Impact of Credit Constraints on Agricultural Productivity in the face of Climate Variability: Panel Data Evidence from Rural Ethiopia

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Abstract

Increasing agricultural productivity is a major step towards transforming the rural economy and ensuring food security. This paper uses household level panel data linked with climate data to examine the impact of different credit constraint conditions on agricultural productivity under changing climatic conditions. A propensity score matching (PSM) and a difference-in-differences (diff-in-diff) methods were employed to provide unbiased estimates of the production impacts of credit constraints on crop productivity. After controlling for potential selection bias, it found that relaxing credit constraints increases agricultural productivity by Ethiopian Birr 169 per hectare, while the real crop revenue for discouraged and quantity constrained farmers declined by Ethiopian Birr 443 and 275 per hectare respectively. These results suggest that relaxing credit constraints by improving performance of the rural credit market could significantly increase agricultural productivity in rural Ethiopia.

Key words: *Credit constraints, agricultural productivity, PSM, Climate variability, Ethiopia.*
GEL Codes: C23; G29; Q12; Q16; Q18; Q54

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1. Introduction

African agriculture is characterized by low productivity and harsh weather conditions including erratic rainfall and high average temperatures (Di Falco et al, 2011; Mulwa et al. 2017). Among African countries, Ethiopia is the most vulnerable country to climate change with the least adaptive capacity (Thornton et al., 2008). This is mainly because rain-fed subsistence agriculture is the primary source of food and income for more than 80 percent of Ethiopians and hence, climatic factors present a great risk to agricultural productivity and food security. This calls for the adoption of effective climate adaptation strategies and agricultural technologies to improve productivity and achieve food security. Climate adaptation actions, like any other investment, require financial resources and access to an affordable source of credit could be expected to relax the liquidity constraints of farmers.

However, performance of the rural credit market in developing countries is generally poor due to imperfections including weak contract enforcement, underdeveloped information systems, imperfect property rights, and unstable political institutions (Andersen, 2012). Contract challenges and problems related to information asymmetries about borrower type and behavior leave poor households in a credit constraint condition (Jack, 2011). Lenders often use collateral as a strategy to offset problems related to asymmetric information and moral hazards. Farmers however, lack the required loan collateral and face credit constraints during crucial periods such as peak planting seasons. This forces them to use minimal amounts of productivity-enhancing technologies, leading to lower yields (Morduch, 1995; Moser and Barrett, 2005).

Despite the immense literature on the links between climate change and choice of different adaptation strategies in the African context (see: Kurukulasuriya, 2008; Hassan and Nhemachena, 2008; Deressa et al, 2008; Di Falco et al., 2011; Bezabih and Di Falco, 2012), the effect of different credit constraint conditions on agricultural productivity under changing climatic conditions has not been studied in depth, especially within a panel framework. Previous studies did not assess this link in the context of rural Ethiopia in general, or use household level panel data particularly from our study area.

In filling this gap, the current study is set out to examine the agricultural productivity trend in the study area; identify key variables which determine the probability of a household to fall into a given credit constraint category; evaluate the impact of multiple credit constraints on agricultural productivity under changing climatic condition; and generate policy-relevant information on approaches to enhance agricultural productivity by improving performance of the rural credit market.

Section 2 of this paper describes the data and variables used in the analysis and the methodological approach consisting of a theoretical model on the productivity effects of credit constraints. The econometric strategy is presented in section 3 and discussion of the results is provided in section 4. Section 5 concludes with some policy implications.

2. The Dataset and Variables used in the Study

The data used for this study were drawn from two waves of panel survey conducted by the Ethiopian Project on Interlinking Insurance and Credit in Agriculture (EPIICA) designed by the Ethiopian Economics Association/Ethiopian Economic Policy Research Institute (EEA/EEPRI) and implemented jointly by the Ethiopian Economics Association, the University of California San Diego, the University of Athens, Greece, Dashen Bank and the Nyala Insurance Company. While the first survey was conducted in 2011, the second round was conducted two years later in 2013. This study is based on the data drawn from both rounds.

The farm households were selected from four zones (north Shewa, south Wollo, north Wollo and west Gojjam) of the Amhara National Regional State located in the northern and central highlands of Ethiopia (Figure 2). About 33 percent of the 1,200 sampled households resided in north Shewa zone, 31 percent in west Gojjam, 23 percent in south Wollo, and the remaining 13 percent in north Wollo zone.

This unique panel data contains quantitative information on agricultural production, agricultural input use, access to credit, consumption expenditure and household's socio-economic characteristics. The household socio-economic characteristics contain demographic information (e.g. age, education, and marital status), household borrowing and lending behaviour, food consumption items, consumption and non-consumption expenditure, income from different sources, risk, food security, and asset holdings of farm households. The agricultural production section contains detailed information on crop production, cultivated land area, types of inputs used, types of crops grown, total crop production and sales, as well as livestock production and marketing of farm households.

2.1 Constructing the Panel Data Set and Linking it with Climate Data

Even though the measurement for most of the variables used in the analysis was straight forward, the data cleaning process required explanation for some of the variables. Farmers reported the cultivated area of land using different local units of measurement and these local units were converted into a standard measure of hectares, using EPIICA's standard conversion factors collected during the survey periods. The plot level information was aggregated into household level and quantity of crop produced was also converted into standard units (kilograms) using the local unit conversion factors. The quantity of production (cereals, root crops and fruits) was converted into value in ETB. To account for inflation, the nominal values of production were converted into real values using the CSA's 2011 production price as a base year data. Finally, a balanced panel of 1,189 households consisting of 2,378 observations over the two rounds of data collection was created.

Monthly rainfall data were obtained from the National Meteorological Agency of Ethiopia, from stations close to the study districts (woredas) for the years between 1983 and 2013. The rainfall measure was constructed by taking the sum of monthly rainfall for each year and averaging it over 30 years. The temperature average was also calculated as the monthly temperature average, also averaged over 30 years. The coefficient of variation (CV) for rainfall was calculated as the standard deviation divided by the mean for the respective periods. These climate variables were linked with the household survey data using the latitude, longitude and other relevant geographic information such as the zone and districts of the households (Wahba, 1990; Wood, 2003).

2.2 Dependent Variable: Agricultural Productivity

The outcome variable of interest in this study is real crop revenue per hectare, since crop production is the major agricultural activity in the study area and provides the largest share of agricultural production. Various annual crops (cereals, pulses, oil seeds, fibers, cotton and root crops) and perennials are grown in different parts of the Amhara region based on the suitability of agro-ecological conditions. Because farmers in the study area are engaged in the production of several different types of crops, monetary values were used instead of quantities to measure productivity and make it comparable across households. Productivity was measured as real crop revenue per hectare after accounting for inflation.

2.3 Explanatory Variables and Hypothesis

Variables explaining agricultural productivity were categorized into measures of climate variability; indicators of credit constraint status; household demographic characteristics; ownership of physical assets, and social capital.

2.3.1 Credit constraint categories

Farm households were classified into four credit constraint categories based on responses to the specific questions raised in relation to willingness to participate in the rural credit market. The first category included unconstrained borrowers who applied for credit and received the amount they requested and did not want to borrow more. The other three categories, quantity-constrained, risk-rationed and discouraged borrowers, were identified using a direct (survey-based) elicitation strategy. Quantity-constrained borrowers are characterized by an excess effective demand for credit and they face a credit limit due to supply-side problems. It means that these households have applied for additional funds, but given the available contract terms, their request is partially or completely rejected. The risk-rationed sub category includes those who do not want to participate in the credit market even if the market is available because they do not want to risk their assets and hence are not willing to provide the necessary collateral, or simply do not want to incur debt. The discouraged households are those who do not want to borrow because of the high transaction cost of borrowing. These costs include, among others, the cost of preparing the loan application, evaluating viability of the project and value of the loan collateral, and monitoring the periodic loan repayment. These costs are independent of the loan amount and discourage farmers who apply for smaller amounts of loan (Kon and Storey, 2003; Guirkinger, 2008; Ayalew and Deininger, 2014).

2.3.2 A measure for climatic factors[2]

Climatic factors were captured using rainfall variability and the incidence of drought. Monthly rainfall data were obtained from the National Meteorological Agency of Ethiopia, from the stations close to the study districts (woredas) for the years between 1983 and 2013.

Among the rainfall stations, Gudoberet and Haik represent two major climate zones or patterns in the study area. Haik station represents the more arid and drought prone zones including south Wollo and north Wollo, while Gudoberet has comparable rainfall pattern as in west Gojjam zone, which gets relatively higher total annual rainfall.

The rainfall and temperature data collected from Gudoberet station in Basona Worena Woreda (district) of north Shewa zone, for instance, shows that there is an increasing but highly fluctuating trend in the rainfall. Even if there is an increase in the mean annual rainfall (by about 30 mm per year), the rainfall was more or less constant during the period 1994 to 2004. In the remaining years, specially, before 1994 and after 2004, there is high fluctuation (anomaly) from the mean annual rainfall in this station. Such high variability may adversely affect agricultural activities in general, and particularly, crop production and productivity in the study area. The mean annual maximum temperature in this site has also been slightly increasing over the last three decades. The regression model for the mean maximum temperature tells that the annual temperature is increasing by 0.023^{o}C per year while, the mean minimum temperature is declining by 0.04^{o}C per annum. This suggests that days are becoming hotter while nights are becoming cooler over the years.

Variation of the mean maximum temperature from its mean value was 0.5^{o}C in 1995 and this has increased by 1.5^{o}C in 2013, showing an enormous change in the atmospheric temperature in this woreda within about a decade (Figure 5). This agrees with the general global warming phenomenon. Global climate models predict that a higher upward variation of the temperature is a disaster both for plants and animals (Brooks, 2006; Moorhead, 2009). Plants, for example, are very sensitive to high temperatures during their decisive flowering and seed development stages, while livestock die due to reduced feed, lack of water, and incidence of animal diseases.

[2] Although we analyzed the climate data from all the nearest stations of the study area, detailed discussion of the results is not presented in this section to keep the document more compact. The full set of tables and graphs are available on request for interested readers.

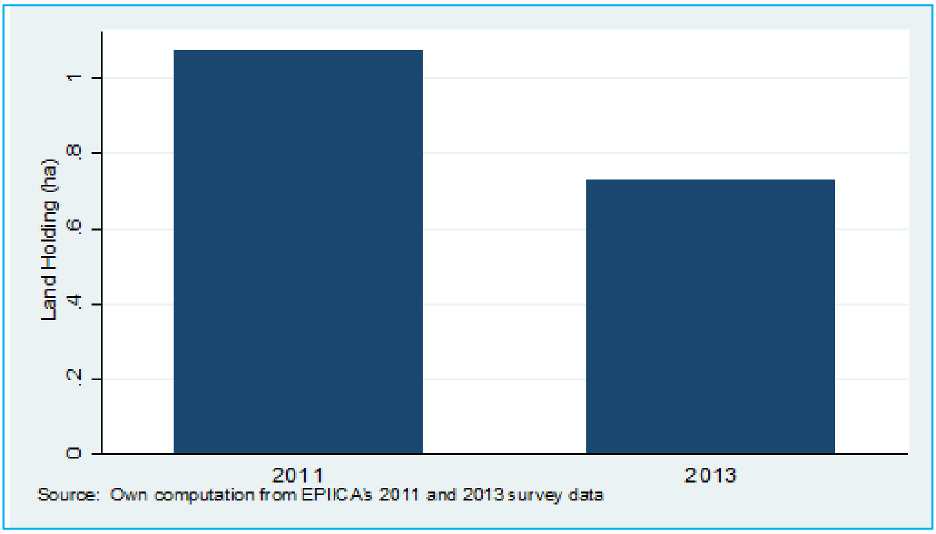
Similar analysis was conducted for the data from Haik station, but detailed discussion of the results is not presented in this section to keep the document more compact. As noted in the foot note, the full set of tables and graphs are available on demand for interested readers.

The subjective responses also show that about 39 percent of the households had faced drought shock during the two survey periods.

2.3.3 Ownership of physical assets and social capital

Land holding is the major productive physical asset that determines the social and economic status of farmers in the study area. The data reveals that the mean land holding was about 1.07 hectares (ha) in 2011 and it had declined to about 0.73 in 2013 (Figure 1). A major reason for this might have been fast population growth in the country in general, and that of the region in particular. As the population grows, the demand for farm land increases while the land size is fixed. Among the farming communities surveyed, farmers in west Gojjam owned relatively larger amounts of land in 2011 followed by north Shewa and south Wollo. Estimates indicate that an average household with 5 members would require about one hectare of land for subsistence production (Alemneh, 1990), and the decline in land holdings observed in the study area is a major cause of concern in terms of feeding an ever-increasing population, especially given the low levels of productivity.

Figure 1: Land holding (ha) by year



The social capital variables included in the analysis as explanatory variables are trust and participation in farmers' primary cooperatives, and membership in a rotating saving and credit association (ROSCA). These are important social assets enjoyed for their own sake, used for material gain, and called upon in times of shock or crisis (Woolcock and Narayan, 2000). Trust in cooperatives is represented by a dummy variable with a value of 1 if respondents trust their cooperatives and 0 otherwise.

2.3.4 Socio-economic characteristics

Household socio-economic characteristics such as age, gender, marital status, and level of education of the household head were included in the analysis as control variables. The average age of household heads in the sampled zones was about 50 years, with heads in west Gojjam zone being relatively younger than those in the other three zones. The average household size was approximately five. About nine percent of the households in the study sites were headed by females in 2011, with this figure increasing to twelve percent by 2013. About 22 percent of the household heads have around 5 years of formal education; 27 percent had attended some informal education in 2011 and 24 percent in 2013.

3. Methodology

3.1 Quantifying the Productivity Effects of Credit Constraints and Climatic Factors: A Theoretical Framework

To increase crop production and to cope with the changing climatic conditions, rural farm households use both modern and traditional technologies including multiple cropping on one field, mixed farming of crops and livestock, using improved seeds (e.g. drought resistant crop varieties), irrigation, selling valuable assets, reducing household consumption, and other related mechanisms (Teklewold et al., 2013). However, credit constraints have an adverse impact on the adoption of such strategies to deal with a multitude of agricultural production constraints. This implies that useful information can be obtained by analyzing the link between financial constraints and agricultural productivity, both theoretically and empirically.

3.1.1 The set up

Following the theoretical literature on producer-consumer models (e.g. Singh et al., 1986; Sadoulet and De Janvry, 1995; Petrick, 2004; and Briggeman et al., 2009), the impact of credit constraints on agricultural productivity under changing climatic conditions was conceptualized as below.

Assume a farm household which maximizes its utility by consuming c_0 and c_1 amounts of goods and services in periods 0 and 1, given a set of household characteristics z^h. The utility function is assumed to be inter-temporally additive, twice differentiable and quasi-concave such that:

$$u = (c_0, c_1; z^h) \qquad [3.1]$$

Agricultural production in period 0 requires purchase of variable inputs (x) such as seeds and fertilizer at a given price p and harvest occurs in period 1. These inputs can be purchased either with own resources (w) or with a borrowed capital (k) that will be repaid back with k (1 + r) in period 1 where r is the loan interest rate.

Let the agricultural production follow a twice differentiable and concave function:

$$y = f(x, z^y) \qquad [3.2]$$

where Z^y represents fixed and exogenous production inputs such as land and major farm tools.

Under this setup, a farm household tries to maximize the following utility function:

$\max u(c_0, c_1; z^h)$ subject to:

$$w + k - c_0 - px = 0 \qquad [3.3]$$

$$f(x, z^y) - c_1 - (1+r)k = 0 \qquad [3.4]$$

$$\bar{k}(z^h, z^y) - k \geq 0 \qquad [3.5]$$

where equations (3.3) and (3.4) state the household budget constraints in periods 0 and 1, while equation (3.5) describes the credit[3] constraint condition in period 0 where $\bar{k}(z^h, z^y)$ denotes the upper bound of credit that the household can obtain. In the rural areas of developing countries like Ethiopia, this constraint is compulsory due to a number of reasons. These include: the problem of adverse selection, moral hazard, and costly state verification due to information asymmetries as discussed in Stiglitz and Weiss (1981); screening, monitoring, and enforcement problems in under developed rural credit markets (Hoff and Stiglitz, 1996; and the problem of a lack of collateral. Lenders usually consider collateral as an important means of reducing default risk and hesitate to grant credit to the poor who lack the required collateral. This makes credit constraints binding for the poor (Ghosh et al., 2001).

To solve the above utility maximization problem, set the Lagrangian as:

$$L = u(c_0, c_1; z^h) + \psi(w + k - c_0 - px) + \zeta[f(x; z^y) - c_1 - (1+r)k] + \gamma[\bar{k}(z^h, z^y) - k] \quad [3.6]$$

The first order conditions (FOCs) of the optimal solution can be expressed as:

$$\frac{\delta L}{\delta c_0} = \frac{\delta u(.)}{\delta c_0} - \psi = 0 \quad [3.7]$$

$$\frac{\delta L}{\delta c_1} = \frac{\delta u(.)}{\delta c_1} - \zeta = 0 \quad [3.8]$$

$$\frac{\delta L}{\delta x} = -\psi p + \zeta \frac{\delta f(.)}{\delta x} = 0 \quad [3.9]$$

$$\frac{\delta L}{\delta k} = \psi - \zeta(1+r) - \gamma = 0 \quad [3.10]$$

$$\frac{\delta L}{\delta \gamma} = \bar{k}(z^h, z^y) - k \geq 0, \gamma \geq 0, \gamma \frac{\delta L}{\delta \gamma} = 0 \quad [3.11]$$

[3] We took the Kuhn-Tucker conditions for equation (3.5) because it is an inequality constraint

where equation (3.9) represents optimal production, while equations (3.7) and (3.8) represent optimal consumption. Equations (3.3), (3.4) and (3.11), on the other hand, are conditions which must be satisfied by an optimal solution, while $\psi, \zeta and \gamma$ are the lagrangian multipliers.

The subsequent section discusses how credit constraints affect household's production decisions under changing climatic conditions, first, by finding an optimal production decision when credit constraints are not binding[4]. Inserting equation (3.10) in to (3.9) given that $\gamma = 0$ yields[5]:

$$\frac{\delta f(.)}{\delta x} = p(1+r) \tag{3.12}$$

This shows that the household production function does not depend on the utility function or on any of the household characteristics and that household production and consumption decisions are now, separable. Hence, removing credit constraints by allowing farm households to have access to credit can ensure separability of production decisions from consumption decisions, allowing standard recursive household models to work. This in turn means that household resource allocation decisions will be efficient as the standard neo-classical household models predict (e.g Singh et al., 1986; Sadoulet and De Janvry, 1995).

Equation (3.12) is similar to the standard resource allocation rule. However, it was assumed that household production and input purchase decisions are made in period zero, while income is earned in period one and hence input prices are inflated by the interest rate (r).

On the other hand, when credit constraints are binding, equation (3.5) will hold with equality and hence $\gamma > 0$ in equation (3.11) above. To show the effect of this constraint on input use, it is possible to rewrite equation (3.10) as: $(1+r) = \frac{\psi - \gamma}{\zeta}$. Solving for ψ and substituting this expression in equation (3.9) yields:

[4] In the above setting, it is clear that credit constraints are not binding when gamma is zero ($\gamma = 0$)

[5] Given that $\gamma = 0$ in equation (3.10) means that $\psi = \zeta(1+r)$ and inserting it in equation (3.9) gives equation (3.12).

$$\frac{\delta f(.)}{\delta x} = [(1+r) + \frac{\gamma}{\zeta}]p \qquad [3.13]$$

If the optimal input and agricultural technology demand which can be derived from equation (3.12) for credit unconstrained (cuc) households be denoted by x^*_{cuc} and the optimal input and agricultural technology demand for credit constrained (cc) households (which can be derived from equation (3.13)) by x^*_{cc}, then it is possible to note that the opportunity cost of the optimal input for the credit-constrained household (x^*_{cc}) is greater than the opportunity cost for the credit-unconstrained household (x^*_{cuc}) because it is inflated by$\left(\frac{\gamma}{\varsigma}\right) P$ amount for credit-constrained households (see equation 3.13). This implies that credit-constrained households will lower the purchase of production inputs and agricultural technology (x) to increase the value of the marginal product.

From the above theoretical analysis, it can be noted that total agricultural production and productivity of a credit-constrained household will be lower than that of a non-constrained household because of credit constraints and one objective of this study is to show the effect of this constraint on agricultural productivity under changing climatic conditions. The next section will focus on an econometric strategy to test the above theoretical model empirically.

3.2 The Econometric Model

In relation to credit constraint conditions, farmers are not randomly assigned in different credit constraint categories. The probability of a given farmer falling in a constrained (treatment) or unconstrained (control) category depends, among other things, on the personal characteristics of that individual. In estimating the impact of credit constraints on agricultural productivity, it is crucial to take note of this potential selectivity bias.

Prior studies used different methods to control for such selection bias. Petrick (2004), for instance, used the Heckman estimator to show the effect of credit constraints on agricultural output while, Foltz (2004) used the switching regression technique to estimate the effect of credit constraints on agricultural investment. In another study, Briggeman et al., (2009) used the propensity score matching (PSM) method to control for a potential selection bias in estimating the impact of credit constraints on the value of the production for farm and non-farm sole proprietorships. This method was first suggested by Rosenbaum and Rubin (1983), and it has become a common impact evaluation tool. Using the PSM method can reduce the potential bias by making productivity comparisons between farmers who are credit constrained and those who are unconstrained. The main purpose of using the PSM method is to find a group of non-treated (unconstrained) farmers similar to the treated (constrained) groups in all relevant observable characteristics with the only difference being that one group is constrained and the other unconstrained.

Here, the PSM method is used to control for the possible selectivity bias in estimating the effect of credit constraints on agricultural productivity in rural Ethiopia (For more details, see: Smith and Todd, 2005; Briggeman et al., 2009; and Kassie et al., 2009).

The outcome of interest (which is the real crop revenue per hectare) is identified from the following equation:

$$E[Y_1 - Y_0 \mid D = 1] = E[Y_1 \mid D = 1] - E[Y_0 \mid D = 1] \qquad [3.14]$$

where Y is the real crop revenue (rcr) per hectare and D indicates to which credit constraint category the household belongs. D takes the value of 1 for credit constrained farmers (treatment group) and it takes the value of 0 for unconstrained borrowers (control group). Thus, the outcome of interest is the average difference in Y_1 and Y_0. However, this matching exercise tries to estimate only $E[Y_0|D=1]$ which is the counterfactual or the unobservable case, since one farmer falls only in one state (either in the treatment group or in the control group) at a time. It means trying to estimate the impact of being credit constrained on the real crop revenue for those farmers who are actually unconstrained.

Had there been experimental data in which the farmers are randomly assigned to the treatment and control groups, it would have been possible to estimate the average treatment effect as:

$$E[Y_1 \mid D = 1] - E[Y_0 \mid D = 0] \qquad [3.15]$$

However, the data at hand is only observational and hence, it is a must to follow the Rosenbaum and Rubin (1983) approach to solve the selection bias by estimating the equation below:

$$E[Y_1 - Y_0 \mid Z, D=1] = E[Y_1 \mid Z, D=1] - E[Y_0 \mid Z, D=1] \quad [3.16]$$

where Z is set of covariates which determine the credit constraint status of farmers. If the probability of being credit constrained is determined by Z, then it is possible to establish a control group of unconstrained farmers that are similar in Z relative to the constrained farmers (the treatment group). Thus, from equation (3.16), it is possible to estimate the average treatment effect on the treated (ATT) as:

$$ATT = E[Y_1 - Y_0 \mid P(Z), D=1] = E[Y_1 \mid P(Z), D=1] - E[Y_0 \mid P(Z), D=0] \quad [3.17]$$

where P(Z) is the probability of selection conditional on Z or is the propensity score (Pscore) which is: $P(Z) \equiv \Pr(D=1 \mid Z)$.

The PSM was, therefore, done in two stages. First, the propensity scores (pscores) were calculated using Stata's "pscore" command, which are the conditional probabilities that a given farmer is credit constrained. Calculating the propensity score is crucial since it is difficult to do the matching on each explanatory variable when there are many covariates. The main purpose of the propensity score estimation is to balance the observed distribution of covariates across the constrained and unconstrained groups. Following Lee (2008), a matching test was also conducted after matching to check whether or not the differences in covariates in the two groups in the matched sample have been eliminated. In the second stage, the ATT was estimated using Stata's "psmatch2" command, a sensitivity analysis was conducted and the results are discussed below.

In addition to the PSM, the difference-in-differences (diff-in-diff) method was also used as a robustness test and the result is provided in Table 2A in the Appendix.

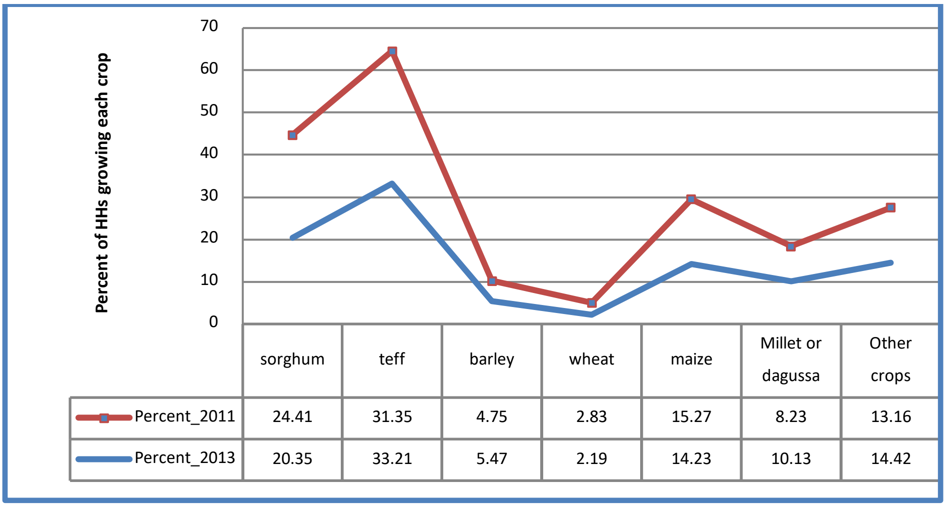
4. Results and Discussion

4.1 Descriptive Evidence

Agricultural production in the study area is dominated by 6 major cereals that account for about 86 percent of the total crop production (Figure 2). Among the cereals, teff, sorghum, and maize are the three major crops grown in the study area and they account for 31, 24, and 15 percents respectively in 2011. The last column in Figure 2 shows that the production of other crops such as oil seeds, pulses, perennials, and fruits and vegetables accounts for less than 15 percent over the survey period.

Agricultural productivity also remained very low over the years. Although there was a slight increase in productivity in north Shewa and north Wollo zones, the overall real value of output per hectare has been below ETB 1,500 during the study period (Figure 3). As in the case in Ethiopia in general, climatic shocks, deforestation and land degradation, as well as lack of access to credit have been among the major causes for the lower agricultural productivity in the study sites.

Figure 2: Major crops grown in the study area by year

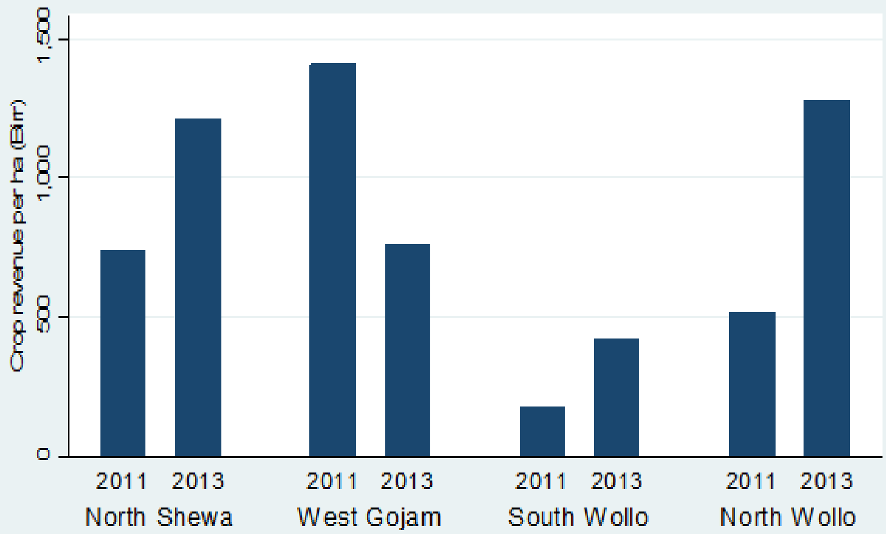


	sorghum	teff	barley	wheat	maize	Millet or dagussa	Other crops
Percent_2011	24.41	31.35	4.75	2.83	15.27	8.23	13.16
Percent_2013	20.35	33.21	5.47	2.19	14.23	10.13	14.42

Land expansion to increase agricultural production is no more a feasible option because of the high population pressure and scarcity of suitable farm land. Improving agricultural productivity must be the way out and this requires more investment in sustainable adaptation strategies, improved farming systems and adoption of agricultural technologies such as high-yielding, drought resistant varieties, chemical fertilizers, and soil conservation measures (Kassie et al., 2011). Nevertheless, adaptation efforts have been very weak and technology adoption has remained very low in the Amhara region. There are a number of reasons including a lack of information and know-how about different agricultural technologies, and weak integration of research with agricultural extension to learn from day-to-day problems of farmers and incorporate these in designing better agricultural technology policies as well as minimal access to innovative and reliable credit facilities to purchase recommended agricultural technologies that could improve productivity (BoFED, 2013).

Future climate Predictions using General Circulation Models (GCM) also show that the mean maximum temperature will increase by 2.3 °c in north Shewa, south Wollo and north Wollo zones in the 2080s while it will rise by 1.8 °c in west Gojjam zone. In addition, rainfall is expected to decrease by 27.2 percent in the first three zones while reducing by 12.2 percent in west Gojjam zone (Ayalew et al., 2012). This implies that climate change will continue to be a major threat for the study area leading to increased exposure to rainfall variability, recurrent droughts and shortage of water. In the future, this can be expected to further reduce agricultural productivity of the study sites.

Figure 3: Average real crop revenue per hectare (Productivity)



Source: Own computation from EPIICA's 2011 and 2013 survey data

4.2 Econometric evidence

4.2.1 Impact of being an unconstrained borrower on agricultural productivity under changing climatic conditions

The determinants of being an unconstrained borrower is estimated in the first stage of the propensity score matching method (Table 1), checked whether the balancing property is satisfied, and then the impact estimated on the average crop revenue per hectare in the second stage. Climatic factors, membership in social networks and associations such as rotating saving and credit associations (ROSCA), socio-economic condition of the household, and location are found to be correlated with the probability of being an unconstrained borrower. The result shows that experiencing drought shock reduces the probability of being an unconstrained borrower by about 17 percent. This might be because of the dependence of agricultural production in the study area on rainfall, and lenders do not want to take uninsured risk of loan default in the case of crop failure caused by various climatic shocks including drought.

The probability of being an unconstrained borrower is found to be higher for female-headed households, and married farmers in the study area. The possible reason for this may be because married heads are more likely to be stable, trustworthy and abide by rules and regulations compared to the unmarried or separated heads; financial institutions view them as more reliable and may allow better access to credit (Mpuga, 2008).

In terms of location, farmers living in west Gojjam zone are less constrained while those in south Wollo are more constrained compared to households residing in north Shewa zone. This implies that the credit constraint conditions of farmers vary across the study sites.

From the second stage regression, it was found that being an unconstrained borrower significantly increases the average crop productivity or crop revenue per hectare. Controlling for the effects of several covariates and the selection bias, having full access to credit is associated with significant crop revenue improvement. Unconstrained borrowers tend to enjoy Ethiopian birr 169 higher crop revenue per hectare compared to constrained borrowers (Table 2). This is the average treatment effect on the treated (ATT) and it is statistically significant.

4.2.2 Impact of being a discouraged borrower on agricultural productivity under changing climatic conditions

Adopting various agricultural technologies is a common strategy used by farm households to insure themselves against uncontrollable climatic factors. It also ensures their food security, and helps them to adapt to different agro-ecological production conditions, and to meet market demands (Winters et al., 2006). However, credit constraints have significant negative effects on technology adoption since such investments require substantial cash outlay.

In this paper, before estimating the impact of being a discouraged borrower on real crop revenue per hectare, key factors influencing the probability of being discouraged were identified. Climatic factors such as drought and rainfall variability, and year dummies were found to have a significant positive effect on the probability of being discouraged (Table 3).

Table 2 shows the average effect of being discouraged over agricultural productivity in the study area. The estimated average treatment effect on the treated (ATT) shows that discouraging credit market conditions significantly reduce real crop revenue per hectare by about ETB 443, which is much lower than the productivity of unconstrained borrowers. This indicates the serious adverse effect of credit constraints on agricultural productivity in the study area.

4.2.3 Impact of being quantity constrained borrowers on agricultural productivity under changing climatic conditions

The result in Table 4 shows that climatic factors, membership in social networks and associations, socio-economic condition of the household, the year dummy, and location of residence are correlated with the probability of being quantity constrained borrowers, though some variables are insignificant. Table 2 shows the average effect of quantity constrained borrowers on agricultural productivity in the study area. Quantity constrained borrowers would have earned crop revenue in real terms of about ETB 275 higher had they not been constrained in the credit market. In other words, the estimated average treatment effect shows that quantity constraint has a negative and statistically significant effect on crop revenue per hectare for constrained farmers.

These results agree with micro-level studies from different countries which show that household crop income and welfare is significantly reduced when credit constraints are intertwined with climatic shocks. Rosenzweig and Wolpin (1993) and Jacoby and Skoufias (1997) found that credit constraints caused by imperfections in the credit market have long-term welfare effects on farm households when they are entangled with climatic shocks. The effect is most severe on poorer households because such shocks can destroy their lifetime wealth directly and also reduce their current and future agricultural income. It may also reduce their earning potential through forced sales of productive assets.

4.2.4 Impact of being risk rationed borrower on agricultural productivity under changing climatic conditions

Experiencing drought shock and rainfall variability found to significantly increase the probability of being risk-rationed borrower (Table 5). This might be because such farmers do not want to borrow from the formal credit market not to take the risk of loan default in the case of crop failure. After controlling for the potential selectivity bias, it was found that being risk-rationed borrower has a negative but insignificant effect on agricultural productivity in the study area.

4.2.5 Sensitivity Analysis: Matching Quality and Rosenbaum bounds

Matching Quality check

Figure 4 in the Appendix shows the plausibility of the confoundedness and overlap assumption which is necessary for the impact identification with the propensity score-matching method. The figure depicts the propensity distributions of the treated and control households for the model. In both cases, the distributions are similar and there is good overlap except only a few cases which are off the common support.

Rosenbaum bounds

A sensitivity analysis is performed using the Rosenbaum bounds (rbounds) to check how strongly unobserved variables affect the matching results. Result of the analysis for the outcome variable (real crop revenue) is shown in Table 6 in the Appendix. In conducting the analysis, we assume that there was no unobserved confounder due to selection bias and all relevant characteristics were matched so that the treatment group and the control group both had the same basis for analysis.

When gamma equals one, both the upper and lower bounds remained the same for the real crop revenue variable and this implies that there is no hidden bias due to unobserved confounder. However, if the gamma is increased to two or if the odds of a household being in the treatment group are doubled because of different values of unobserved factors, there may be a slight effect on the outcome variable.

According to Becker and Caliendo (2007), one should be cautious in interpreting the results obtained from different gamma values. It should be noted that the result obtained by calculating with different gamma values shows the level of sensitivity of the produced results and it does not imply that unobserved heterogeneity exists and there is no effect of treatment on the outcome variables. Result of the sensitivity analysis shows only the confidence interval of the treatment effect would include zero if the odds ratio of the treatment assignment differs between the treatment and control groups by the gamma value.

5. Conclusion and Implications

The main objective of this paper was to investigate the effect of different credit constraint conditions on agricultural productivity among smallholder farmers in selected zones of the Amhara Regional State in the northern highlands of Ethiopia. Household level survey data were used to estimate these effects. To mitigate biases stemming from heterogeneity, the propensity score matching (PSM) method was applied to measure the effect of the treatment (being credit constrained) on the treated farmers.

The results provide evidence for the adverse effects of being credit constrained (falling within discouraged or quantity constrained borrower groups) in improving agricultural productivity in the study area. Farmers want to invest in fertilizers, improved seeds, and drought-resistant crops which can increase productivity in the face of changing climatic conditions. However, adoption of such technologies is hampered by credit constraints and, as we have seen, this has a direct and negative effect on agricultural productivity in the study area.

The result from the impact estimates using the propensity score matching method indicated that relaxing credit constraints has a significant positive impact on agricultural productivity, while higher transaction costs and discouraging credit market policies were found to reduce productivity significantly. At the household level, the average treatment effect (ATT), which is the actual effect that constrained households experience, are ETB 443 and ETB 275 lower real crop revenue (productivity) for discouraged and quantity constrained borrowers, respectively.

The results also suggest the importance of climatic variables in explaining the probability of farm households falling into different credit constraint categories. Discouraged and risk averse farmers are not willing to participate in the credit market to avoid losing assets in the case of crop failure. A feasible strategy to encourage these farmers to participate and benefit from agricultural loans is linking credit with crop insurance to manage the uncertainty in agricultural production. Designing "productivity-based credit" (PBC) products might also help both lenders and borrowers in two ways. First, it could motivate farmers to work hard, easing the moral hazard problem; and secondly, it could also reduce the probability of adverse selection, allowing lenders to target the right borrowers who really need the loan to invest in productivity-enhancing agricultural technologies.

In relation to these findings, governments of some developing countries give due attention to the performance of the rural credit market given its role in improving productivity, household food security and reducing vulnerability to climate change. In Brazil, for instance, the official rural credit portfolio covers about a third of the annual financial needs of the agricultural sector (Assunção et al., 2013). Although this is a good step forward, the solution to the low productivity and credit constraint problems of farm households is not a mere injection of loanable funds into the rural credit market. Instead, government interventions should focus on improving the institutional setup of lending institutions, investing in human capital formation and building the capacity to innovate new loan products and efficient ways of serving genuine borrowers. This involves designing creative and climate-smart credit policies and procedures which can tackle the information asymmetry problem entailed in rural lending without reducing the welfare of borrowers.

To help farmers better adapt to changing climatic conditions, it is, for example, crucial to think of a flexible climate adaptation loan product. Among the study sites, south Wollo and north Wollo zones are more vulnerable to drought and climate variability, and this calls for designing climate-smart loan (CSL) products so that farmers in these zones have better access to the rural credit market and can build their adaptive capacity. Relaxing collateral requirements for small loans and increasing the loan repayment period to more than a year may also encourage farmers to participate in the rural credit market.

Generally, the results suggest that credit constraints are significant determinants of participation in the adoption of various technologies and adaptation strategies that can improve agricultural productivity. This highlights the need to recognize the complex relationships between financial provision and climate change policies, and the implications for situation–specific policy design regarding rural credit and adaptation to climate change in the study area.

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Appendix 1

Table 1: Determinants of the propensity to be unconstrained borrowers

Variables used for the PSM regression	Pscore (PSM Stage 1)	
	coefficient	**std.err.**
Dependent variable: Probability of being unconstrained borrowers		
Rainfall variability (CV)	0.078	(0.123)
HH experienced drought shock	-0.170**	(0.081)
Market-related shocks	0.123	(0.118)
Idiosyncratic shocks	0.096	(0.144)
Participation in Productive Safety net prg (PSNP)	0.30**	(0.132)
Head is member in a ROSCA (Ekub)	1.220***	(0.074)
Age of head	-0.008***	(0.003)
dummy for female head of the household	0.478**	(0.208)
Dummy for a married head	0.448**	(0.199)
Household size	0.001	(0.020)
Head has no education	0.087	(0.090)
Head attended some formal education	0.033	(0.106)
Dummy for west Gojjam	0.365***	(0.097)
Dummy for south Wollo	-0.603***	(0.151)
Dummy for north Wollo	-0.072	(0.155)
Constant	-1.457***	(0.282)
Diagnostic tests		
Number of observations	2,146	
Log likelihood	-816.64	
LR chi2(15)	502.75	
Prob > chi2	0.00	
Standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1		

Source: Author's computation from EPIICA's 2011 and 2013 survey data

Table 2: Effect of different credit constraints on agricultural productivity (Real Crop revenue per Hectare): Propensity Score Matching

Credit constraint categories	Sample	Treated	Controls	Difference (ETB)‡	std.err.	T-stat
Unconstrained borrowers	Unmatched	1275.55	903.29	372.26	62.85	5.92
	ATT	1310.42	1141.89	168.53*	94.42	1.78
Discouraged borrowers	Unmatched	814.16	1025.18	-211.02	127.23	-1.66
	ATT	809.03	1252.08	-443.05***	187.85	-2.36
Quantity Constrained borr.	Unmatched	848.94	1158.35	-309.40	92.22	-3.36
	ATT	848.87	1124.02	-275.15***	120.20	-2.29
Risk-rationed borrowers	Unmatched	1027.80	1025.18	2.62	78.18	0.03
	ATT	1028.00	1040.91	-12.91	104.79	-0.12

‡ETB = Ethiopian Birr, 1 USD = 18.5 ETB as of March 2013, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source: Author's computation from EPIICA's 2011 and 2013 survey data

Table 3: Determinants of the propensity to be discouraged borrower

Variables used for the PSM regression	Pscore (PSM Stage 1)	
	coefficient	std. err.
Dependent variable: Probability of being discouraged borrower		
Rainfall variability (CV)	1.976***	(0.182)
HH experienced drought shock	1.289***	(0.186)
Crop damage due to wild animals	-0.138	(0.292)
Market-related shocks	-0.209	(0.220)
Idiosyncratic shocks	-0.336	(0.288)
Participation in Productive Safety net prg (PSNP)	-0.225	(0.194)
Trust farmers' cooperative	-0.088	(0.141)
Year effect	0.487***	(0.133)
Head is member in a ROSCA (Ekub)	-0.158	(0.158)
Age of head	-0.008*	(0.004)
dummy for female head of the household	-0.077	(0.292)
Dummy for a married head	-0.201	(0.261)
Household size	-0.015	(0.033)
Head has no education	-0.167	(0.147)
Head attended some formal education	-0.064	(0.173)
Dummy for west Gojjam	0.037	(0.223)
Dummy for south Wollo	0.776***	(0.206)
Dummy for north Shewa	-0.791***	(0.214)
Constant	-1.418***	(0.436)
Diagnostic tests		
Number of observations	1,412	
Log likelihood	-281.51	
LR chi2(19)	233.05	
Prob > chi2	0	
Standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1		

Source: Author's computation from EPIICA's 2011 and 2013 survey data

Table 4: Determinants of the propensity to be Quantity constrained borrower

Variables used for the PSM regression	Pscore (PSM Stage 1)	
	coefficient	std.err.
Dependent variable: Probability of being Quantity constrained borrower		
Rainfall variability (CV)	0.086	(0.125)
HH experienced drought shock	0.205**	(0.089)
Market-related shocks	-0.054	(0.129)
Idiosyncratic shocks	-0.186	(0.156)
Participation in Productive Safety net prg (PSNP)	0.341***	(0.112)
Trust farmers' cooperative	-0.022	(0.087)
Year effect	0.394***	(0.081)
Age of head	0.001	(0.003)
dummy for female head of the household	0.136	(0.188)
Dummy for a married head	0.008	(0.172)
Household size	0.006	(0.021)
Head has no education	-0.204	(0.160)
Head attended some formal education	-0.050	(0.206)
Dummy for west Gojjam	-0.136	(0.163)
Dummy for south Wollo	0.359***	(0.121)
Dummy for north Shewa	-0.491***	(0.142)
Head has no education time avg.	-0.197	(0.190)
Head attended some formal education time avg.	-0.028	(0.238)
Head is member of farmers' coop time avg.	-0.003	(0.158)
Land holding time avg.	-0.118	(0.075)
Constant	-0.589*	(0.309)
Diagnostic tests		
Number of observations	1,723	
Log likelihood	-866.64	
LR chi2(20)	136.38	
Prob > chi2	0	
Standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1		

Source: Author’s computation from EPIICA's 2011 and 2013 survey data

Table 5: Determinants of the propensity to be Risk Rationed Borrowers

Variables used for the PSM regression	Pscore (PSM Stage 1)	
	coefficient	std.err.
Dependent variable: Probability of being Risk Rationed Borrowers		
Rainfall variability (CV)	0.791***	(0.148)
HH experienced drought shock	0.247***	(0.096)
Market-related shocks	0.018	(0.133)
Idiosyncratic shocks	-0.350*	(0.187)
Participation in Productive Safety net prg (PSNP)	0.240	(0.158)
Trust farmers' cooperative	-0.132	(0.096)
Year effect	0.181**	(0.090)
Age of head	0.000	(0.003)
dummy for female head of the household	-0.022	(0.216)
Dummy for a married head	-0.004	(0.196)
Household size	-0.003	(0.022)
Head has no education	-0.085	(0.097)
Head attended some formal education	-0.090	(0.120)
Dummy for west Gojjam	0.026	(0.197)
Dummy for south Wollo	-0.196	(0.183)
Dummy for north Shewa	0.052	(0.181)
Constant	-1.496***	(0.338)
Diagnostic tests		
Number of observations	1,600	
Log likelihood	-677.66	
LR chi2(16)	122.38	
Prob > chi2	0	
Standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1		

Source: Author’s computation from EPIICA's 2011 and 2013 survey data

Figure 4: Propensity score distribution for the treated and untreated

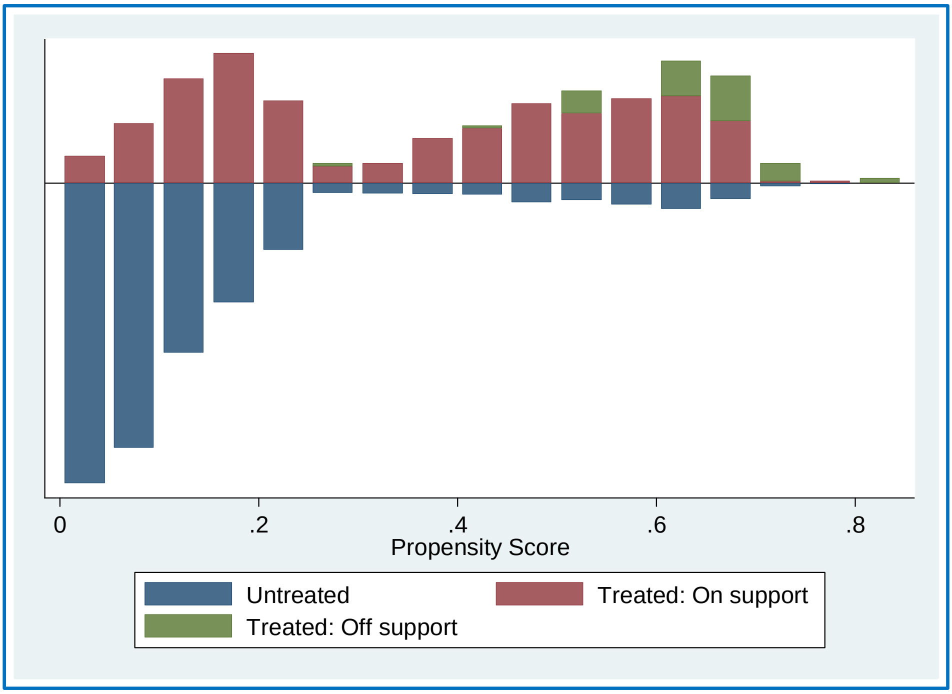

Table 6: Sensitivity analysis-Rosenbaum bounds for the outcome variable

Outcome	Gamma*	Matched pairs	Significance level		Hodges-Lehman Point estimate		95% Confidence Interval	
			Upper bounds	Lower Bounds	Upper bounds	Lower Bounds	Upper bounds	Lower Bounds
Real crop revenue	1	269	0.0164	0.0164	0.1433	0.1433	0.0105	0.2715
	2		0.9971	0.0000	-0.1823	0.4690	-0.3309	0.6119
	3		1.0000	0.0000	-0.3792	0.6551	-0.5515	0.8189

Table 2A: Effect of Credit Constraint on Agricultural Productivity (using diff-in-diff as a robustness test)

Credit Constraint cat.	Outcome	Control BL	Treated BL	Difference BL	Control FU	Treated FU	Diff. FU	DID
Unconstrained Borrower	Rcr	1047.95	1131.31	83.36	1064.75	1397.76	333.01	249.64
	Std. Error	59.45	59.45	84.08	72.40	53.18	89.83	123.04
	T	17.63	19.03	0.99	14.71	26.29	3.71	2.03
	P>|t|	0.00	0.00	0.32	0.00	0.00	0.00	0.04
Quantity Const. Borr.	Rcr	1121.27	972.93	-148.34	1052.42	746.81	-305.61	-157.27
	Std. Error	60.35	60.35	85.34	73.99	77.70	107.29	137.10
	T	18.58	16.12	-1.74	14.22	9.61	-2.85	-1.15
	P>|t|	0.00	0.00	0.08	0.00	0.00	0.00	0.25
Risk rationed borr.	Rcr	1121.64	1146.75	25.11	922.67	711.43	-211.24	-236.35
	Std. Error	63.99	63.99	90.50	79.64	57.86	98.44	133.72
	T	17.53	17.92	0.28	11.59	12.30	-2.15	-1.77
	P>|t|	0.00	0.00	0.78	0.00	0.00	0.03	0.08
Discouraged Borr.	Rcr	1097.25	1225.03	127.78	895.40	723.48	-171.92	-299.71
	Std. Error	51.99	51.99	73.52	59.03	54.75	80.51	109.03
	T	21.11	23.56	1.74	15.17	13.21	-2.14	-2.75
	P>|t|	0.00	0.00	0.08	0.00	0.00	0.03	0.01

‡ETB = Ethiopian Birr, 1 USD = 18.5 ETB as of March 2013, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Location map of the study area, Ethiopia; Amhara Regional State

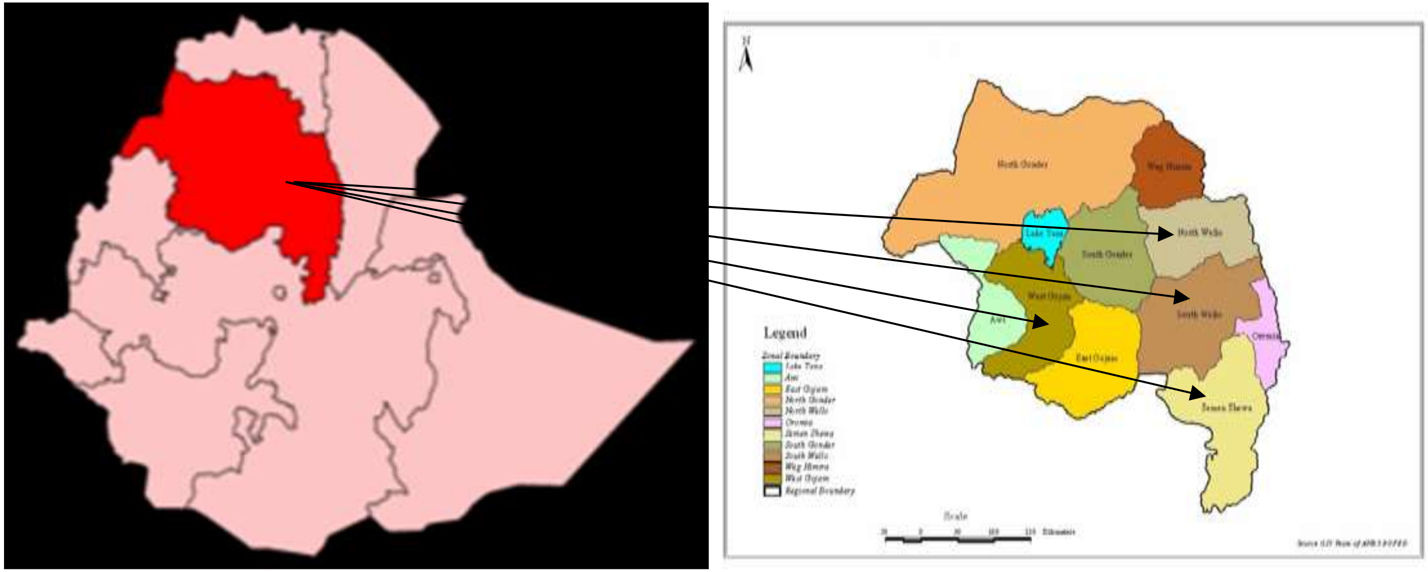

Figure 5: Anomaly from Mean of the Annual Minimum and Maximum Temperatures (^{o}C) in Gudoberet Station