imperfection, 'borrower's reasons to get the loan', 'amount obtained by borrowers from Formal, Semi-formal and Informal lenders', and 'procedure to credit' are also highlighted. 'Duration of loan' and 'loan purpose as well as spending' is also analyzed in various ways to explore the credit market behavior.

After analyzing the market imperfection through access to credit, farmer's awareness about credit and procedure to credit are reported at Table 9. If farmers are well aware with the available procedure to credit from Formal and Informal institute, they can mitigate the constraints of credit market. People knowledge for the 'procedure of borrowing from Bank, MFIs and Informal lenders' is presented. Only 14% (56) and 15.5% (62) farmers have knowledge about the procedure to obtain credit from Banks and MFIs, respectively while large percentages of farmers (89%) are well aware about the procedure to credit from Informal Lenders. This awareness about procedure to credit from Informal lenders and unavailability from Formal and Semi-formal

lenders consistently support to inequities attached with the programs of Banks and MFIs which restrict themselves and don't launch credit information as well as credit procedure programs for climate change vulnerable farmers.

**Table 9: Market Procedure to Credit**

Variables		Percent
People knowledge for the Procedure of borrowing from	Bank	14.0
	MFIs	15.5
	<b>Informal Lenders</b>	<b>89.0</b>
People knowledge for Easy availability of credit from	Bank	9.0
	MFIs	12.2
	<b>Informal Lenders</b>	<b>80.5</b>
People Demand/Application for Loan at	Bank	10.0
	MFIs	13.5
	<b>Informal Lenders</b>	<b>88.5</b>
People's Loan obtaining from	Bank	9.5
	MFIs	11.2
	<b>Informal Lenders</b>	<b>85.0</b>

In addition to the procedure for credit, people knowledge for easy availability of credit from Formal and Informal credit institute also works to reduce the inefficiencies and inequities from credit market. But available evidence at Table 9 supports that only 9% and 12.2 % farmers have knowledge about easy availability of credit from Banks and MFIs while large number of borrowers (80.5%) have knowledge about easy availability of credit from Informal lenders. In this perspective, it's also necessary to consider the people demand or application of loan to both Formal and Informal lenders, but again large number of farmers (88.5%) are observed to apply for loan at Informal lenders and small numbers only (40) applied for loan at Banks which ensure people preference about credit, mainly due to their scant knowledge about credit opportunities at Banks and MFIs. Hence, it supports to inequities in credit market in awareness perspective. It's also interesting to mention that rejection rate is very small for both Formal and Informal institutes that's evident from 'people demand for loan' and 'people's loan obtaining' from Banks, MFIs and Informal Lenders.

**Table 9A: Procedure Type to Access and Obtain Credit (by percentage of sample)**

Variables		Bank	MFIs	Informal Lender
Procedure to borrow	Through Application Letter	4.50	4.25	0.50
	Introduced by customer/friend	1.00	3.25	22.50
	Introduced by Dominant Person of Village	1.50	3.50	8.00
	Through 'Pass Book' (Land Revenue Dep.)	8.25	4.75	0.00
People Information about acquire credit		11.25	13.75	85.75
Credit acquired in form of	Cash	88.64	94.75	24.23
	'In Kind'	11.36	3.64	58.59
	Both Cash and 'In Kind'	0.00	1.82	100.00
Credit availability is affected	Land size	6.25	5.50	51.50
	Credit history	5.75	8.50	63.50
Local Pressure to repay loan		—	—	14.04
Legal pressure to repay loan		13.15	3.70	6.74
Use of 'Law and enforcement agency' to get credit by lender		7.89	—	3.08

In extending the market procedure in accessing the credit from Formal and Informal lenders, detailed analysis about the characteristics of borrowers from both lenders are explained at Table 9A. For banking sectors, 'procedure of borrow' through application letter is important which is very low and lies only 4.50% percent. While, 22.50% borrowers claim that they are 'introduced

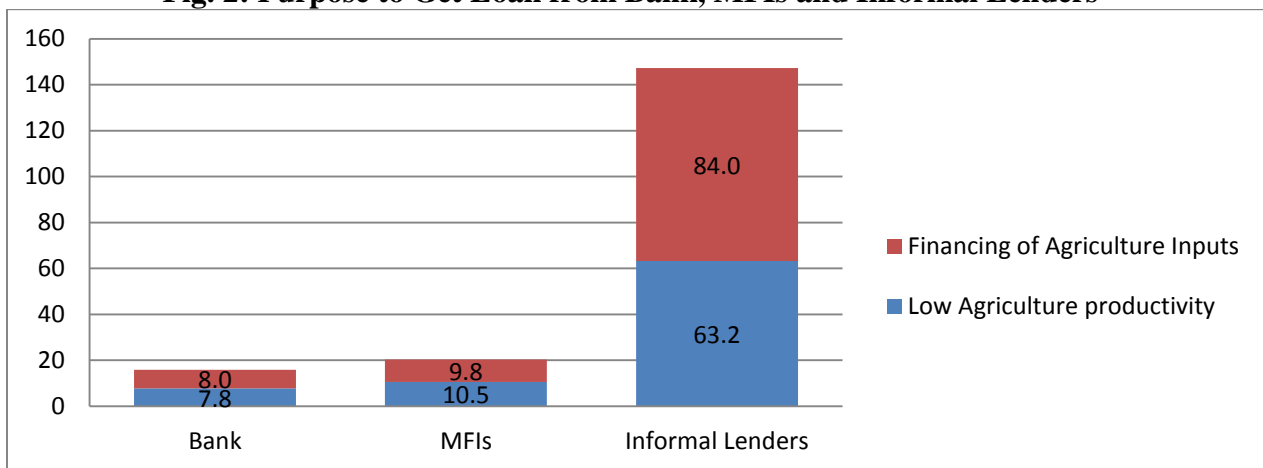


by the friends’ to Informal lenders, indicating the lack of information about market conditions. ‘Pass Book’ is an important component to get loan from Banks that is only adopted by 8.25% of total sample. People have more information to acquire credit from Informal lenders (85.75%) as compared to MFIs and Banks and it is acquired in form of ‘cash’ and ‘in-kind’ or ‘both’. Most of the borrowers get loan from Formal lenders, Banks and MFIs in form of cash while this work mixed for Informal lenders where borrowers get loan both in form of cash and in-kind, 24.23% and 58.59%, respectively.

‘Land size’ and ‘credit history’ are important factors to contribute in getting credit from all type of credit market but it has important implication while framers get credit from Informal lenders. Additionally, credit history has imperative role for borrowers in getting loan from Informal lenders who always take it as ‘Collateral’ and facilitates farmers in accessing to credit opportunities. In Table 9A, 63.50% farmers think that credit availability is affected by credit history while they borrow from Informal lenders. In last, use of local and legal pressure to get back loan has been prominent by lenders, where 14.04% of borrowers claim about the use of local pressure by Informal lenders. Only 6.74% of borrowers face legal pressure by Informal lenders while 8.50% borrowers claim pressure by MFIs. Banks have been present to use the ‘law and enforcement agency’ to get back credit with 7.89% lenders.

In capital market literature, incentive effect or moral hazard that is captured by ‘willingness to repay’ (by debtors) plays an important role in affecting the lenders decision to disburse credit. If farmers have access to credit and demand loans for farming relating activities or to finance their agriculture inputs in adaptation investment context, in result, lenders usually come to know that farmers would get bump crop in future and will repay their loan in time. Against this background, framers purpose to get loan from Bank, MFIs and Informal lender is considered and explained at fig. 2.

**Fig. 2: Purpose to Get Loan from Bank, MFIs and Informal Lenders**



**Note:** Y-axis shows the percentage while X-axis explains source of borrowing from lenders.

Purpose to get loan is usually based on “*financing of agriculture inputs*” and “*low agriculture productivity*” among borrowing farmers. Farmers usually consider the purpose before getting loan from Banks, MFIs and Informal lenders and its use the loan to ‘finance the agricultural

inputs’ and also due to ‘low agriculture productivity’. Only 9.5%<sup>32</sup> obtain loan and 8% of total sample (84.2 % of Bank’s borrowers) use loan for the “financing of agriculture inputs” while large number of borrowers obtain loan from Informal lenders and use them for “*financing of agriculture inputs*” (84%) and “*low agriculture productivity*” (63.2%). Major proportion of borrowers use loan for agriculture input financing related activities instead of using it for domestic or personal purpose, ensuring the willingness to repay in strong extent.

**Table 10A: Borrower’s Reason to Get Loan (by percentage)**

Reasons	Bank	MFIs	Informal Lender
Easy to Approach	8.50	11.75	—
Easy to Access	8.25	12.25	82.25
Easy to get Credit	3.50	5.50	78.25
Availability of Land for Collateral	3.00	0.25	—
Person known in the village	—	—	63.25

**Table 10B: Type of Security observed by Borrowers (by percentage of farmers/borrowers)**

Securities	Bank	MFIs	Informal Lender
Agriculture Land (Immovable property)	86.84	15.56	5.59
Personal Security /guarantee	2.63	51.11	70.00
Group Security/guarantee	10.53	26.67	5.59
Without security /collateral	0.00	4.44	18.82

As far as demand of credit from capital market is concerned, market constraints are crucial in effecting the borrowers capacity to apply and obtain loan from Formal and Informal lenders. Climate change vulnerable farmers decide to apply loan based on the available market reasons at Table 10A. Only 8.50% and 11.75% claimed about ‘easy approach to Bank and MFIs’ respectively. Further market constraint related variables are introduced by using ‘easy Access’ to Formal and Informal institutes and only 8.25%, and 12.25%, for Banks and MFIs, respectively responded for that while ‘easy access’ to informal lender is recorded 82.25% which strongly support that absence of ‘easy access’ substantiate credit market imperfection.

‘Easy to get credit’ from Formal and Informal institutes is important market related variables and it’s efficiency interlinked with market perfection but in whole sample only 14 (3.50%) and 22 (5.50%) climate change vulnerable farmers claims about market easiness to get credit from Banks and MFIs. ‘Availability of Land for Collateral’ is only 3% and 0.25% for Banks and MFIs where farmers consider that access can be obtained if they have availability of land for collateral. At Informal credit market, ‘person known in the village’ matters which means if any farmer has good relation with community person(s), he can get loan from Informal lender. Additionally, this variable doesn’t matter for Bank or MFIs which induce the inefficiency of formal lender in disbursing loan to poor farmers.

In credit market at supply side, lenders follow scrutiny process to identify the best borrowers with maximum probability to repay loan. This process is linked with adverse selection and can be measured in terms of amount delivered to borrowers. Table 11 gives the description of borrower’s amount of loan (in USD)<sup>33</sup> from Bank, MFIs and Informal lender. Mean value of borrowing in cash from Bank is 1,884/- USD with maximum value taken by farmer is 9,009/- USD while mean value of loan form MFIs is 561/- USD with maximum amount.

<sup>32</sup> See Table 9 for more detail about loan obtains etc.

<sup>33</sup> Current exchange rate is used in converting rupees in USD.

**Table 11: Amount Obtained by Borrowers (Total)**

Amount	Bank (38)	MFIs (54)	Informal Lender (356)
Borrowing in cash (USD \$)	1,884 (9,009) [2,098] {248}	561 (581) [3,784] {36}	1,062 (1,913) [13,514] {27}
Borrowing in kind (USD \$)	---	541 (541) [0] {541}	1,062 (18,018) [2,058] {14}
Amount borrowed total (USD \$)	1,884 (9,009) [2,098] {248}	571 (3784) [585] {36}	1,250 (25225) [2497] {14}
Application processing fees* (USD \$)	18.50 (162.60) [30.05] {0.40}	5.36 (24.39) [4.49] {0}	3.00 (65.00) [7.97] {0}

Note: ( ), [ ] and { } stand for maximum value, standard deviation and minimum values.

\*Takes into account costs on application, registration and round-trip to office/lenders

Credit market inefficiency is not only explained by the amount of credit obtained by borrowers, rather duration of loan, loan period, and information about interest rate are also important indicators to highlight the inefficiency in credit market. Table 11A extends the market inefficiency analysis by incorporating all these indicators and it's evident that duration of loan is mean value in the range of 6.41 to 17.02 months for Formal and Informal lenders, respectively. Higher number of months of loan duration is observed by MFIs (60 months) while minimum number of months of loan duration exists for Banks. Minimum deviation for loan offering duration exists by Informal lenders which are confirmed by the village structure or crop based loan options. Most of the farmers are observed to be satisfied with loan duration options with 87.32% from Informal lenders and 76.32%, 77.78% exist for Banks and MFIs, respectively. Farmers have less information about interest rate from both Formal and Informal lenders. This is possible due to the Islamic nature of society that strictly prohibits the loan on interest. This is also interesting to note that farmer's knowledge about the interest rate also effect to the choice of credit.

**Table 11A: Duration of Loan and Interest on Loan (by percentage of borrowers)**

Variables	Bank	MFIs	Informal Lender
Duration of Loan (in months)	17.02 (30.0) [7.62] {1.00}	10.94 (60.0) [7.91] {2.0}	6.41 (25.0) [2.75] {2.0}
Duration of loan is enough? (in percent)	81.57	75.92	89.60
Satisfaction level about loan period			
Completely	76.32	77.78	87.32
Less or No	23.68	22.22	12.68
Did you Request to increase the Pay Back period	18.42	5.55	5.61
Have you pay back all amounts?	73.68	85.18	83.14
Information about Interest Rate from	45.49	44.07	42.03
Interest rate knowledge and credit choice relation	80.00	77.36	72.13

Note: ( ), [ ] and { } stand for maximum value, standard deviation and minimum values.

After explaining the fundamental of capital market imperfection through access to credit, Table 12 explains the adaptation strategies or adaptation investment choice by districts at various Agro-ecological zones of Pakistan. Top 9 mostly used adaptation strategies are mentioned that directly or indirectly undertake credit financing but some of these adaptation strategies are not the response of climate change rather these are adopted due to market requirements, labor scarcity,

opportunity of worker and to get the gains of higher production which is named as “non-climate change related adaptations”. These most widely used adaptation strategies includes, ‘increase in the use of tractor’, ‘use of more fertilizer’, ‘increase in the use of pesticides’, ‘use of better and expensive fertilizer’, and ‘change in crop planting/sowing date’. However, some of the adaptation strategies are the direct response of climate change which includes, ‘*stop growing particular verity and introduce new*’, ‘*use more irrigation*’, ‘*use better and expensive seed*’, and ‘*introduced a new crop*’ which is named as “climate change related adaptations”.

‘Increase in the use of tractor’ are the technology and non-climate related adaptations with the highest user among vulnerable farmers (83%). In developing countries, farmers has converted traditional cultivation system into modern cultivation, leaving ‘use of Bullock’ and moving towards the ‘use of Tractor’ which is time efficient and also much productive. Additionally, it is labor saving, solution of labor scarcity and also the ‘opportunity of worker’ and that technological component/Tractor needs more investment as compared to ‘bullock’ and may demand for credit for financing from Formal as well as Informal lenders.

‘Use of more fertilizer’<sup>34</sup> is modern invention with maximum productivity gains in place of ‘farm yard manure’ which give less production per-hectare as compared to former. In order to mitigate the climate change impacts and to increase the soil fertility, the combinations of Nitrogen, Potassium, and Phosphorus is much productive but this adaptation strategy is based on market requirement and also very expensive at local market. Farmers based at developing countries face difficulties in its financing while they apply for loan from Formal lender and most of the time, they have to rely on Informal lenders who give them fertilizer without following any application process but charge exorbitant rate on the market price of fertilizer at the time of crop harvesting and selling.

**Table 12: Adaptation Strategies (percentage of total)**

	Full Sample	Mianwali	Muzaffargarh	Sukkur	Peshawar
<b>Non-Climate Change Related Adaptations</b>					
Increase the use of Tractor	83.00	95	79	88	70
Use more Fertilizer	77.50	85	84	68	73
Increase the use of Pesticides	63.75	48	83	40	84
Use better and expensive Fertilizer	61.50	84	45	66	51
Change in crop Planting/Sowing date	53.00	63	63	51	35
<b>Climate Change Related Adaptations</b>					
Use better and expensive Seed	57.00	89	40	56	43
Use more Irrigation	56.25	77	55	40	53
Stop growing particular Verity and introduce new	54.75	70	51	64	34
Introduced a New Crop	44.75	54	39	53	33

‘Increased use of pesticides’ is adaptation strategy with 63.75% of its users which is also based on market demand and to improve the agriculture productivity. It requires huge amount of investment for the purchase of input material. These are expensive inputs, usually funded through savings and loan from Formal and Informal lenders. Pesticides are mostly used by large set of population at ‘Peshawar’ District while better seeds are prominently used at ‘Mianwali’ District by 89% of sample population. ‘Change in crop planting/sowing date’ has been important

<sup>34</sup> It consists of DAP/NP and Urea bags to get benefits of crop production. Additionally, ‘use better and expensive fertilizer’ is also documented as adaptation strategy that can be the part of ‘use of more fertilizer’.

component to increase the agriculture productivity and literature considers it as climate change adaptation due to change in season rotation and season hot days.

As far as the climate change adaptations are concerned, ‘use of better and expensive seed’ is strategy with 57% users and also demands for huge amount of investment for the purchase of input material. Wheat growing farmers are using new variety of seeds to get the gain in agriculture productivity. ‘Mianwali’ district is observing sudden climatic change and farmers of this region are the highest users (89%) in taking new trails of seed for each crop period while this has been lowest (40%) at ‘Muzaffargarh’. In order to purchase new seed for each crop period, farmers rush to get loan to finance the seed related adaptations. In response to that, Banks and MFIs take time to finance these adaptations while Informal lenders give financing options to farmers ‘in kinds’.

Farmers are observing huge scarcity of water while they use irrigation techniques to watering their farms. They have been in response to improve the productivity through the splendid use of irrigation methods and also to mitigate the impact of climate change. Farmers are very concerned about ‘variety related’ adaptation and they introduce new varieties for production gains and to improve the crop cycle. But introduction of ‘new variety of stress or flood related’ requires large amount of financing for its purchase. Table 12 reports the findings about the ‘stop of growing particular variety and introduction of new variety’ with large number of borrowing farmers (54.75%). In local market, large set of varieties are available and farmers prefer to practice new one in each production cycle and stop growing already used varieties. This process is necessary to increase the production of wheat but it demands for high cost of financing from Banks, MFIs and Informal lenders. In local market, Formal lenders don’t response for these variety related adaptation through small scale loan financing rather informal lenders offer them timely option of loan to purchase these kinds of adaptation strategies. Introduction of new crop is very similar to introduction of new variety and also demand large amount of investment.

**Table 12A: Loan and Adaptation Strategies (percentage of total)**

Variables		Full Sample	Mianwali	Muzaffargarh	Sukkur	Peshawar
Whole credit spent on adaptation strategies		94	90	97	93	96
<b>Climate and non-climate adaptation strategies</b>	Increase in use of seeds	51.00	29.00	79.00	76.00	20.00
	Use of better and expensive seed	28.25	30.00	37.00	32.00	14.00
	Increase the use of pesticides	54.50	32.00	78.00	74.00	28.00
	Use of more fertilizer	60.25	66.00	64.00	68.00	51.00
	Use of better and expensive fertilizer	35.50	63.00	19.00	8.00	52.00

Table 12A extends the analysis of adaptation strategies using the loan and investment options. It is explained that in ‘full sample’ 94% farmers are investing whole credit amount on adaptation investment. While the farmers of ‘Mianwali’ district invest the minimum (90%) of borrowing amount on adaptation investment as compared to the farmers of ‘Muzaffargarh’ district who invest the highest amount (97%) on adaptation strategies. As far as climate and non-climate strategies are concerned, most of the farmers spent the whole borrowing amount on non-climate adaptation strategies including ‘the use of ore fertilizer’ (60.25%) in contrast to the climate strategy ‘use of better and expensive seed’ (28.25%). Most of the users of climate adaptation strategies named as ‘better and expensive seed’ are observed at ‘Muzaffargarh’ district.

After getting detail response about climate and non-climate adaptation strategies, Table 13 reports adaptation strategies in relation with Access to credit from Bank, MFIs and Informal

lenders. It also considers these adaptations along with agriculture, livestock and household assets. All adaptation strategies, particular adaptation investment and climate change related include ‘stop growing particular variety and introduce new’, ‘use more irrigation’, ‘use better and expensive seed’, and ‘introduced a new crop’ have relation with ‘Access to Bank, MFIs and Informal lenders’ and household assets including agriculture, and livestock. In most of the cases, these strategies have been significantly linked and induce about the adaptations.

Farmers those who are taking into account these adaptations require large amount of spending for the purchase of relevant agriculture commodities. In response to high cost attached with it, they usually spread out their activities for farming in vibrant way and expect to cover this high cost through their return from agriculture productivity. But the cost to finance these climate change adaptation strategies are still too much high that needs for credit from Formal and Informal lenders. The literature clearly validates that use of new variety and seeds have been very expensive at local market and poor as well as the most climate change vulnerable farmers have meager access to credit opportunities. They have to relay to Informal lenders who provide loan with easy access to credit opportunities rather than Formal lenders.

**Table: 13 Adaptation Strategies with Access to Credit and Assets**

	Non-climate change Adaptation Strategies				Climate change Adaptation Strategies			
	Use of more Fertilizer	Increase use of Pesticides	Use of more Fertilizer	change in crop planting and sowing date	Stop growing variety and introduce new	Use of Better & Expensive seeds	Use of more Irrigation	Introduce new crop
<b>BANK Access</b>	84.82 [70.35] (0.000)	70.34 [24.00] (0.000)	59.31 [24.00] (0.000)	46.69 [0.92] (0.336)	62.06 [8.44] (0.004)	57.24 [3.04] (0.081)	25.77 [52.80] (0.000)	35.2 [12.75] (0.000)
<b>MFI Access</b>	76.51 [41.88] (0.000)	68.45 [20.30] (0.000)	60.40 [20.30] (0.000)	60.40 [6.45] (0.011)	56.37 [2.42] (0.12)	59.73 [5.64] (0.018)	42.28 [3.55] (0.06)	34.90 [13.5] (0.000)
<b>Informal Lender Access</b>	78.7 [1.25] (0.000)	65.26 [35.41] (0.000)	60.52 [35.41] (0.000)	54.2 [2.69] (0.101)	55.26 [4.21] (0.04)	55.52 [4.64] (0.031)	55.78 [5.09] (0.024)	44.47 [4.64] (0.031)
<b>Agriculture Assets</b>	86.79 [28.69] (0.000)	67.92 [6.81] (0.009)	69.811 [8.321] (0.004)	62.3 [3.189] (0.074)	64.15 [4.24] (0.039)	67.92 [6.811] (0.009)	67.92 [6.81] (0.009)	56.60 [0.925] (0.336)
<b>Livestock Assets</b>	76.47 [61.941] (0.000)	60.63 [9.995] (0.002)	64.25 [17.959] (0.000)	51.58 [0.222] (0.638)	53.84 [1.308] (0.253)	59.72 [8.367] (0.004)	60.63 [9.995] (0.002)	48.41 [0.222] (0.638)
<b>Household Assets</b>	76.61 [1.054] (0.000)	62.36 [22.75] (0.000)	62.63 [23.75] (0.000)	52.41 [0.871] (0.351)	53.49 [1.817] (0.178)	58.06 [9.67] (0.002)	55.64 [4.742] (0.029)	45.43 [3.108] (0.078)

**Note:** Chi-squares test is performed for association of variables where [ ] stands for value of chi-squares while ( ) stands for Asymptotic significance.

Other non-climate change adaptation strategies including ‘fertilizer related’, ‘pesticides related’, ‘change in crop planting/sowing date’ related have statistical significant relation with access to credit from Bank (Formal institute). All these adaptation strategies have on average above 50% relation with credit access to Informal lenders. Additionally, agriculture, livestock and household assets have also strong and statistically significant relation with access to credit from Banks, MFIs, and Informal lenders.

In order to gauge more about the farming activities and spending conditions for credit demand, adaptation strategies and farming status e.g., marginal, small, medium and large farmers, non-farm income and tenancy status are explained at Table 14 along with the findings of chi-square

test. Each category of farming status has been observed significantly linked with climate change related adaptation strategy, expect ‘stop growing variety and introduce new one’ which has been non-significant except for ‘medium farmers’. Significant linked adaptation strategies necessitate the demand for credit and farmer activities which is not supplement to improve the agriculture productivity and also help the farmers in credit financing. They have to move for the improvement in their socio-economic status through land acquisition so that farm size may be improved. Further, they also need to change their framing status from Tenant to owner through the purchase of land and also loan from Formal and Informal lenders. This improvement in their economic status may help them to invest more in adaptation strategies of variety and seed related.

Non-farm income and canal irrigation have non-significant relation with most of the climate change and non-climate change related adaptation strategies but irrigation from Tubewell that require huge investment for the financing of input fuel material, has significant relation with adaptation strategies. In addition to that, tenancy status, determined by owners and tenants has significant and non-significant relation, respectively with most of adaptation strategies.<sup>35</sup>

**Table: 14 Adaptation Strategies and Farming Status**

	Non-climate change Adaptation Strategies				Climate change Adaptation Strategies			
	Use of more Fertilizer	Increase use of Pesticides	Use of more Fertilizer	change in crop planting/ sowing	Stop growing variety/ introduce	Use of Better & Expensive seeds	Use of more Irrigation	Introduce new crop
<b>Marginal Farmer</b>	77.81 [82.34] (0.000)	64.66 [22.87] (0.000)	59.39 [9.39] (0.002)	52.63 [0.737] (0.391)	52.22 [0.541] (0.462)	53.00 [0.962] (0.327)	50.75 [0.060] (0.806)	39.47 [11.78] (0.001)
<b>Small Farmer</b>	74.71 [21.25] (0.000)	56.32 [1.391] (0.238)	63.21 [6.080] (0.014)	48.27 [0.103] (0.748)	58.62 [2.586] (0.108)	66.66 [9.667] (0.002)	62.068 [5.069] (0.024)	51.72 [0.103] (0.748)
<b>Medium Farmer</b>	75.75 [8.75] (0.003)	63.63 [2.45] (0.117)	78.78 [10.93] (0.001)	63.63 [2.45] (0.117)	66.66 [3.66] (0.056)	72.72 [6.81] (0.009)	72.72 [6.81] (0.009)	60.60 [1.48] (0.223)
<b>Large Farmer</b>	92.85 [10.28] (0.001)	92.85 [10.28] (0.001)	50.00 [0.00] (1.000)	64.28 [1.14] (0.285)	50.00 [0.00] (1.000)	35.71 [1.14] (0.285)	85.71 [7.14] (0.008)	64.28 [1.14] (0.285)
<b>Non-Farm Income</b>	82.82 [42.67] (0.00)	66.66 [11.00] (0.00)	55.55 [1.22] (0.26)	62.62 [6.31] (0.01)	53.53 [0.49] (0.48)	42.42 [2.27] (0.13)	45.45 [0.81] (0.36)	38.38 [5.34] (0.02)
<b>Canal Irrigation</b>	74.81 [66.5] (0.00)	65.92 [27.39] (0.00)	55.55 [3.33] (0.06)	50.37 [0.01] (0.90)	50.37 [0.01] (0.90)	49.25 [0.05] (0.80)	48.50 [0.23] (0.62)	42.96 [5.34] (0.02)
<b>Tube well Irrigation</b>	83.59 [57.78] (0.00)	58.59 [3.78] (0.052)	74.21 [30.03] (0.000)	58.59 [3.78] (0.052)	64.02 [10.1] (0.001)	73.43 [28.12] (0.00)	72.65 [26.28] (0.00)	47.65 [0.28] (0.59)
<b>Owner</b>	81.37 [1.14] (0.00)	64.13 [23.18] (0.000)	63.10 [19.91] (0.000)	55.17 [3.10] (0.078)	58.27 [7.94] (0.005)	57.58 [6.67] (0.010)	55.51 [3.53] (0.06)	42.75 [6.08] (0.01)
<b>Tenant</b>	54.79 [0.671] (0.41)	60.27 [3.08] (0.07)	54.79 [0.67] (0.41)	36.98 [4.94] (0.026)	45.20 [0.67] (0.41)	56.16 [1.11] (0.29)	42.46 [1.65] (0.19)	42.46 [1.65] (0.19)

**Note:** Chi-squares test is performed for association of variables where [ ] stands for value of chi-squares while ( ) stands for Asymptotic significance.

<sup>35</sup> For more discussion of adaptation strategies with education categories and climate change perception, please see Appendix B, Table 14A and 14B.

In getting the detailed response about adaptation strategies and its links with farming and market related factors, the barrier to adaptations are explored in detail at Table 15. These barriers are related with financial, information, institutional, socio-culture, land constraint, input, labor and technology related. ‘Limited income by the farmers’ is mostly observed barrier with the highest number (79%), followed by institutional barrier namely ‘poor agricultural extension service delivery’ (60%), and ‘high cost of farm labor’ (50%). Climate change vulnerable farmers of ‘Peshawar’ District observe barriers in investing for adaptation from Formal, Semi-formal and Informal lenders. Technological barriers, relating to ‘lack of advance technologies, tools and structure’ and ‘Lack of modern Agriculture Tools (Tractor etc.)’ are mostly observed by the farmers of ‘Mianwali’ District. Farmers of ‘Sukkur’ District mostly observe ‘High cost of farm Labor’, and ‘Lack of money/limited income’ as barrier to adaptation.

**Table 15: Barrier to Adaptation Investment** (*percentage of total*)

<b>Barriers</b>	<b>Full Sample</b>	<b>Mianwali</b>	<b>Muzaffargarh</b>	<b>Sukkur</b>	<b>Peshawar</b>
Lack of money/limited income by the farmers	79.00	77	90	54	97
Poor Agricultural Extension Service delivery	60.00	61	68	52	61
High cost of farm Labor	50.00	63	28	69	43
Lack of access to Market Information	28.00	34	20	27	31
Lack of modern Agriculture Tools (Tractor etc.)	27.50	48	15	21	25
Lack of advance technologies, tools and structure	23.50	59	20	8.0	7.0
Non-availability of farm Labor	23.00	32	19	14	27
High cost of Fertilizers	21.75	20	20	21	26
Non-availability of credit Facilities	20.50	31	27	8.0	16
High cost of improved Varieties	18.50	36	7.0	9.0	22

## 5.2. Findings of Econometric Analysis

This section explains the results of Heckman Treatment Effect Model for Access to credit from Formal, Semi-formal and Informal lenders. Additionally, it also gives findings of adaptation strategies and choice of adaptation finance in the presence of imperfect capital market. The choice about access to credit is analyzed using the Probit model where probabilities and marginal impacts are derived out for all explanatory variables. Additionally, there can be the problem of endogeneity that is handled through the application of two-stage least square (2SLS). Instrumental variables are introduced to remove the endogeneity and also to get the unbiased estimators.

In order to support the findings of imperfect capital market, different socio-economic variables, climate change and weather relevant indicators, district related agro-ecological zone dummies, farming status, collateral, and also proxies for information such as distance to Formal and Informal lenders from borrowers place, paying back whole credit amount, and working more in farms after getting credit are taken.

Table 16 presents the findings of both probit model and also 2SLS. The marginal impacts are also derived out for probit model that are also presented. In order to support the imperfect capital market, various proxies of information are taken that directly or indirectly consider the phenomena of credit market imperfection. ‘Duration of loan’ and ‘distance to lenders’ from Formal and Informal lenders is taken to support the imperfect capital market hypothesis. In Probit model, the probability of ‘loan duration’ shows that increase in ‘duration of loan’ may reduce farmer’s access to credit from Formal and Informal lenders, supporting the capital market imperfection hypothesis while increase in the ‘distance to lender’ may increase the farmers access to credit from Banks. Access to canal and Tubewell water irrigation significantly reduces



**Table 16: Results of Probit and Two-stage Least Square (2SLS) for Imperfect Capital Market**

Variables	Lending from Banks			Lending from MFIs			Lending from Informal Lenders		
	Probit Model		2SLS	Probit Model		2SLS	Probit Model		2SLS
	Regression	Marginal	Coefficients	Regression	Marginal	Coefficient	Regression	Marginal	Coefficient
Constant	16.147 (589.40)	—	0.042 (0.211)	-0.580 (1.073)	—	0.582*** (0.160)	7.275 (323.39)	—	0.682*** (0.193)
Dependent	0.324* (0.189)	0.099	0.010 (0.018)	-0.002 (0.019)	-0.001	0.011** (0.005)	0.022 (0.040)	0.001	0.000 (0.003)
Not Attended	-1.438 (1.156)	-0.444	—	-0.486** (0.191)	-0.177	—	0.278 (0.342)	0.014	—
Primary Education	-1.359 (1.082)	-0.419	-0.005 (0.120)	-0.317 (0.220)	-0.115	0.022 (0.035)	-0.030 (0.370)	-0.002	-0.020 (0.035)
Middle Education	-1.501 (1.287)	-0.463	0.025 (0.141)	-0.044 (0.272)	-0.016	-0.038 (0.046)	-0.357 (0.421)	-0.018	-0.034 (0.038)
Marginal Farmer	0.163 (1.314)	0.050	-0.289* (0.152)	0.211 (0.244)	0.077	0.268*** (0.060)	-0.955* (0.519)	-0.048	-0.068 (0.046)
Small Farmer	1.896 (1.411)	0.585	-0.241* (0.139)	0.123 (0.261)	0.045	0.301*** (0.089)	-0.078 (0.580)	-0.004	-0.046 (0.039)
Non-Farm Income	0.224 (0.704)	0.069	0.053 (0.267)	0.319* (0.173)	0.116	0.024 (0.034)	-0.108 (0.295)	-0.005	-0.041 (0.044)
Canal Irrigation	-4.786 (589.33)	-1.477	0.240 (0.148)	0.317 (0.991)	0.115	-0.019 (0.039)	-4.826 (323.38)	-0.244	0.007 (0.035)
Tube well irrigation	-0.655 (589.33)	-0.202	—	0.326 (0.982)	0.119	—	-4.720 (323.38)	-0.238	—
Owner	1.845* (0.983)	0.569	0.217 (0.140)	-0.425** (0.172)	-0.155	0.014 (0.030)	0.218 (0.311)	0.011	0.038 (0.031)
Agriculture Assets	2.217 (2.062)	0.684	0.227 (0.156)	0.307 (0.225)	0.112	0.017 (0.058)	-0.462 (0.366)	-0.023	-0.082* (0.049)
Immovable Property_Collateral	—	—	-0.151 (0.335)	—	—	—	—	—	—
Personal Security_ Collateral	—	—	—	—	—	-0.059* (0.034)	—	—	0.084* (0.050)
Group Security- Collateral	—	—	—	—	—	-0.063 (0.044)	—	—	0.118* (0.072)
Paying back whole loan	—	—	0.174 (0.225)	—	—	-0.077 (0.049)	—	—	0.071 (0.090)
Working more at farms after getting loan	—	—	0.260 (0.270)	—	—	0.202*** (0.064)	—	—	0.132* (0.075)
Loan Duration obtained*	-9.704* (5.475)	-2.996	0.211 (0.243)	0.031 (0.083)	0.011	0.038 (0.045)	-0.233** (0.119)	-0.012	-0.040 (0.165)
Distance to Lenders*	0.669* (0.351)	0.206	-0.001 (0.019)	—	—	-0.001 (0.002)	—	—	0.001 (0.001)
Weather Information from Media	1.223 (1.206)	0.377	0.090 (0.121)	0.232** (0.221)	0.084	-0.079 (0.052)	0.011 (0.444)	0.001	0.190 (0.128)
Weather Information from community	0.969 (1.200)	0.299	—	-0.496 (0.201)	-0.181	—	0.174 (0.410)	0.009	—
Barani Sandy Agro- zone	-3.001 (2.241)	-0.926	0.178 (0.150)	0.415 (0.259)	0.151	0.085 (0.069)	-0.900* (0.466)	-0.045	0.031 (0.049)
North Irrigated Agro-zone	-1.012 (1.714)	-0.312	0.398*** (0.138)	0.993*** (0.221)	0.361	0.064 (0.056)	0.480 (0.479)	0.024	0.081* (0.042)
North_dry	0.738 (1.367)	0.227	0.440** (0.193)	-0.560** (0.238)	-0.204	—	—	—	0.086** (0.038)
Chi-square (Prob.)	25.12 (0.121)	—	60.64 (0.000)	109.05 (0.000)	—	66.57 (0.000)	—	—	79.64 (0.000)
Log likelihood	-14.714	—	—	-209.58	—	—	—	—	—
Pesudo-R_Squared	0.460	—	0.2373	0.206	—	0.5565	—	—	—

Note: ( ) shows the standard-errors while \*, \*\*, \*\*\* stand for level of significance at 10%, 5%, and 1%.

the farmer's access to credit from Formal and Informal lenders. Additionally, various categories of education may also reduce the farmers access to credit from Formal (Banks) and Semi-formal lenders (MFIs). The response of marginal and small farmers has been ambiguous across various types of lenders.

In order to handle the endogeneity issues, 2SLS results are also reported along with additional proxies of information (imperfect capital market) e.g., 'collateral requirements for both Formal and Informal lenders', 'working more at farms after getting loan', and 'paying back whole borrowing amount to lenders', etc. The findings of collateral requirement for Banks (immovable property) and MFIs (personal and group security) suggest that increase in collateral reduces the farmer's access to credit, strongly support to the capital market imperfection while this doesn't hold true for Informal lenders where their personal and group contacts have significant impact to improve the access to credit. Most of the farmers work more at agriculture farms after getting loan from lenders which has been significantly positive and may improve the farmer's access to credit from Formal, Semi-formal and Informal lenders. Increase in 'duration of loan' from Formal and Informal lenders has ambiguous sign in determining the farmer's access to credit while increase in distance to lenders non-significantly reduces the farmers access to credit from Banks and MFIs.

As far as socio-economic and farming status related variables are concerned, increase in 'primary education' help to decrease the access to credit from Formal and Informal lenders while the increment in middle education (more educated farmers) help to improve the access to credit from Formal and Informal lenders. Farming status such as 'marginal and small' farmers has negative and significant relation with access to credit from Banks and Informal money lenders, supporting the capital market imperfection. Irrigation from canal also reduces the farmer's access to credit from MFIs, supporting that MFIs are creating the inefficiency in credit market.

In order to handle the problems of unbiased estimators, this study also utilizes the application of Heckmen Treatment Effect Model to analyze the access to credit and thereof the imperfect capital market. Table 16A explains the credit market imperfection using the Heckman Treatment effect model for access to credit from Formal, Semi-formal and Informal lenders. The dependent variable for selection equation is 'access to credit' while for outcome equation is 'amount of credit'<sup>36</sup> borrowed by Formal and Informal lenders. In all of the three models for Formal lenders, MFIs and Informal lenders, inverse mill ratio is found to be significant, confirming the selection biasness in selected sample.

In supporting to the hypothesis of imperfect capital market, collateral as security for loan (land/immovable property, personal and group security) from Bank, MFIs and Informal Lenders are introduced to analyze the response of access and amount to credit. For Banks, immovable property is taken as collateral which increase the access to credit non-significantly but amount to credit, significantly. It is evident that as farmers use their immovable property in getting the 'Pass Book' which strengthen credit access and amount from Formal sector. As far as screening process of Banks are concerned, positive sign of collateral for Banks induce the market imperfection at supply-side of loanable market. In demand-side of loanable market, farmers who don't have access to immovable property as collateral, are inherently not involved in process and

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<sup>36</sup> See Vuong *et al.*, (2012)

**Table 16A: Results of Heckman Treatment Effect Model for Imperfect Capital Market**

Dependent Variable	Selection Equation: Access to Credit					
	Outcome Equation: Amount of Credit ( <i>in log</i> )					
	Lending from Banks		Lending from MFIs		Lending from Informal Lenders	
Variables	Selection	Outcome	Selection	Outcome	Selection	Outcome
Constant	-1.119 (1.227)	-0.238 (1.343)	-7.064 (---)	-0.827 (1.140)	7.409 (658.572)	-1.045 (1.008)
Dependent	0.022 (0.027)	-0.032 (0.031)	0.008 (0.029)	0.019 (0.025)	0.001 (0.060)	0.028 (0.024)
Primary Education	0.240 (0.282)	-0.668** (0.302)	0.078 (0.296)	-0.102 (0.245)	-0.450 (0.602)	0.696*** (0.266)
Middle Education	0.335 (0.334)	-0.214 (0.349)	0.261 (0.336)	-0.130 (0.275)	-0.613 (0.716)	-0.108 (0.330)
Second & Above Education	0.084 (0.253)	-0.191 (0.272)	0.223 (0.270)	0.059 (0.238)	0.218 (0.668)	0.334 (0.246)
Marginal Farmer	-0.314 (0.329)	-0.092 (0.406)	-0.128 (0.321)	0.169 (0.307)	-1.017 (0.729)	-0.657* (0.395)
Small Farmer	-0.043 (0.342)	-0.305 (0.415)	0.094 (0.345)	-0.140 (0.347)	-1.184 (0.868)	-0.265 (0.430)
Non-Farm Income	0.412* (0.232)	-0.588** (0.262)	0.008 (0.237)	0.008 (0.204)	-0.048 (0.472)	-0.376* (0.222)
Canal Irrigation	0.623 (1.121)	-0.444 (1.173)	6.697*** (0.547)	-0.587 (1.018)	-0.142 (0.745)	0.291 (0.283)
Tube well irrigation	0.464 (1.114)	-0.440 (1.158)	6.412*** (0.590)	-0.208 (1.005)	—	—
Owner	0.232 (0.238)	-0.198 (0.261)	-0.099 (0.268)	0.011 (0.210)	0.131 (0.592)	-0.345 (0.223)
Agriculture Assets	0.486 (0.320)	-0.667 (0.493)	0.409 (0.323)	-0.186 (0.408)	0.129 (0.591)	0.218 (0.540)
Marginal farmer* Agriculture Assets	0.368 (0.587)	—	0.215 (0.471)	—	-0.111 (0.737)	—
Small Farmer* Agriculture Assets	0.458 (0.581)	—	0.229 (0.467)	—	-1.522** (0.737)	—
Immovable Property_ Collateral	7.792 (613.119)	2.029*** (0.676)	—	—	—	—
Personal Security_ Collateral*	—	—	-31.761 (24.385)	0.279 (0.417)	-0.147 (0.885)	0.869*** (0.253)
Group Security- Collateral*	—	—	-7.857 (16.486)	1.441*** (0.448)	4.014 (4348.9)	1.144** (0.498)
Distance to Lenders*	0.864 (48.891)	0.028 (0.032)	-0.061 (0.176)	-0.002 (0.009)	-0.006 (0.063)	0.006*** (0.001)
Loan Duration obtained ( <i>in log</i> )	0.096 (0.120)	-0.088 (0.119)	4.844 (7.509)	1.311*** (0.215)	1.393*** (0.432)	2.485*** (0.227)
Interest Rate Information*	—	-0.157 (0.163)	—	-0.072 (0.146)	—	0.048 (0.224)
Cost (Registration and Trip) fee to apply loan*	-0.639 (61.168)	0.704*** (0.120)	5.530 (3.987)	0.405*** (0.099)	0.136 (0.182)	0.151*** (0.043)
Access to Formal and Informal Lender	—	3.061*** (0.939)	—	2.287*** (0.635)	—	3.886*** (0.982)
Paying back whole loan	—	1.463*** (0.538)	—	2.151*** (0.484)	—	0.957*** (0.266)
Working more at farms after getting loan*	—	1.650** (0.657)	—	2.263*** (0.552)	—	1.756*** (0.255)
Weather Information from Media	0.514** (0.255)	—	0.608** (0.251)	—	0.238 (0.558)	—
Barani Sandy Agro-zone	-0.534 (0.405)	0.555 (0.463)	-0.299 (0.432)	0.529 (0.403)	-6.489 (658.567)	1.209*** (0.383)
North Irrigated Agro-zone	0.316 (0.347)	-0.382 (0.394)	0.617 (0.381)	-0.382 (0.361)	-0.199 (1391.307)	1.215*** (0.346)
South Irrigated Agro-zone	-0.844** (0.354)	1.148** (0.471)	-0.783** (0.394)	0.533 (0.397)	-6.791 (658.565)	-0.589* (0.327)
Inverse Mill ratio	-1.850*** (0.572)		-1.404*** (0.388)		-1.176* (0.602)	

Note: ( ) shows the standard-errors while \*, \*\*, \*\*\* stand for level of significance at 10%, 5%, and 1%.

hence induce the credit market imperfection in consumer perspective. So, they would have meager access to credit and borrowed amount.

In developing connection for access and amount to credit from MFIs, and Informal lenders, personal security and group security are taken as collaterals. Both of the collateral relating variables have significantly reduces the access to credit while increases the amount to credit. Hence, it clearly indicates the credit market imperfection at both supply and demand side. For Informal lender, the constraint of collateral is relaxed and large numbers of farmers mostly use personal security<sup>37</sup>. Everyone in local communities willingly pledge their crops as well as future production and use personal security in accessing the borrowing amount. Further, they improve their credit history and get high amount of loan in future that significantly increase their amount to credit borrowed. The negative relation of personal security with access to credit strongly support to the credit market imperfection.

In literature, distance of lenders from borrower's location has been effective to improve the credit access. The findings based at Table 16A suggest that distance to lender location increase the credit access as well as amount for those farmers who borrow from Banks which means that famers don't care about the distance that they have to cover or how many miles away they have to travel. It also means that farmers move to get loan irrespective of the distance and decide to get credit base on the collateral. Additionally, distance to lenders non-significantly reduces the access to credit from MFIs and Informal lenders and it matters for farmers to borrow from those lenders (MFIs and Informal) who are adjacent to their wheat farms.

In further supporting the capital market imperfection, more variables of market imperfection are introduced in the regression analysis. In this perspective, 'loan duration', interest rate information' and 'cost to borrow (including registration and trip to lender place), 'paying back whole amount' and 'working more time in farming activities after getting loan' are taken as important variables of market information which may also support to the capital market imperfection.

Increase in Loan duration positively and significantly improve the access to credit by farmers from Formal and Informal lenders. In credit market, any time extension to repay loan may support the farmers to reinvest the amount in order to get the productivity gains that further make them able to repay the amount in future. Hence, this process makes them more accessible to get the loan. Information about interest rate makes borrowers more rational in deciding what and where to obtain and hence helps to reduce the amount borrowed for Banks and MFIs while it improves the borrowed amount for Informal lenders. Framers who obtain credit from Informal lenders, they usually don't decide based on the market interest rate information rather they decide based on their needs and demands.

Increase in cost (registration and trip to lenders) helps to reduce the access to Banks. High cost of registration to apply at Banks discourages borrowers which may support to the capital market imperfection and hence farmers search alternate source of borrowing like, MFIs and Informal lenders. That's why; MFIs and Informal lenders have positive relation with initial cost of borrowing because both of these lenders don't have initial cost to apply in extant amount. Both variables 'paying back whole amount' and 'working more time in farming activities after getting loan' have positive relation in access to credit and also amount to borrowed. In credit market, both variables explain the credibility of borrowers and help to strengthen their ability to access more.

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<sup>37</sup> See Table 10 for collateral

Climate change vulnerable farmers care about weather situation and their source of information relating to weather. As their source of information from media improves, they take care of adaptation strategies and also help to strengthen their access to credit. In order to control the effects of each district as well as agro-ecological zone, the district or agro-zone elate dummies are introduced. Most of the dummies have significant relation with access and amount to credit. Inverse mill ratio is significantly determining the selection biasness in selected sample for Formal, Semi-formal and Informal lenders.

‘Number of dependents’ is positive related with access to credit from Bank, Semi-formal (MFIs) and Informal lenders at selection equation which induce that the increase in number of non-workers in family (dependents) motivate farmers to demand more from lenders to fulfill the domestic needs and also repay in well time that further help them to increase the access to credit. As far as outcome equation is concerned which take amount of credit as dependent variable, family size is negative for access to Banks while it is positively related with Informal lenders. As Informal lender are more concerned with the labor force proportion, available at each home and decide to offer higher loan to such families but Banks don’t consider such families ratio while they offer loan.

Education status and its categories, primary, middle, secondary & above education has both significant and non-significant positive relation with access to credit from Formal and Informal institute. It’s all categories have been statistically insignificant with ambiguous sign for the amount of access to credit. Increase in Marginal farming status reduces their access to credit when they borrow from Formal and Informal lenders. Additionally, access to credit from Banks reduces while it increases for MFIs for Small famers. This has been positively in improving the amount of credit for Informal lenders.

Non-farm income can be used as collateral at Bank and MFIs which significantly and positively improve the agriculture productivity. As far as irrigation from canal and Tubewell is concerned, both source of irrigation are positively but non-significantly linked with access to credit from Banks and MFIs but canal irrigation reduces the access to credit from Informal lenders, might be due to the available free water resources. For amount of credit that can be received from Formal and Informal lenders, canal and Tubewell irrigation is significantly and positively attached with Banks but negatively with MFIs. Credit borrowing farmers with already available water resources improve farming status and help them to accumulate more collateral which further strengthen their response to get loan from Banks. But MFIs have already credit amount constraints and are not allowed to offer loan higher than that amount so any improvement in collateral may be redundant and additional improvement in water resources don’t help to get more loan from MFIs. Ownership has ambiguous sign for both access and amount to credit but it is insignificant in most of the cases.

Agriculture assets positively improve the access to credit from Formal and Informal lenders. In credit market, lenders offer loan to those farmers who have more agriculture assets. In order to explore it more, land status is multiplied with agriculture assets and they have been positively related with access to credit from Formal lenders and MFIs but they are negatively related with Informal lenders which supports that increase in land area and agriculture assets in combined may reduce the access to credit. This phenomenon may support to capital market imperfection.

Adaptation investment is explored at Table 17 in the presence of imperfect capital market, where dependent variable of selection equation is *'particular adaptation strategy'* while dependent variable of outcome equation is *'total land area of wheat cultivator'*. Table 12 has split the top nine (9) adaptation strategies as climate and non-climate based within districts and also in complete sample. Only four (4) adaptation strategies are known to be climate change based adaptations but three (3) of these climate change induced strategies, known as *i) 'use of better & expensive seeds'*, *ii) 'use of more irrigation'* *iii) 'stop growing particular variety and introduce new variety'* are explained in Heckmen Treatment Effect Model at Table 17 which explore the adaptation investment. Additionally, financing of these adaptations are considered using the capital market imperfection (with relevant variable of amount borrowed from formal and informal lenders), climate change, socio-economic, information and market relevant variables (loan duration and interest rate information). In all of the models, the inverse-mill ratio is found to be significant, explaining the sample selection bias in selected sample.

In adaptation investment equations, capital market imperfection is captured by introducing the *'Access to total amount borrowed by Banks, MFIs and Informal lenders'* as explanatory variables. These variables are taken in all three types of adaptation strategy equations and across various types of models. As far as *'Access to amount borrowed from Bank and Informal lenders'* is concerned, it has positively significant relation with all adaptation strategies, except *'stop growing particular variety and introduce new variety'* where it has been insignificant along with negative sign. The possible reason for this negative direction on adaptation investment is that it has been cheaper in the local market as compared to other two expensive strategies, namely, *'use of better & expensive seeds'*, and *'use of more irrigation'*. Further, farmers get loan from Banks in large amount and also from Informal lenders in very distinctive way and they invest highest proportion in these two adaptation strategies.

Table 12A also explains that farmers spend large fraction of their borrowed amount on *'Increase in use of seeds'*, and *'Use of better and expensive seed'* with 51% and 28.25%, respectively. This table also explains that farmers spend remaining large amount on non-climate based adaptation strategies such as *'purchase of fertilizer and pesticides'*. While farmers borrow credit amount from Informal lenders, they are more concerned to invest them in expensive strategies. Additionally, to invest at *'stop growing particular variety and introduce new variety'* is one time process in each crop while *'use of better & expensive seeds'*, and *'use of more irrigation'* is investment process of multiple time during each crop cycle and farmers need high borrowing amount from Bank and Informal lenders to invest them. *'Access to credit'* from Informal lenders has been significantly positive related with adaptation strategies. It has been documented that large number of climate change vulnerable farmers get loan from Informal lenders, ranging small to large amount that significantly help to increase the farmer capacity for various types of adaptations. Credit access from Informal lenders also increases the area under wheat cultivation in most of cases.

As far as *'Access to total amount borrowed by MFIs and Informal lenders'* are concerned, both of the variables have been positive and significantly related with all three type of adaptation strategies. In order to explore more for market imperfection, *'access to credit from MFIs'* is introduced that has been positively related in reducing the choice for all types of adaptation strategies with significant implications. This relation can be explained as MFIs usually offer loan to farmers in small extent and on small scale who usually invest them support expensive

**Table 17: Results of Heckman Treatment Effect Model for Adaptation Strategies**

Variables	Use of Better & Expensive seeds				Use of more Irrigation				Stop growing Verity and Introduce New Verity			
	Selection	Outcome	Selection	Outcome	Selection	Outcome	Selection	Outcome	Selection	Outcome	Selection	Outcome
Constant	-22.634** (9.176)	-1.843 (3.798)	-23.659** (9.294)	-1.262 (3.844)	-15.294** (7.791)	-9.430* (5.675)	-19.793** (8.050)	-11.437** (5.734)	5.268 (7.503)	2.501 (4.882)	3.435 (8.114)	4.823 (3.6585)
Age	-0.003 (0.010)	0.004 (0.006)	-0.003 (0.010)	0.004 (0.005)	-0.001 (0.009)	0.001 (0.010)	-0.002 (0.009)	0.002 (0.010)	-0.014 (0.009)	0.018* (0.011)	-0.013 (0.009)	0.012 (0.007)
Number of Dependents	—	—	-0.022 (0.030)	0.023 (0.015)	—	—	-0.071** (0.028)	0.079** (0.031)	—	—	0.029 (0.027)	0.022 (0.020)
Not-Attended school	-0.876*** (0.331)	-0.096 (0.210)	-0.897*** (0.334)	-0.095 (0.205)	-0.439 (0.282)	0.182 (0.332)	-0.460 (0.286)	0.262 (0.328)	0.023 (0.273)	-0.493* (0.264)	0.146 (0.286)	-0.470** (0.185)
Primary Education	-0.611* (0.355)	0.070 (0.201)	-0.639* (0.358)	0.084 (0.197)	-0.095 (0.305)	0.053 (0.333)	-0.168 (0.311)	0.158 (0.328)	-0.195 (0.300)	0.073 (0.329)	-0.100 (0.306)	-0.011 (0.222)
Middle Education	-1.068*** (0.415)	0.300 (0.244)	-1.101*** (0.421)	0.274 (0.239)	-0.038 (0.340)	0.145 (0.370)	-0.027 (0.351)	0.159 (0.360)	0.346 (0.338)	-0.338 (0.373)	0.411 (0.3456)	-0.186 (0.254)
Marginal Farmer	-0.043 (0.383)	—	-0.060 (0.382)	—	-0.637* (0.339)	—	-0.781** (0.351)	—	-0.204 (0.316)	—	-0.114 (0.345)	—
Small Farmer	0.049 (0.399)	—	0.043 (0.397)	—	-0.395 (0.354)	—	-0.478 (0.362)	—	0.023 (0.343)	—	0.040 (0.345)	—
Non-Farm Income	-0.972*** (0.279)	-0.024 (0.183)	-0.979*** (0.280)	-0.038 (0.178)	-0.285 (0.235)	0.119 (0.283)	-0.295 (0.238)	0.133 (0.274)	-0.357 (0.230)	0.003 (0.294)	-0.334 (0.231)	-0.149 (0.194)
Canal Irrigation	-0.826 (1.015)	-0.375 (0.620)	-0.817 (1.017)	-0.399 (0.607)	-0.607 (0.934)	0.128 (1.154)	-0.504 (0.927)	0.023 (1.116)	0.247 (0.913)	-0.963 (1.068)	0.307 (0.927)	-0.803 (0.735)
Tube well Irrigation	0.077 (1.015)	-0.244 (0.612)	0.071 (1.016)	-0.238 (0.600)	0.128 (0.936)	-0.152 (1.130)	0.196 (0.928)	-0.163 (1.098)	0.459 (0.912)	-0.936 (1.074)	0.559 (0.927)	-0.680 (0.738)
Owner	-0.193 (0.261)	-0.041 (0.147)	-0.198 (0.262)	-0.044 (0.144)	-0.205 (0.233)	0.202 (0.270)	-0.202 (0.235)	0.246 (0.264)	0.345 (0.236)	-0.401 (0.296)	0.363 (0.238)	-0.232 (0.200)
Agriculture Assets	0.037 (0.356)	0.876*** (0.171)	0.046 (0.354)	0.839*** (0.169)	-0.084 (0.297)	0.923*** (0.312)	-0.047 (0.303)	0.833*** (0.306)	0.047 (0.296)	—	0.037 (0.298)	—
Temperature	0.946*** (0.364)	0.105 (0.133)	0.993*** (0.370)	0.081 (0.135)	0.673** (0.308)	0.311 (0.197)	0.877*** (0.321)	0.369* (0.198)	-0.195 (0.299)	-0.070 (0.171)	-0.138 (0.322)	-0.138 (0.131)
Precipitation	2.643*** (0.834)	0.383 (0.419)	2.748*** (0.847)	0.326 (0.423)	1.484** (0.702)	1.293** (0.658)	1.909*** (0.726)	1.513** (0.663)	-0.205 (0.679)	-0.312 (0.556)	-0.081 (0.728)	-0.389 (0.434)
Perception of winter rainy season	0.471 (0.317)	—	0.462 (0.317)	—	0.376 (0.286)	—	0.325 (0.287)	—	0.240 (0.296)	—	0.253 (0.297)	—
Weather info Media	0.306 (0.337)	—	—	—	-0.120 (0.303)	—	-0.050 (0.307)	—	—	—	0.145 (0.304)	—
Weather info Community	0.076 (0.295)	—	—	—	0.248 (0.265)	—	0.217 (0.267)	—	—	—	-0.158 (0.262)	—
Access Amount to Bank	0.015 (0.032)	—	0.012 (0.033)	—	0.027 (0.031)	-0.052 (0.110)	0.019 (0.031)	-0.052 (0.107)	-0.017 (0.029)	—	-0.013 (0.029)	—
Access Amount to MFIs	0.329** (0.141)	—	0.336** (0.140)	—	0.013 (0.066)	0.225 (0.147)	0.027 (0.066)	0.252* (0.144)	0.039 (0.075)	—	0.042 (0.075)	—
Access Amount to Info Lender	0.112* (0.063)	—	0.114* (0.063)	—	0.043 (0.047)	0.106 (0.166)	0.045 (0.048)	0.077 (0.162)	-0.067 (0.049)	—	-0.057 (0.050)	—
Loan duration Bank	-0.003 (0.117)	-0.032 (0.061)	-0.002 (0.117)	-0.033 (0.059)	-0.003 (0.101)	—	-0.007 (0.103)	—	0.098 (0.100)	-0.149 (0.115)	0.099 (0.099)	-0.099 (0.078)
Loan duration MFIs	-1.150* (0.590)	-0.013 (0.072)	-1.188** (0.588)	-0.002 (0.071)	-0.168 (0.295)	—	-0.247 (0.299)	—	-0.555* (0.335)	0.276 (0.185)	-0.558 (0.340)	0.151 (0.119)
Loan duration Informal lender	-0.613* (0.338)	0.135 (0.091)	-0.621* (0.340)	0.128 (0.089)	-0.174 (0.245)	—	-0.171 (0.247)	—	0.037 (0.263)	0.312* (0.183)	-0.013 (0.266)	0.213* (0.124)
Interest rate Info Bank	—	-0.413** (0.201)	—	-0.411** (0.199)	—	-0.197 (0.296)	-0.215 (0.292)	—	—	-0.393 (0.271)	—	-0.388* (0.217)
Interest rate Info MFIs	—	0.295 (0.210)	—	0.297 (0.209)	—	0.060 (0.302)	0.103 (0.298)	—	—	0.269 (0.268)	—	0.292 (0.223)
Interest rate Info lender	—	0.019 (0.136)	—	0.008 (0.135)	—	0.008 (0.182)	0.002 (0.180)	—	—	0.029 (0.172)	—	0.018 (0.144)
Adaptation strategy	—	0.838** (0.419)	—	0.752* (0.410)	—	3.023*** (0.859)	—	3.003*** (0.785)	—	2.487* (1.335)	—	1.178 (0.818)
Inverse-Mill Ratio	-0.498** (0.244)	—	-0.448* (0.238)	—	-1.797*** (0.514)	—	-1.7641*** (0.465)	—	-1.555* (0.810)	—	-1.006* (0.536)	—

Note: ( ) shows the standard-errors while \*, \*\*, \*\*\* stand for level of significance at 10%, 5%, and 1%.

adaptations. The findings based at Table 5 indicates that very small segment of sample population/farmers have access to credit from Banks, which reduces the farmer choice of adaptation strategy in borrower perspective and hence leading to the phenomena of credit market imperfection. In addition to that ‘access to credit’ from Banks has been significantly effective in improving the ‘area under wheat cultivation’.

The hypothesis of imperfect capital market is strengthened by introducing the more variables of market information related such as ‘duration of loan’ and ‘information about interest rate’ from Formal and Informal lenders. From Table 17, it is shown that ‘duration of loan’ is negatively related in selecting the particular adaptation strategy with significant impact across various strategies. The possible reason is evident from Table 11A where most of the farmers get loan from Banks and MFIs for almost seven month period, on average and three month period from Informal lenders. It is also interesting to note that almost more than 80% credit borrowing farmers are satisfied with loan duration from Banks, MFIs and Informal lenders. Further, very small numbers of farmers (only 5% farmers from Informal lenders and MFIs while 18% from Banks) requested to increase in loan duration. Keeping in view all these reason, it is justifiable to argue that increase in loan duration doesn’t matter for farmers and they are reluctant to adapt more strategies with the increase in loan duration. As far as information about interest rate is concerned, it positively improves the adaptation choice for farmers. It means that improvement in information about loanable market elements help to strengthen the choice of adaptation strategies.

In order to capture the climate change vulnerability and thereof its impact on adaptation investment, weather relating information from media and community, ‘Perception of winter rainy season’ and the most important ‘six year long-run moving average of temperature and precipitation’<sup>38</sup> are given with respect to all three major climate change adaptation strategies. Perception increases the farmer’s ability to adapt to climate change across all strategies while ‘information of weather from media and community’ has ambiguous sign in determining the adaptations. Climate change impact is captured using the temperature and precipitation which has been significantly positive for adapting the ‘*use of better & expensive seeds*’, and ‘*use of more irrigation*’. Climate change vulnerable farmers have only choice to mitigate the loss in agriculture productivity by adapting the climate change and investing the borrowed amount in the purchase of better and expensive seeds and also more irrigation. For Table 17, it’s also mentioned that both ‘Temperature’ and ‘Precipitation’ have been negatively associated with the choice to adapt the ‘*stop growing particular variety and introduce new variety*’ but they have been insignificant across various choice of this strategy. The negative relation may exists due to the meager choice of farmers in investing for this strategy as it is used once in crop cycle and don’t require high amount.

In all of the adaption strategies, ‘Age’ has negative but insignificant impact on the choice of adaptation strategy as well as increase in area under wheat production at selection and outcome equations, respectively. Increase in age reduces the farmer decision to invest the borrowed amount on the choice of adaptation as more elderly people have less decision power to think and decide to invest. The impact of working age or non-working age family members is also captured

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<sup>38</sup> Data is downscaled at village level using the climate tools provided by Pakistan Meteorological Department (PMD, 2018). See Table 2 above for detail definition.



by introducing the ‘number of dependents’ in all of the climate change adaptation strategies. Increase in ‘number of dependents’ reduces the financing of adaptation strategies with significance effect in almost all cases but it significantly increases the area under wheat production. The reason to increase in amount of credit for adaptation investment or strategies is obvious by the number of family members and their contribution in labor force participation. As their contribution in labor market increases, lenders agree to offer high amount based on labor participation and working force of same household. Further, large number of dependents has more choice to invest the borrowed amount on their family members rather to adapt any strategy.

For all categories of education, including ‘Not-attended school’, Primary education’, and Middle education are concerned, the increase in non-attending/uneducated farmers reduce the choice of adaptation strategies as well as area for wheat across all strategies. Primary education is positive for most of the adaptation financing while has been negative for the choice of area under wheat production. Borrowing farmers tied with ‘Middle education’ significantly invest more in using the adaptation strategy of ‘stop growing particular variety and introduce new variety’ while it has been significantly negative in the ‘use of better & expensive seeds’ and ‘use of more irrigation’. The reason for this negative impact is evident from very small number of farmers (only 10%) of ‘middle educators, explained at Table 3.

Farm land size status is defined through the structural definition of Marginal farmers (> 0 and <6.25 acre land) and Small farmers (> 6.25 and <12.50 acre land area). Marginal farmers usually consisting on low land ownership farmers and increase in their size reduces the farmer’s capacity to adapt to all three types of adaptation strategies. Further, these adaptation strategies usually become redundant and inefficient on small land holding size. But increase in ‘small farmers’ help to improve the adaptation investment in the ‘use of better & expensive seeds’, and also ‘stop growing particular variety and introduce new variety’. Land holding greater than 6.25 acre and less than 12.50 acre is somewhat desirable in investing the adaptation strategies.

‘Increase in non-farm income’ significantly reduces the farmers’ investment on all three types of adaptation strategies. The reason behind their reduction in adaptation investment can be explained through their incentive for investment on non-farm activities rather than on farm based activities. Additionally, non-farm income has ambiguous in effecting the area under wheat crop. Source of irrigation has been important factor in determining the adaptation investment where canal and Tube well as source of irrigation are used and analyzed to get the response of adaptation choice and area of wheat grower farmers. In Table 17, canal irrigation is negative while Tubewell irrigation is found to be positive and insignificantly related with the all types of adaptation strategies. In selected sample and particularly at district, Mianwali, and Sukkur, farmers have less access to canal water for irrigation and most of the time they have to invest the borrowed amount to purchase or invest in tubewell water for irrigation.

Land tenancy related variable, measured by ‘ownership of land’ is non-significantly related in reducing the adaptation investment and use of adaptation strategies. The reason may be that land owners farmers don’t get credit from Banks, MFIs and Informal lenders and improvement in their land ownership status doesn’t invest on credit induced adaptation rather they sue their saving for investing in adaptations. Agriculture assets significantly and positively increase the adaptation investment and choice of adaptation strategy. The case is evident across all types of adaptation strategies and various models where the availability of agriculture and livestock assets strengthens their credit demand request and ultimately they investment in variety and irrigation

related adaption after obtaining credit. In order to check the districts effects of each agro-ecological zone, the dummy variable of each districts are introduced in regression analysis of adaptation investment. All districts including ‘Barani Sandy Agro-zone’, ‘North Irrigated Agro-zone’, and ‘South Irrigated Agro-zone’ significantly determine the increase or decrease in adaptation investment for diverse adaptation strategies.

## 6. Conclusion

Climate change has adverse impact on various sectors of economy including agriculture, where farmers have observed reduction in their agriculture production of various crops. In order to overcome that productivity loss through the financing of climate change adaptations, they have to borrow from Formal and Informal lenders. But there exists inefficiency and inequity in financing the adaptations by Formal lenders. This study explores the capital market imperfection of adaptation finance for various agro-ecological zones of Pakistan.

Findings of study through Exploratory Data Analysis (EDA), Probit model, Two-stage least square (2SLS) and Heckman Treatment Effect Model evaluate the existence of imperfect capital market in financing the farmer’s climate change adaptations. It further raises the issue about the unavailability of loan from Formal lenders, mainly due to tight contractual conditions and absence of collateral as security for loan. In resultant, they have scant access to credit opportunities from Formal lenders (Banks) and have to move toward Informal lenders (Brokers, agents), while Semi-formal lenders (MFIs) offer loan on very discriminatory basis that further generates the inefficiency in credit market. The field evidence suggest that only 36% and 37% farmers have access to loan from Formal (Banks) and Semi-formal lenders (MFIs), respectively while 95% farmers have access to credit from Informal lenders which support the inequity issue in credit market. Additionally, around 70% farmers use ‘Personal Security’ as Collateral to get loan instead of Agriculture Land (Immovable property) while they borrow from Informal lenders and this instrument is redundant to apply for loan to Formal Banks. This tight Formal lending market condition induces inefficiency of agriculture banking sector to finance the climate change vulnerable farmers for adaptation. Additionally, the findings of Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) evaluates that farmers have to observe strict rules and regulations as well as tough screening process while they apply for loan to Formal lenders that further reduces farmer’s potential to get loan and inducing the inefficiency in credit market.

The findings also claim that ‘average distance to lender’ is 21.71 miles, indicating that borrowers have to travel from far-off areas to get credit which may strengthen the imperfection of capital market in allocating and financing loans to vulnerable farmers. Additionally, application processing fees<sup>39</sup> is highest while borrowing from Formal lenders (18.50 USD) as compared to Semi-formal and Informal lenders. Farmers have to pay highest amount in terms of application while they borrow from Banks which further restrict to climate change vulnerable farmers to borrow from Formal lenders and induce the capital market imperfection hypothesis.

Adaptation findings also suggest that more than 94% farmers spend the whole borrowing amount in adapting the climate change and 57% of farmers invest in purchasing the ‘use of better and expensive seed’ as adaptation strategy to climate change. ‘Access to credit’ from MFI and ‘duration of loan’ reduces the choice for all types of adaptation strategies with significant

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<sup>39</sup> Consisting on application, registration and round-trip to office/lenders place.

implications. Increase in ‘marginal farmers’ reduces the farmer’s capacity to adapt to climate change. Finally, ‘ownership of land’ is non-significantly related in reducing the adaptation investment and use of adaptation strategies. There have been need to disseminate awareness about MFIs among backward farmers that is scarce. In order to promote the welfare and adaptation finance for small land holding farmers and tenants, Banks need to redesign small scale loan structure without collateral requirements. In addition, market imperfection should be minimized through the direct provision of agriculture inputs at local market without the role of Informal lenders.

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### Appendix-A

**Table: 2 Vulnerability and Agro-Ecological Summary of Wheat Growing Districts**

Sr. No.	Province	Districts	Climate Change	Vulnerability Quintile	Agro-ecological Zones
1	Punjab	Rawalpindi	Not Affected	5	Barani (Rainfall) and part of Wet Mountains
2	Punjab	Jhelum	Not Affected	5	Barani (Rainfall)
3	Punjab	Sargodha	Moderate Affected	4	Northern Irrigated Plain
4	Punjab	Mianwali	Severely Affected	4	Part of Barani (rainfall) and Sandy Desert
5	Punjab	Faisalabad	Not Affected	5	Northern Irrigated Plain
6	Punjab	Sialkot	Not Affected	5	Barani (Rainfall)
7	Punjab	Lahore	Not Affected	5	Northern Irrigated Plain
8	Punjab	Multan	Moderately Affected	3	Northern Irrigated Plain
9	Punjab	Muzaffargarh	Severely Affected	2	Northern Irrigated Plain
10	Punjab	D.G.Khan	Severely Affected	3	Sulaiman Piedmont
11	Punjab	Rajanpur	Severely Affected	1	Southern Irrigated Plain
12	Punjab	Bahawalpur	Not Affected	3	Sandy Desert
13	Punjab	Bahawalnagar	Not Affected	3	Sandy Desert
14	Sindh	Sukkur	Severely Affected	3	Southern Irrigated Plain
15	Sindh	Nawabshah	N/A	N/A	Southern Irrigated Plain and Sandy Desert
16	Sindh	Hyderabad	Moderately Affected	3	Indus Delta
17	Balochistan	Nasirabad	Not Affected	2	Southern Irrigated Plain
18	KP	Peshawar	Severely Affected	4	Northern Dry Mountains
19	KP	Mardan	Moderately Affected	4	Western Dry Mountains

*Source: Ahmad et al. (2012); Khan (2005) and Khan & Salman (2012)*

## Appendix-B

**Table: 14A: Adaptation Strategies and School Rate**

	Increase in use of Tractor	Use of more Fertilizer	Increase use of Pesticides	Use of more Fertilizer	Use of Better & Expensive seeds	Use of more Irrigation	Stop growing variety and introduce new	change in crop planting and sowing date	introduce new crop
<b>Not attended school</b>		74.22 [45.54] (0.000)	60.82 [9.09] (0.003)	60.82 [9.09] (0.003)	55.15 [2.06] (0.151)	53.60 [1.010] (0.315)	55.15 [2.062] (0.151)	54.12 [1.32] (0.251)	46.39 [1.010] (0.315)
<b>Primary school</b>		83.78 [33.78] (0.000)	72.97 [15.62] (0.000)	58.10 [1.94] (0.163)	52.70 [0.216] (0.642)	54.05 [0.486] (0.485)	47.29 [0.216] (0.642)	59.45 [2.649] (0.104)	31.08 [10.59] (0.001)
<b>Middle school</b>		90.0 [25.60] (0.000)	72.5 [8.10] (0.004)	50.0 [0.00] (1.000)	47.5 [0.10] (0.752)	70.0 [6.40] (0.011)	60.0 [1.60] (0.206)	55 [0.400] (0.527)	52.5 [0.100] (0.752)
<b>Secondary above school</b>		73.90 [21.043] (0.000)	58.69 [2.783] (0.095)	70.65 [15.696] (0.000)	68.47 [12.565] (0.000)	57.60 [2.130] (0.144)	57.60 [2.130] (0.144)	44.56 [1.087] (0.297)	48.91 [.043] (0.835)

*Note: Chi-squares test is performed for association of variables where [ ] stands for value of chi-squares while ( ) stands for Asymptotic significance.*

**Table 14B: Adaptation Strategies and Weather Indictors**

	Increase in use of Tractor	Use of more Fertilizer	Increase use of Pesticides	Use of more Fertilizer	Use of Better & Expensive seeds	Use of more Irrigation	Stop growing variety and introduce new	change in crop planting and sowing date	introduce new crop
<b>Perception of Winter Day Temperature</b>		76.43 [1.02] (0.000)	62.46 [22.68] (0.000)	61.64 [19.79] (0.000)	58.9 [11.57] (0.001)	55.61 [4.60] (0.032)	54.52 [2.98] (0.084)	52.05 [0.61] (0.432)	45.47 [2.98] (0.084)
<b>Perception of Winter Cool days</b>		90.6 [21.12] (0.000)	81.25 [12.50] (0.000)	53.12 [0.125] (0.724)	37.5 [2.00] (0.157)	59.37 [1.125] (0.289)	56.25 [0.500] (0.48)	71.87 [6.12] (0.013)	25.00 [8.00] (0.005)
<b>Perception of Winter rainy days</b>		77.52 [1.051] (0.000)	61.95 [19.85] (0.000)	62.53 [21.81] (0.000)	59.36 [12.176] (0.000)	56.48 [5.83] (0.016)	56.8 [6.36] (0.012)	52.44 [0.833] (0.361)	46.97 [1.27] (0.26)
<b>Weather information-Media Source</b>		78.02 [85.74] (0.000)	64.46 [22.86] (0.000)	62.63 [17.4] (0.000)	61.53 [14.53] (0.000)	54.57 [2.28] (0.13)	56.77 [5.01] (0.02)	56.41 [4.48] (0.034)	43.95 [1.27] (0.26)
<b>Weather information-Community Source</b>		76.30 [47.86] (0.000)	61.27 [8.79] (0.003)	58.38 [4.86] (0.027)	52.60 [0.468] (0.494)	62.42 [10.68] (0.001)	49.13 [0.052] (0.82)	46.82 [0.69] (0.403)	47.39 [0.46] (0.494)

*Note: Chi-squares test is performed for association of variables where [ ] stands for value of chi-squares while ( ) stands for Asymptotic significance.*



## Appendix-C

### Remaining part of Adaptation Equation

$$\Omega_{ik} = \gamma'_3 X_{ik} + v_{ik} \begin{cases} E(\Omega_{iM} / X_{iD}, A_2 = 1, A_1 = 1) \\ E(\Omega_{iN} / X_{iA}, A_2 = 0, A_1 = 1) \end{cases} \quad (10)$$

Where conditional disturbance of error-terms  $\mu_{i1}$ ,  $\mu_{i2}$  and  $v_{ik}$  are distributed as zero-means and with constant variance (=1), i.e.  $(\sigma_{u1}^2 = \sigma_{u2}^2 = \sigma_v^2 = 1)$  with correlation coefficients  $\rho_{12}$ ,  $\rho_{1v}$ ,  $\rho_{2v}$ .

The multinomial structure of the model gives us following variance co-variance matrix

$$\omega = \begin{bmatrix} \sigma_1^2 & \rho_{12} & \rho_{1v} \\ \rho_{12} & \sigma_2^2 & \rho_{2v} \\ \rho_{1v} & \rho_{2v} & \sigma_v^2 \end{bmatrix} \quad (11)$$

And unconditional probabilities are written as follows:

$$A = \begin{bmatrix} 1, & A_{i2} = 1: \text{Pr ob}(A_{i1} = 1, A_{i2} = 1) = \theta_2 [\gamma'_1 X_{i1}, \gamma'_2 X_{i2}, \rho_{12}] \\ 1, & A_{i2} = 0: \text{Pr ob}(A = 0, A_{i2} = 0) = \theta_2 [\gamma'_1 X_{i1} - \gamma'_2 X_{i2} - \rho_{12}] \\ 0, & : \text{Pr ob}(A_{i1} = 0) = \theta_2 [-\gamma'_{11} X_{i1}] \end{bmatrix} \quad (12)$$

The conditional probabilities for X can be written as:

$$\frac{\partial \text{Pr ob}(A_{i1} = 1, A_{i2} = 1)}{\partial X_i} = \lambda_{i1} \gamma_1 + \lambda_{i2} \gamma_2 \quad (13)$$

$$\lambda_{i1} = \phi(\gamma'_1 X_{i1}) \theta_2 \left( \frac{\gamma'_2 X_{i2} - \rho_{12} \gamma'_1 X_{i1}}{\sqrt{1 - \rho_{12}^2}} \right) \quad (13a)$$

$$\lambda_{i2} = \phi(\gamma'_2 X_{i2}) \theta_2 \left( \frac{\gamma'_1 X_{i1} - \rho_{12} \gamma'_2 X_{i2}}{\sqrt{1 - \rho_{12}^2}} \right) \quad (13b)$$

$\theta_2$ ,  $\theta$  and  $\phi$ 's are bivariate normal cumulative distribution function, univariate normal cumulative distribution function and normal distribution function, respectively. The terms  $\gamma_1, \gamma_2$  are zero if  $X_i$  does not appear in  $X_{i1}, X_{i2}$ , respectively.

$$\begin{aligned} E(A_{i2} / X_{i1}, X_{i2}, A_{i1} = 1) &= \text{Pr ob}(A_{i2} = 1 / X_{i1}, X_{i2}, A_{i1} = 1) \\ &= \frac{\theta_2(\gamma'_2 X_{i2}, \rho_{12})}{\theta(-\gamma'_1 X_{i1})} \end{aligned} \quad (14)$$

And

$$\frac{\delta E(A_{i2}/X_{i1}, X_{i2}, A_{i1}=1)}{\delta X_i} = \frac{\lambda_{i1} \gamma_1 + \lambda_{i2} \gamma_2}{\theta(-\gamma_1' X_{i1})} - \frac{\theta_2(\gamma_1', \gamma_2' X_{i2}, \rho_{12}) \phi(\gamma_1' X_{i1}) \gamma_1}{[\theta(-\gamma_1' X_{i1})]^2} \quad (14a)$$

The Heckman (1979) gives the maximization of likelihood function with respect to  $\gamma_1', \gamma_2', \rho_{12}$ , given as:

$$\Omega = \sum_{\substack{A_{i1}=1, \\ A_{i2}=1}} \ln \theta_2(\gamma_1' X_{i1}, \gamma_2' X_{i2}, \rho_{12}) + \sum_{\substack{A_{i1}=1, \\ A_{i2}=0}} \theta_2(\gamma_1' X_{i1} - \gamma_2' X_{i2}, \rho_{12}) + \sum_{A_{i1}=0} \theta(-\gamma_1' X_{i1}) \quad (15)$$

The extension of Heckman's two-step estimator is the estimation of equation 8 and 9 at first step using bivariate Probit model (BPM) to get the two selectivity bias terms  $\lambda_{i1}$  and  $\lambda_{i2}$ , also named as Inverse Mill's ratios (Greene, 2003)<sup>40</sup>.

$$\lambda_{i1} = \phi(\gamma_1' X_{i1}) \left[ \frac{\theta[\gamma_2' X_{i2} - \gamma_1' X_{i1} \rho_{12}] / \sqrt{1 - \rho_{12}^2}}{\theta_2[\gamma_1' X_{i1}, \gamma_2' X_{i2}, \rho_{12}]} \right] \quad \text{if } A_1 = 1 \quad (15a)$$

$$\lambda_{i2,M} = \phi(\gamma_2' X_{i2}) \left[ \frac{\theta[\gamma_1' X_{i1} - \gamma_2' X_{i2} \rho_{12}] / \sqrt{1 - \rho_{12}^2}}{\theta_2[\gamma_1' X_{i1}, \gamma_2' X_{i2}, \rho_{12}]} \right] \quad \text{if } A_2 = 1 \quad (15b)$$

$$\lambda_{i2,N} = \phi(-\gamma_2' X_{i2}) \left[ \frac{\theta[\gamma_1' X_{i1} - \gamma_2' X_{i2} \rho_{12}] / \sqrt{1 - \rho_{12}^2}}{\theta_2[-\gamma_1' X_{i1}, \gamma_2' X_{i2}, \rho_{12}]} \right] \quad \text{if } A_2 = 0 \quad (15c)$$

The BPM get maximum likelihood estimation (MLE) that allows stochastic error term to correlate with equation. The parameter  $\rho_{12}$  estimates the correlation between the error-terms of the BPM equations (8) and (9). If MLE estimates of correlation coefficient  $\rho_{12}$  is significant then the estimated BPM coefficients are efficient than the independent probit equations.

The sample selectivity adjusted equation is written as:

$$E(\psi_{i1} / X_{iM}, A_2=1, A_1=1) = \gamma_3' X_{iM} + \beta_1 \pi_{i1} = \beta_2 \pi_{i2M} + \varepsilon_M^* \quad (16)$$

$$\text{Where } \varepsilon_M^* = \varepsilon_{iM} - \beta_1 \pi_{i1} - \beta_2 \pi_{i2M} \quad E(\varepsilon^* / A_2 = 1, A_1 = 1) = 0$$

$$E(\psi_{iN} / X_{iN}, A_2=0, A_1=1) = \gamma_4' X_{iN} + \beta_1 \pi_{i1} = \beta_2 \pi_{i2N} + \varepsilon_N^* \quad (17)$$

$$\text{Where } \varepsilon_N^* = \varepsilon_{iN} - \beta_1 \pi_{i1} - \beta_2 \pi_{i2N} \quad E(\varepsilon^* / A_2 = 0, A_1 = 1) = 0$$

<sup>40</sup> In Heckman Treatment effect, these ratios are automatically calculated and treaded in outcome equation

As far as second stage adaptation equation is concerned, Tobit issue size equation takes into account the probability of the limit and non-limit observations from the first stage and considers the correlation across equation. Unobservable components can correlate that may influence the choice of perception as from the correlation coefficient of equations (8) and (10) and equations (9) and (10) may not be equal to zero. The Heckman estimators help to solve that problem in consistent and efficient way.