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Food Security, Climate Change, and Poverty Reduction in Rural Nepal

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To my love, Zhenbin Wu

And my little boy, Gavin Wu.

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Abstract

Smallholder famers in the developing countries, especially those who mainly depend on rain-fed agriculture, are vulnerable and sensitive to climate change because such agricultural cultivators largely depend on traditional farming techniques, and are less capable of coping with climate change (Krishnamurthy et al., 2013). Like many other developing countries, agricultural production in Nepal is largely dependent on rainfall, which causes high sensitivity to climate change for household food security. This dissertation, which is composed of three main studies, examines how serious climate change affects household food security, as well as the potential strategies households could adopt to cope with food insecurity and climate change.

The first study investigates effects of temperature and rainfall trends since 1976 on individual caloric intake and household food diversity using cross-section data from Nepal Living Standard Survey 2010/2011. The analysis utilizes a Copula method to estimate the caloric intake and food diversity models simultaneously. Results show that the estimated correlation parameter between the two models is statistically significant from zero at the 1% level, confirming the validity of

using the Copula method. We also find that the rainfall and temperature risk in rural Nepal negatively affects household food security (both caloric intake per capita and food diversity). Findings also highlight the importance of community social capital, coping strategies (i.e., remittance, access to credit, and government support), infrastructure, and agricultural income.

The second study uses a Stochastic Frontier Production Model to examine the spatial effects of extreme climate events as well as the mean temperature and rainfall on rice production. We also analyze the factors affecting agricultural production efficiency using panel data from Nepal Living Standard Survey in 2003/2004 and 2010/2011. The results show that 1℃ increase in summer temperature causes a total loss of 4183 kg of rice in the sample. We also find that households located in the districts with more river and road systems are more efficient in rice production, and conclude that agricultural extension programs and education of the household head contribute to production efficiency.

Driven by the findings, the following study investigates effects of farmers' perception of climate change on their willingness to pay (WTP) for a weather index-based crop insurance. The study considers two crop insurance products: product A only insures rice and B insures both rice and livestock. We use the Biprobit method with contingent valuation data collected from a primary survey conducted in Bahunepati, Nepal. The results indicate that people who perceive the continuity of climate change or experience adverse effects of climate change are more willing to pay for the insurance products. In addition, we find that other existing mitigation strategies crowd out individuals' WTP. Finally, the annually median WTPs are 1.6% and 3% of household income for product A and B, respectively.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Food Security in Nepal

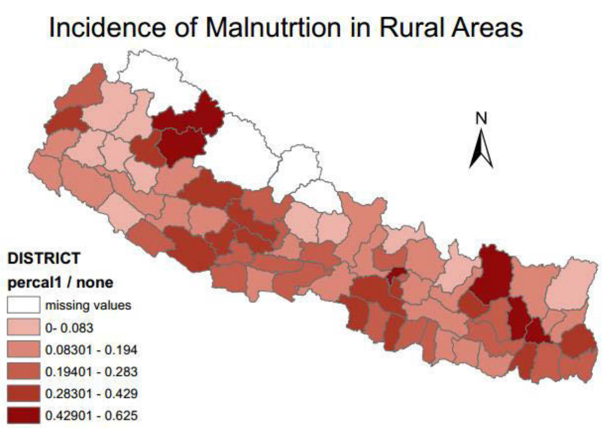
People in most developing countries still face hunger and malnutrition due to comprehensive reasons, such as economic situation, geographical location, etc. There was approximately 805 million worldwide population experiencing food-insufficiency as of 2014 (FAO, 2014). Like many other developing countries, food insecurity is a serious problem in Nepal, where households largely lives on agricultural activities. As of 2011, around 63.4% of the population earns income from agricultural activities and 34% of GDP is contributed by agriculture as of 2011 (Nepal Economic Outlook, 2013/2014). Yet the agricultural activity in the country is still in a nascent stage due to the requirement of huge labor input rather than mechanical, and the rain-fed farming systems rather than irrigated. This causes a serious food insecurity problem in Nepal. According to the reports of the Central Bureau of Statistics and the National Planning Commission (2013) in Nepal, around 38% of the population was in a food-deficiency situation as of 2011. Moreover, the level of hunger in this country is serious. The Global Hunger Index (GHI) Report reports that the GHI of Nepal is in the 58th position among 104 countries in 2015 (Global Hunger Index Report, 2015).

Figure 1.1 and 1.2 provide an overall description of the food security status in the rural areas of Nepal. Figure 1.1 describes the incidence of malnutrition of each district[1]. More specifically, it presents the percentage of the households which is energy-insufficient. The threshold of malnutrition is set as 2,200 Calories per capita per day reported by National Planning Commission. This threshold is also set based on the energy consumption of "light activity", and

[1] Data is from Nepal Living Standard Survey (NLSS) 2010/2011. The Humla, Dolpa, Mustant, and Manang districts are not covered.

the standard is uniform for both urban and rural areas (National Planning Commission, Central Bureau of Statistics, 2013). Since people in rural areas tend to consume more energy due to heavy farming activities, the threshold may result in underestimation of malnutrition in rural Nepal (National Planning Commission, Central Bureau of Statistics, 2013).

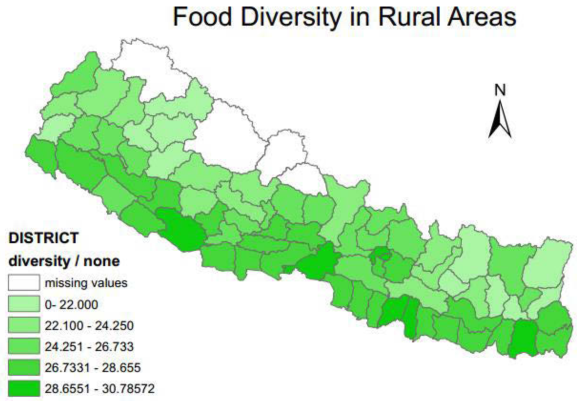
Among the three ecological zones, malnutrition is modest in the Terai Zone, where the rates in most of the districts are between 0 and 28.3%. By comparison, the range of rates in the Hill and Mountain Zones is bigger and polarized in the Mountain Zone. In Mountain, among the 12 districts covered in the sample, only two districts have all households that meet the requirement of 2,220 Calories. While in the Solukhumbu, Jumla, and Mugu districts, more than half of the household are in a status of poor nutrition.



Source: Author's calculation

Figure 1.1 Malnutrition situation in rural areas in Nepal

With regard to dietary quality, the average number of different kinds of food consumed by a household in a month ranges from 19 to 31. Figure 1.2 describes the dietary quality in each district, which improves gradually from the north to the south. All of the districts in the Terai Zone consume more than 27 food items during a month, while most of the households in the Mountain Zone consume less than 25 food items.



Source: Author's calculation

Figure 1.2 Dietary quality in rural areas in Nepal

1.2 Food Security and Climate Change

A consistently increasing temperature pattern has been observed in the past four decades in Nepal. On the other hand, the pattern of rainfall becomes more erratic and reduces agricultural growth (Krishnamurthy et al., 2013) as heavier rainfall occurs in the wet area and arid area becomes much drier due to decreasing precipitation (National Adaptation Programme of Action, 2010). The abnormal climate pattern results in extensive uncultivated agricultural land. Over the last decade, 30,845 hectares of land, which is owned by 5% of household in the country, became uncultivable due to climate hazards (Krishnamurthy et al., 2013).

There is a growing body of qualitative studies analyzing the adverse effect of climate change on food security (Schmidhuber and Tubiello, 2007; Brown and Funk, 2008; Arndt et al., 2011; Nelson et al., 2012; etc.). In these papers, the authors discuss the impact of climate change from different dimension of food security: food availability, food supplies stability, food utilization, and food access (Carletto et al., 2013). They all conclude that climate change negatively affects household food security.

Food availability and stability of food supplies refer to the direct impact of climate change on agriculture (Gregory, et al., 2005; and Wheeler and Braun, 2013). While food utilization and access to food are impacted by climate change indirectly (Schmidhuber and Tubiello, 2007). To be specific, food availability is food production that is highly related to climate conditions. Teka et al. (2010) and Brown and Funk (2008) argue that declining precipitation and increasing temperature, along with the extreme climate events, such as flood, drought, and storm, have resulted in shortfalls in agricultural and livestock production. In the context of food supplies stability, Asada and Matsumoto (2009) discuss that the highly variant rainfall and temperature affects the stability of food production. Furthermore, food access and food utilization refer to that the amount of food individuals consume.

1.3 Mitigation Strategies to Cope with Climate Change

Smallholder famers are vulnerable to climate change because they heavily depend on traditional farming techniques, and are less capable of coping with climate change. As discussed by scholars, the vulnerability of the agricultural sector to climate change will be largely dampened with adaptation strategies (Smit and Skinner, 2002; Gbetibouo, 2009). Compared to traditional adaptation strategies such as crop diversity, irrigation maintenance, etc., the emerging mechanism, weather index-based micro-crop insurance, provides more protection and higher returns for farmers when they faced adverse climate impact (for example, Janvry et al., 2014). It is a more attractive strategy. For instance, Danso-Abbeam et al., (2014) show that 57.7% of households in their sample respond positively to cocoa insurance in Ghana. In other words, the policy of weather index-based insurance may be a valid tool to help low-income farmers reduce vulnerability and get out of poverty (e.g., Quagranie, 2006; Ramasubramanian 2012; Abdullah et al., 2014; Abebe and Bogale, 2014; Janvry et al., 2014).

The study of willingness to pay (WTP) for weather index-based insurance is a popular topic in the past two decades (e.g., Deressa, et al., 2009; Phiri, 2011; Falco and Veronesi, 2013), especially in Africa and South Asia where abundant low-income households that are vulnerable to climate change are located. McCarthy (2003) studies the demand of rainfall-index crop insurance in Morocco. She argues that the crop insurance reduces the moral hazard problem as well as administrative costs. The author carries out her survey in four regions in the country, standing for different standards of rainfall variations. She focuses on the influence of rainfall variation on willingness to pay for the insurance. The results indicate that households located at the area with higher rainfall variability are more willing to pay for the crop insurance. Hill et al., (2011) find similar results as McCarthy. They use data from Ethiopian Rural Household Survey covering 1400 Households who have been tracked for 15 years to investigate the topic. They find that people facing higher rainfall risk are more likely to purchase the insurance program compared to their counterparts. They also indicate that females and risk-averse people negatively respond to the insurance program.

1.4 Contributions and Discussions

This dissertation utilizes various cutting-edge econometrical methods to investigate the impacts of climate change on household food security in Rural Nepal and farmers' willingness to pay for a weather index-based insurance product. The analyses are presented in Chapter 2, 3, and 4. In this section, we will discuss the main methods, findings, and contributions of each study.

The second chapter explores the role of climate change as a determinant of household food security. It investigates the influence of temperature and rainfall trends since 1976 on household food security using data from Nepal Living Standard Survey 2010/2011. Despite the consequent impact of climate change on food production, the current literature has not examined its effect on food security in the context of food utilization. Moreover, this research adds to the previous literature by using both caloric intake and food diversity as food security indicators, thus better capturing the dietary information. It is also novel in that it uses a flexible estimation method, Copula, to account for the correlation between the two food security indicators.

We find that as the temperature and rainfall risk index increases by 0.1, the weighted caloric intake for each individual per day will be 8.1 Calories less, and the number of different types of food consumed by a particular household during a month will be 0.114 less on average. The knowledge gained from this research can contribute to the real world economic development in crucial ways. From a pilot study we conducted in Bahunepati, Nepal, we found that 95% of households in the sample did not realize the occurrence of climate change. Therefore, they were not aware of the need to adopt any mitigation strategy. The findings point out the importance of educating households about climate change. It also provide policy makers with recommendations in designing programs that help households improve their food security levels through: a) a better understanding of effective mitigation strategies to cope with climate change; b) the construction of road networks to increase households' access to markets; and c) providing social capital formation opportunities (e.g., agriculture community user groups) for households to share farming experiences and resources.

The third chapter examines the spatial effects of climate change on rice production, and analyzes the factors contributing to production efficiency in rural Nepal. We utilize a Stochastic Frontier Production Model based on a Cobb-Douglas function with panel data from Nepal Living Standard Survey in 2003/2004 and 2010/2011. We construct four indices for climate change using data from ground weather stations in a district: variant rainfall events, temperature above 32℃, and mean temperature and rainfall. The results show that variant rainfall and summer temperature negatively affect rice production. This research is innovative in that it considers climate conditions as inputs within the Stochastic Frontier Production Model framework. It also improves on previous literature by utilizing a spatial filtering technique to address the spatial correlation caused by climate conditions between adjacent neighborhoods. The results show that in our sample, 1% increase in the number of days with extreme heavy rainfall and 1℃ increase in summer temperature leads to a reduction of 2,435 and 4,183 kg of rice production per year, respectively. We also find that households located in the districts with more river systems and road network are more efficient in rice production. Finally, we conclude that agricultural extension programs and the education level of household head contribute to agricultural production efficiency.

Driven by the results from the previous two studies, the fourth chapter analyzes individuals' WTP for a crop insurance to cope with climate change. Over the past decade, there has been a growing body of literature on crop insurance programs in developing countries. Nevertheless, the topic has not been studied in the context of Nepal. The fourth chapter is a pioneering study investigating effects of farmers' perception of climate change on their WTP for a weather index-based crop insurance in this Country. We use contingent valuation data collected from a primary survey conducted in Bahunepati, Nepal. The research adds to the previous literature by analyzing two crop insurance products: Product A only insures rice and Product B insures both rice and livestock. Estimation results using a Biprobit method indicate that the existing adaptation strategies crowd out households' tendency to engage in the insurance program. Moreover, people who perceive the continuity of climate change is 18% and 16% more likely to pay for Product A and Product B, respectively. We also find that females are less likely to pay for the insurance than males. Finally, the annually median WTPs are around 1.3% and 2.2% of household income for Product A and B. The findings will provide the basis for future studies which will investigate the crop insurance policy in Nepal. It will also provide policy recommendations to the Nepalese government about the implementation of programs related to climate change, agricultural production, and poverty reduction.

Chapter 2: Joint Regression Analysis of the Effect of Climate Change on Food Security in Rural Nepal Using A Copula Approach

2.1 Introduction

This analysis studies the effect of climate change on food security focusing on rural Nepal because food security is in a more worrisome situation in rural areas due to their less developed economy. We use the Nepal Living Standard Survey (NLSS) 2010/2011 conducted by the World Bank, including both the household survey and the community survey, to generate the dependent and most of the independent variables. The climate change index, which focuses on the temperature and rainfall risk, is from the report of the National Adaptation Programme of Action (NAPA) implemented by the Nepalese Government (2010). Our study will fill the research gap of limited existing quantitative analysis investigating the impact of climate change on food security.

We adopt caloric intake per capita per day and household food diversity during a month as proxies for food security, and utilize a Copula method[2] to estimate the models since the two indicators are potentially correlated (Hoddinott and Yohannes, 2002). The Copula method is used to obtain a flexible bivariate parametric model for the continuous-count data (Song et al., 2009). The validity of using the Copula method is confirmed by the highly significant Copula parameter, as well as the preference of both the Clayton and Frank Copulas to the Product Copula.

We also address the endogeneity issue of the remittance variable in two stages, and use a bootstrapped method to correct the biased standard errors in the second stage. Our results show

[2] In this study, the Clayton and Frank Copulas are used because the two food security indicators show a strong correlation on the left and in the middle of the distribution.

that a household is less food secure as the temperature and rainfall risk deepens. As the temperature and rainfall risk index increases by 0.1, the weighted caloric intake for each individual per day will be 8.1 Calories less, and the number of different types of food consumed by a particular household during a month will be 0.114 less on average. We also find that households located in the Hill and the Mountain zones have poorer dietary quality than their counterparts in the Terai Zone, while the households living in the Hill consume more food quantity than the Terai households due to climatic conditions and nature of menial work. Effects of the social capital indices are found to be mixed. Specifically, engagement in the farmer user group contributes to household food security, while the forest user group has the reverse effect. Moreover, community infrastructure, government support, remittance and access to credit on food security are found to positively contribute to household food security.

2.2 Literature Review

The quantitative studies in the food security and climate change field focus on analyzing the effects of climate change on food production. Some scholars study the retrospective effect using historical data, and others investigate prospective effect of climate change using simulated data. In the first stream of studies, indicators of climate change are mixed. Some scholars use total or mean of rainfall, and max/min or mean of temperature. Others use extreme rainfall/temperature. A recent study in the first stream is from Auffhmmer et al. (2011), they estimate the sensitivity of rice yield to the total and extreme rainfall during the monsoon season, June to September, from 1996 to 2002 in India. The study defines the highest 95th percentile rainfall as the threshold of extremely heavy rainfall. Their results show that the total monsoon rainfall positively affects rice yield, while the extreme rainfall has the reverse effect. Asada and Matsumoto (2009) also study the effect of rainfall on rice production in India. The studied period is from 1961 to 2000.

Their findings show that total monsoon rainfall adversely affects rice production in already humid area, while it contributes to the food production in typically dry areas. Besides the impact of rainfall, some papers focus on the relationship between temperature and food production. For example, Welch et al. (2010) studies the effect of the daily maximum and minimum temperature on the rice production of 227 rice farms in six Asian countries over the period between 1994 and 1999. They find mixed effect of temperature, with higher maximum temperature raising food production but higher minimum temperature reducing it.

The second stream in the literature assesses the prospective impact of climate change using simulated data (Rowhani et al., 2011; Alcamo et al., 2007; Isik and Devadoss, 2006; and Syaukat, 2011). Rowhani et al. (2011) analyze how maize, sorghum, and rice are affected by climate variability in Tanzania. They find that by 2050, the average maize, sorghum, and rice yields will decrease by 13%, 8.8%, and 7.6%, respectively with a temperature increase of 2 °C. In addition, these three crops production will decrease by 4.2%, 7.2%, and 7.6%, respectively, corresponding with a 20% increase in the intra-seasonal precipitation variability. Syaukat (2011) studies the food balance in two scenarios: with and without climate change by 2050. He predicts that the combination of decreasing rainfall and increasing temperature will lead to a 90 million tons reduction in the husked rice production by 2050. So far, there have been numerous studies that analyze the effect of climate change on food availability. Nevertheless, the research about climate change and food utilization is very limited. This study will contribute to the existing literature by filling this research gap.

2.3 Theoretical Model

The theoretical framework developed in this chapter follows the work of Feleke et al. (2005) and Singh et al. (1986) in the household production theory. Within the framework, both the consumption and production behavior of the household are considered.

A household utility function is specified as:

$$U = U(G_h, G_m, A) \qquad (2.1)$$

where U is the utility level of the household; G_h and G_m are home-produced goods and market-purchased goods consumed by the household, respectively; A is a vector of the community and household characteristics that contribute to the household utility, such as castes, the community infrastructure, etc.

The utility function (2.1) is maximized subject to the household production constraint, Y, the income constraint, I, and the time constraint, T.

$$Y = Y\left(Q_h(EZ, GB, LA), L_{h,m}, K, CR\right) \qquad (2.2)$$

where Y is an implicit household production function. Q_h is the agricultural goods, which is affected by the ecological zone, EZ, and a vector of inputs used by households such as usage of equipment (E), and the agricultural land size (LA), produced on the farm. L is the amount of labor used by households for agriculture, including the household labor (L_h), and labor hired from the labor market (L_m). Unlike Feleke et al. (2005)'s paper, in which K is a fixed stock of capital, the capital indicator utilized in this chapter is a vector of capital which is beneficial to enhancing the production, such as the community social capital (K_{sc}) and manmade capital (i.e. education, K_m). Finally, CR is climate risk.

The income constraint is specified as:

$I = p_h(Q_h - G_h) - p_m G_m + \omega(L_h - L_m) + Remit + GS + Credit$ (2.3)

Income I is decomposed into agricultural income, labor income ($\omega(L_h - L_m)$), and other off-farm income generating activities. Moreover, agricultural income is composed of the income from the market surplus, $p_h(Q_h - G_h)$, and the expenditure on the market-purchase goods, $p_m G_m$. The off-farm income generating activities include remittance received ($Remit$), government support (GS), and the credit they access to ($Credit$).

The time constraint is characterized as:

$T = L_h + L_l$ (2.4)

where L_h is the time spent on working, and L_l is the time spent on leisure.

To conclude, household's utility maximization problem is of the following form:

Max $U = U(G_h, G_m, A)$

Subject to $Y = Y\big(Q_h(E, GB, LA), L_{h,m}, K, CR\big)$

$$I = p_h(Q_h - G_h) - p_m G_m + \omega(L_h - L_m) + R + GS + Credit$$

and $T = L_h + L$

By setting up the Lagrangian function and solving the first order conditions, we obtain the demand function of the household home-produced goods and market-purchase goods.

$G_{h,m} = G(CR, EZ, LA, K, Remit, GS, Credit, E, A)$ (2.5)

2.4 Empirical Methods

We develop the empirical model based on the theoretical model, the equation (2.5). We analyze how the consumption of food (food security (FS)) is affected by the climate change (CR) and a vector of other factors:

$$\mathrm{FS}_i = \beta_0 + \beta_1 CR_i + \beta_2 EZ_i + \beta_3 SC_i + \beta_4 INFRAS_i + \beta_5 COPYSTRA_i + \beta_6 AI_i + \beta_7 E_i + \beta_8 A_i + \varepsilon_i$$

(2.6)

where CR is the indicator of climate change, EZ is geographic belt, SC is social capital, $INFRAS$ is infrastructure, $COPYSTRA$ is copying strategies, AI the agricultural income, E is agricultural equipment, and A is a vector of household characteristics. ε in Equation (2.6) is the stochastic error term, which captures the random part unexplained by the variables presented in Equation (2.6).

With respect to food security, four common indicators have been created by scholars: frequency of a specific food consumed by household over a specific period WFP (2006), caloric intake per capita per day (Hoddinott, 1999; and Deaton and Dreze, 2009), food diversity (Hoddinott and Yohannes, 2002; and Zezza and Tasciotti, 2010), and number of types of coping strategies (Radimer et al., 1990; and Maxwell,1996).

The usage of each indicator has its own advocates and opponents. None of them fully reflects the situation of the household food security level. While caloric intake is the most common indicator adopted by scholars since it reflects the quantity of food consumed (Krishnamurthy et al., 2013), enough caloric intake does not necessarily represent a healthy lifestyle because the energy may be from a single source. Conversely, both the frequency of consumption of a certain food and food diversity measure the dietary quality, recovering the shortcoming of the caloric intake measurement. But they do not capture the amount of food consumed. Finally, coping strategies fail to explicitly reveal the nutrition status of individuals. As an improvement on the previous studies, this analysis uses both caloric intake and food diversity as food security indices to comprehensively reflect the household food security level.

2.5 Copula Method

2.5.1 Definition and Properties

The traditional method of studying food security ignores the correlation between these two indicators. However, as Hoddinott (2002) points out, caloric intake is correlated with food diversity, which is especially high for rich people. Hoddinott and Yohannes (2002) also find that as the household food diversity per capita increases by 1%, the caloric intake per capita increases by 0.7% on average. Thus, in additional to contributing to the literature by using both caloric intake and food diversity as food security indicators, the model developed in this chapter also contributes in the methodology by adopting a joint estimation system for the count and continuous outcomes. Traditional methodologies of joint estimation include the full-information maximum likelihood (Lee's, 1983) and the two-step methods. However, in our model, the right-hand-side variables are highly correlated in the two models. This means that the traditional methods will lead to unreliable results. Thus, this chapter uses a much more flexible econometric estimation method, Copula, to jointly estimate the count-continuous system. A Copula is a parametric distribution function that binds given marginal distributions of each random variable together (Trivedi and Zimmer, 2005). The Copula approach is attractive in econometrics because the joint distribution of the random variables may be unknown. However, if the marginal distributions are known with certainty, then the Copulas allow researchers to derive the joint density and estimate their dependence (Song, 2009).

To introduce the Cumulative Density Function (CDF) of a Copula, we will begin with n dependent uniform random variables $U_1, \dots \dots, U_n$ whose values are in [0,1].

$$C_\theta[u_1, \dots \dots, u_n] = \Pr(U_1 \leq u_1, \dots \dots, U_n \leq u_n) \quad (2.7)$$

where θ is the parameter measuring the degree of dependence between the random variables, and u_i is a particular observation of U_i.

To find out the relationship between a Copula and the joint distribution of the random variables, let $F(y_1, y_2, \dots \dots, y_n)$ denote a continuous n-variate distribution function of the random variables $(Y_1, \dots \dots, Y_n)$ with N univariate marginal distributions $F_1(y_1), \dots\dots, F_n(y_n)$. By setting $F_1(y_1) = u_1$, $F_2(y_2) = u_2, \dots\dots, F_n(y_n) = u_n$, we are able to derive the following formulas: $y_1 = {F_1}^{-1}(u_1), \dots\dots, y_n = {F_n}^{-1}(u_n)$. Finally, the joint distribution function F could be expressed as:

$$F(y_1, \dots \dots, y_n) = \Pr(Y_i \leq y_i; i = 1, \dots, n) = F\left({F_1}^{-1}(u_1), \dots \dots, {F_n}^{-1}(u_n)\right) = Pr(U_1 \leq u_1, \dots \dots, U_n \leq u_n) = C_\theta(u_1, \dots \dots, u_n) \quad (2.8)$$

The above Copula has three properties: it's domain is in $[0,1]^n$; its probability is equal to zero if all outcomes are equal to zero; and it is n-increasing (Sklar, 1973).

2.5.2 Joint Density

If all margins are continuous, the joint density is obtained by taking the derivative of the Copula function with respect to all variables. Denote the Copula density as $c(F_1, \dots \dots, F_n, \theta)$. By the chain rule, we get the joint density function as follows:

$$c(F_1, \dots \dots, F_n, \theta) = \frac{\partial C(F_1, \dots\dots, F_n, \theta)}{\partial y_1 \dots\dots \partial y_n} = \frac{\partial C(F_1, \dots\dots, F_n, \theta)}{\partial F_1 \dots\dots \partial F_n} * \frac{\partial F_1}{\partial y_1} * \dots \dots * \frac{\partial F_n}{\partial y_n} = C_{1\dots\dots n}(F_1, \dots \dots, F_n, \theta) * f_1 * \dots \dots * f_n \quad (2.9)$$

If all margins are discrete variables, the Copula density is obtained by taking the difference with respect to all the variables.

$$c(F_1, \dots\dots, F_n, \theta) = P(Y_1 = y_1, \dots\dots, Y_n = y_n) = \sum_{i_1}^{2} \dots\dots \sum_{i_n}^{2} (-1)^{i_1 + \dots\dots + i_n} C_\theta(\gamma_{1,i_1}, \dots\dots, \gamma_{n,i_n})$$

(2.10)

where $\gamma_{j,1} = F_i(y_i)$, and $\gamma_{j,2} = F_i(y_i - 1)$.

Based on the Copulas, the joint density function, noted as $c_i(y_1, y_2, \theta)$, is derived.

The likelihood can be derived by the joint density function as:

$$L(\theta; X, Y) = \prod_{i=1}^{n} c_i(y_1, y_2, \theta) \qquad (2.11)$$

The log likelihood function is of the form:

$$l(\theta; X, Y) = \sum lnc_i(y_1, y_2, \theta) \qquad (2.12)$$

2.5.3 Joint density function of bivariate Copulas

In this analysis, we adopt the bivariate Copula. Following Song (2009) and Kramer et al., (2010)'s method, the joint density of the bivariate Copula can be derived as:

$$c(y_1, y_2; \theta) = f(y_1) * [C_{y_1}(F(y_1), F(y_2), \theta) - C_{y_1}(F(y_1), F(y_2 - 1), \theta)] \qquad (2.13)$$

where $f(y_1)$, $F(y_1)$, and $F(y_2)$ denote the probability density function (PDF) of y_1, marginal distributions of y_1 and y_2. In addition, y_1 denotes caloric intake per capita per day (continuous) and y_2 denotes food diversity (discrete). $C_{y_1}(\cdot)$ is the derivative of the Copula with respect to y_1 (i.e., $C_{y_1}(\cdot) = \frac{\partial C}{\partial F(y_1)} * \frac{\partial F(y_1)}{\partial y_1}$).

The specific functional form of $f(y_1)$, $F(y_1)$ and $F(y_2)$ are as:

$$f(y_1) = \frac{1}{\varphi^k}\frac{1}{\Gamma_{(k)}}{y_1}^{k-1}e^{-\frac{y_1}{\varphi}} \text{ for } y_1 > 0 \text{ and } k, \varphi > 0 \qquad (2.14)$$

$$F(y_1) = \frac{\gamma\left(k,\frac{y_1}{\varphi}\right)}{\Gamma_{(k)}} = u_1 \qquad (2.15)$$

Based on the assumption of the distributions of the variables, in equations (2.14) and (2.15), $k = \frac{1}{\mu}$, and $\varphi = \frac{1}{\mu\delta}$, where μ is the mean, and δ is the dispersion parameter.

$$F(y_2) = \sum_0^n P(Y = y_{2i}) = \sum_0^n \frac{\lambda^{y_{2i}}e^{-\lambda}}{y_{2i}!} = u_2 \qquad (2.16)$$

There are five common Copulas studied by scholars: Product, Frank, Clayton, Gaussian, and Gumbel Copulas. We focus on the former three Copulas in the econometric estimation, and introduce the derivation of the density function of these three Copulas in this section. The other two common Copulas are introduced in Appendix A.

2.5.3.1 Product Copula

Product Copula is the simplest Copula. It has the following form:

$$C(u_1, u_2) = u_1u_2 \qquad (2.17)$$

The Product Copula assumes independence between the random variables. Estimating the Product Copula is identical to estimating all models separately. Specifically, the Copula function for our model is:

$$C(u_1, u_2) = u_1u_2 = F(y_1)F(y_2) = \frac{\gamma\left(k,\frac{y_1}{\varphi}\right)}{\Gamma_{(k)}} * \sum_0^n \frac{\mu^{y_{2i}}e^{-\mu}}{y_{2i}!} \qquad (2.18)$$

The joint density is:

$$c(y_1, y_2) = f(y_1) * [F(y_2) - F(y_2 - 1)] = \frac{1}{\theta^k}\frac{1}{\Gamma_{(k)}}{y_1}^{k-1}e^{-\frac{y_1}{\varphi}} * \left[\sum_0^n \frac{\mu^{y_{2i}}e^{-\mu}}{y_{2i}!} - \sum_0^n \frac{\mu^{(y_{2i}-1)}e^{-\mu}}{(y_{2i}-1)!}\right]$$

(2.19)

2.5.3.2 Clayton Copula

The Clayton Copula function is of the following form:

$$C(u_1, u_2;\ \theta) = (u_1^{-\theta} + u_2^{-\theta} - 1)^{-\frac{1}{\theta}} = ((F(y_1))^{-\theta} + (F(y_2))^{-\theta} - 1)^{-\frac{1}{\theta}} \qquad (2.20)$$

The dependence parameter is restricted to $(0, \infty)$. The Clayton Copula only allows for positive dependence. Moreover, it exhibits a stronger left tail dependence, that is, the outcomes are more correlated at lower values (Trivedi and Zimmer, 2005).

To derive the joint density function, we first take derivative to $C(u_1, u_2;\ \theta)$ with respect to y_1.

$$\frac{\partial C}{\partial y_1} = -\frac{1}{\theta}\left((F(y_1))^{-\theta} + (F(y_2))^{-\theta} - 1\right)^{-\frac{1}{\theta}-1} (-\theta)(F(y_1))^{-\theta-1} f(y_1) =$$

$$f(y_1)(F(y_1))^{-\theta-1}\left((F(y_1))^{-\theta} + (F(y_2))^{-\theta} - 1\right)^{-\frac{1}{\theta}-1} \qquad (2.21)$$

Thus, the joint density is:

$$c(y_1, y;\ \theta) = f(y_1)(F(y_1))^{-\theta-1}\left((F(y_1))^{-\theta} + (F(y_2))^{-\theta} - 1\right)^{-\frac{1}{\theta}-1} -$$

$$f(y_1)(F(y_1))^{-\theta-1}\left((F(y_1))^{-\theta} + (F(y_2 - 1))^{-\theta} - 1\right)^{-\frac{1}{\theta}-1} \qquad (2.22)$$

2.5.3.3 Frank Copula

The Frank Copula function is:

$$C(u_1, u_2;\ \theta) = -\theta^{-1}\log\{1 + \frac{(e^{-\theta u_1}-1)(e^{-\theta u_2}-1)}{(e^{-\theta}-1)}\} = -\theta^{-1}\log\left\{1 + \frac{(e^{-\theta F(y_1)}-1)(e^{-\theta F(y_2)}-1)}{e^{-\theta}-1}\right\}$$

(2.23)

Unlike the Clayton Copula which requires a positive correlation between the random variables, the dependence parameter of the Frank Copula can take any real value $(-\infty, \infty)$, which indicates that it permits both positive and negative dependence. Moreover, the dependence is symmetric in both tails between the margins, and stronger in the center of the distribution (Meester and MacKay. 1994).

By taking derivative to $C(u_1, u_2;\ \theta)$ with respect to y_1, we get:

$$\frac{\partial C}{\partial y_1} = -\theta^{-1}\frac{1}{1+\frac{(e^{-\theta F(y_1)}-1)(e^{-\theta F(y_2)}-1)}{e^{-\theta}-1}} * \frac{\left(-\theta f(y_1)e^{-\theta F(y_1)}\right)\left(e^{-\theta F(y_2)}-1\right)}{e^{-\theta}-1}$$

$$= -\frac{1}{\theta} * \frac{\left(-\theta f(y_1)e^{-\theta F(y_1)}\right)\left(e^{-\theta F(y_2)}-1\right)}{e^{-\theta}+e^{-\theta\left(F(y_1)+F(y_2)\right)}-e^{-\theta F(y_1)}-e^{-\theta F(y_2)}}$$

(2.24)

Therefore, the joint density is:

$$c(y_1, y_2; \theta) = -\frac{1}{\theta} * [\frac{\left(-\theta f(y_1)e^{-\theta F(y_1)}\right)\left(e^{-\theta F(y_2)}-1\right)}{e^{-\theta}+e^{-\theta\left(F(y_1)+F(y_2)\right)}-e^{-\theta F(y_1)}-e^{-\theta F(y_2)}} - \frac{\left(-\theta f(y_1)e^{-\theta F(y_1)}\right)\left(e^{-\theta F(y_2-1)}-1\right)}{e^{-\theta}+e^{-\theta\left(F(y_1)+F(y_2-1)\right)}-e^{-\theta F(y_1)}-e^{-\theta F(y_2-1)}}]$$

$$= \frac{\left(f(y_1)e^{-\theta F(y_1)}\right)\left(e^{-\theta F(y_2)}-1\right)}{e^{-\theta}+e^{-\theta\left(F(y_1)+F(y_2)\right)}-e^{-\theta F(y_1)}-e^{-\theta F(y_2)}} - \frac{\left(f(y_1)e^{-\theta F(y_1)}\right)\left(e^{-\theta F(y-1)}-1\right)}{e^{-\theta}+e^{-\theta\left(F(y_1)+F(y_2-1)\right)}-e^{-\theta F(y_1)}-e^{-\theta F(y_2-1)}}$$

(2.25)

2.6 Data and Hypothesis

2.6.1 Data Source

The main data source used in this chapter is the cross-section sample of the 2010/2011 Nepal Living Standard Survey (NLSS) conducted by the World Bank, including the household and community surveys. The NLSS covered households across three climate zones of Nepal from the south to the north, and also five topographical development regions from the west to the east (Devkota and Upadhyay, 2010). Seventy-one out of 75 districts were surveyed in the 2010/2011 wave. The NLSS was implemented in two stages. In the first stage, 500 primary sampling units

(PSU) were drawn out of the 800 PSUs[3] selected by the Central Bureau of Statistics. In the second stage, 12 households were randomly selected within each PSU, resulting in a total sample size of 5988 households (the World Bank, 2010). Additionally, the climate change data (temperature and rainfall risk index) is obtained from the National Adaptation Program of Action (NAPA) in Nepal in 2009.

We focus on rural areas in this paper mainly driven by three reasons. First, the food security problem is much more worrisome in rural Nepal. Second, key determinants of food security, such as social capital, are only available in rural areas. Third, caloric intake is measured using the quantity of a specific food consumed reported by the household. Therefore, it is hard to create an accurate index for caloric intake in the urban area where households tend to eat out more often. After dropping the observations in the urban area, a sample size of 3900 households is left. In order to avoid estimation bias resulting from outliers, the analysis further drops the observations that include a daily caloric intake per capita below 600[4] and replaces the calories above 10,000 with the mean value.[5] After excluding the missing values, a sample size of 2971 households is included in the estimation.

2.6.2 Food Security Indicators

We follow World Food Program (WFP) to assign greater weights to more nutrient food when we construct the caloric intake indictor. For example, we assign the highest weight to meat, egg, and milk, and lowest weight to sugar. Overall, the household caloric intake for a particular household ($HHCAL$) is calculated using equation (2.26). Afterwards, the caloric intake per capita is obtained by dividing the $HHCAL$ by household size.

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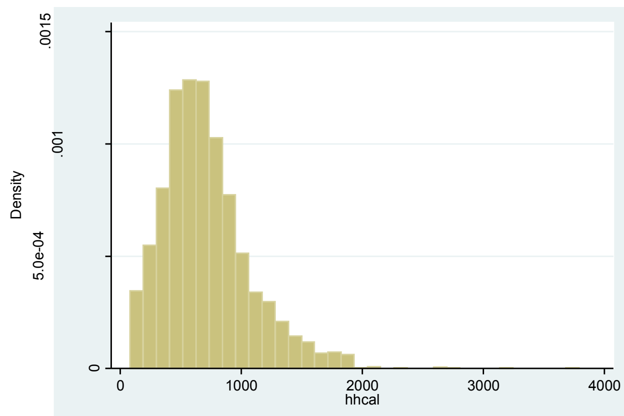
3 The PSUs were originally delimited for the National Labor Force Survey in 2007/2008 (the World Bank, 2011).
4 The caloric intake we consider here is the original calories before weighting.
5 The observations are replaced with the mean value because the quantity consumed is unreasonably high. The reason why we don't replace the caloric intake below 600 Calories with the mean value is that these households are less likely to get enough food. The data for the outliers are available upon request.

$HHCAL = staple * 0.2 + pulses * 0.3 + meat/fish/eggs/milk * 0.4 + fruit * 0.1 + vegetables * 0.1 + oil * 0.05 + sugar * 0.05$ (2.26)

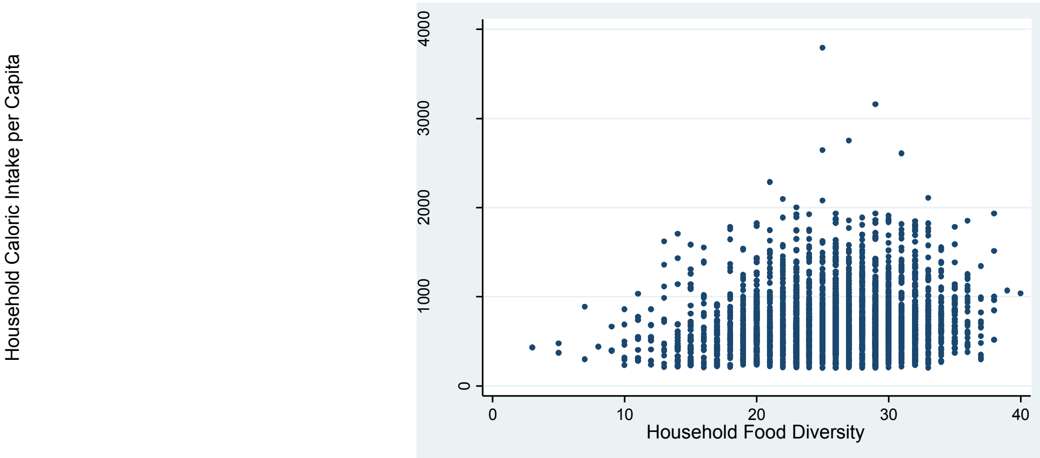
The variable of caloric intake per capita per day is assumed to be distributed to Gama distribution with shape k and scale φ ($y_1 \sim \Gamma(k, \varphi)$). Food diversity is assumed to be distributed to the Poisson distribution ($y_2 \sim P(\lambda)$, where λ is the mean) because the mean (26.158) of this variable is closely approximating its variance (26.266). Figure 2.1 presents the distribution of the caloric variable, in which a right-tailed distribution could be obviously observed.



Source: Author's Calculation

Figure 2.1 Distribution of caloric intake per capita per day

Figure 2.2 displays the relationship between the weighted daily caloric intake per capita and food diversity, which shows a positive correlation between the two indicators. The correlation seems to be stronger on the left tail and in the middle of the distribution, which provides the grounds of using Clayton and Frank Copulas.



Source: Author's calculation

Figure 2.2 Correlation between Individual Caloric Intake and Household Food Security

2.6.3 Hypothesis

2.6.3.1 Climate change

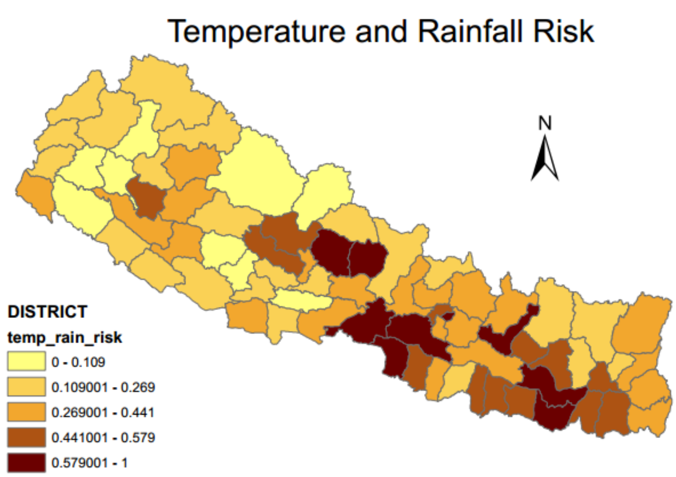
The climate change index used in the analysis focuses on the temperature and rainfall risk. It is obtained from the report of the National Adaptation Programme of Action (NAPA) implemented by the Nepalese Government (2010). The index is created in three steps: in the first step, the trends of average rainfall and average temperature at the district level are obtained from the analysis of monthly precipitation data and temperature records between 1976 and 2005 conducted by Practical Action. Second, an overall trend index for each district is created by assigning equal weight to the trends obtained in the first step. The third step creates the final index using the following formula:

$$Z_i = \frac{X_i - X_i^{min}}{X_i^{max} - X_i^{min}}$$

where Z_i is the standardized temperature rainfall risk index; X_i is the trend index obtained from the second step; X_i^{min} is the minimum value of the trend over 75 districts; and X_i^{max} is the maximum value of the trend over 75 districts. Therefore, the final temperature rainfall index is between 0 and 1 at the district level. The NAPA defines values between 0.580 and 1 as the very high risk, values between 0.442 and 0.579 as high risk, values between 0.270 and 0.441 as moderate risk, values between 0.110 and 0.269 as low risk, and values between 0.000 and 0.109 as very low risk. Figure 2.3, which maps each district according to the temperature and rainfall risk, shows that the climate change is most severe in the eastern and central regions of the Terai Area, while it is lightest in the western region.

In the rural areas of Nepal, most food is home-produced. Erratic patterns of temperature and rainfall, as well as increases in pest disease adversely affect food production, thus threatening household food security (Chakraborty and Newton, 2011). In addition, food prices increase due to reduction in the crop yield, which further aggravates the food security level of households (Schmidhuber and Tubiello, 2007). In conclusion, I expect that climate change negatively affects household food security levels.

Hypothesis 1: $\beta_{CR}^{caloric\ intake} < 0$ & $\beta_{CR}^{food\ diversity} < 0$



Source: Author's calculation

Figure 2.3 Temperature and rainfall risk in each district in Nepal

2.6.3.2 Ecological Zones

There are three main ecological zones in Nepal: Terai, Hill and Mountain. The weather as well as soil fertility in the Terai Zone is more appropriate for the growth of fine crops, such as paddy and various vegetables. Therefore, the Terai Zone yields the highest food and livestock production although it covers the smallest area of the whole nation (21%) (Ministry of Finance, 2013). The Hill Zone is in the middle of Nepal, and contains the most agricultural land (Devkota and Upadhyay, 2013). However, the soil quality in the Hill and the Mountain Zones is more arid than that of the Terai area, and is only suitable for certain types of crops, resulting in less crop diversity (Thapa and Joshi, 2011). To be concluded, we expect that the food security level in the Terai Zone is higher than the other two.

Hypothesis 2:

$$\beta_i^{caloric\ intake} < 0 \qquad i = \{hill, mountain\}$$

$$\beta_i^{food\ diversity} < 0 \qquad i = \{hill, mountain\}$$

2.6.3.3 Social Capital

We measure the social capital by the extent of the community groups at the district level. The NLSS community survey provides detailed information about 5 community user groups, including agriculture, forest conservation, water management, credit, and women issue groups. The information provided include the length of existence of the groups, the number of meetings held during a year, the number of households in the group, and the percentage of women members in the group. Following Nepal et al. (2007), we use these four pieces of information to create the social capital indices (SCI) for each district using the following equation:

$$SCI_{id} = \sum_{n=1}^{4} \frac{X_{nv} - \min(X_n)}{\max(X_n) - \min(X_n)}$$

where i indicates a specific group, d denotes districts, and n indicates a particular piece of information of the group.

Engagement in the community user group affects household food security level in two ways. First, during the socialization through the user groups, assets and resources will be transferred from the well-being households to the poor ones (Dzanja et al., 2013). Therefore, households' bridge bonding with the society, their friends, among others, is stronger, which enhances households' survival strategies (Gallaher and Kerr, 2013; Putnam, 2000). Second, households' specialization ability is improved through communication with other members in the same group (Misselhorn, 2004; Archambault and Bohara, 2012).

In this analysis, we measure the social capital by the contribution of the agriculture user group (*FARM*) and the forest user group (*FOREST*). For the former social capital index, the two effects tend to strengthen each other. Households will gain farming experience from their peers as well as from the community government, thus enhancing agricultural productivity. For the latter social capital index the two effects operate in the opposite direction. Specifically, engagement in the forest group will foster households to focus on the activities of conversing deforestation, which will demotivate agriculture-related exercise. The question is what effect dominates. Hence, the effect of the forest user group is ambiguous.

The third alternative hypotheses are:

Hypothesis 3: $\beta_{FARM}^{caloric\ intake} > 0$ & $\beta_{FARM}^{food\ diversity} > 0$

$$\beta_{FOREST}^{caloric\ intake} ?\ 0 \qquad \& \qquad \beta_{FOREST}^{food\ diversity} ?\ 0$$

2.6.3.4 Infrastructure

On one hand, while purchasing food on the market is a strategy to mitigate the dilemma of food-insufficiency[6] (Baiphethi and Jacobs, 2009), it is determined by the accessibility and travel cost (Ingram, 2011). On the other hand, access to inputs of agricultural production from outside, such as imports of fertilizer and seeds (Khan et al., 2009) is also affected by road infrastructure. Therefore, we hypothesize that household food security is negatively affected by poor infrastructure and limited transportation. The further the household is away from the paved road (*DROAD*), the lower food security the household has. The third alternative hypothesis is:

Hypothesis 4: $\beta_{DROAD}^{caloric\ intake} < 0\ \&\ \beta_{DROAD}^{food\ diversity} < 0$

2.6.3.5 Coping Strategies

Households facing low food security level may be able to solve their subsistence problem by adopting various ex-ante and post-ante coping strategies (Hoddinott, 2002; Sharma, 2012; Crush, 2013). In this paper, we focus on income diversification via various non-farming activities, including household's ability to access to financial credit (*CREDIT*), the amount of remittance received by households (*REMIT*), and access to government support (i.e, child nutrition program, *NUTRICHI*). The coping strategies not only improve the livelihood of the households, but also have positive spill-over effect on the neighbors. For example, the remittance household received is usually spent on the local production in Nepal, which will also increase the non-migrants' income (Ratha, 2003). We hypothesize that households that access to these strategies have higher food security level:

[6] Self-insufficiency here means that the home-produced goods do not satisfy the household consumption demand.

Hypothesis 5: $\beta_{CS_i}^{caloric\ intake} > 0$

$$\& \quad \beta_{CS_i}^{food\ diversity} > 0, \text{ where } i = \{CREDIT, REMIT, CHNUT\}$$

2.6.3.6 Agricultural Income

Agricultural income, a major sector of employment as well as a large component of income in rural Nepal, plays an important role in addressing the household food insecurity problem (Zezza and Tasciotti, 2010). In this analysis, we use the agricultural land size (*LAND*) as the proxy of agriculture income. The reasons are: first, it is difficult to directly measure agriculture income due to the absence of price information, as well as a multitude of agricultural inputs and outputs. Second, agriculture income is directly influenced by agricultural production, which is in turn affected by the size of cultivated land. Overall, we expect that the household food security level is higher as the agricultural land size is larger.

Hypothesis 6:

$$\beta_{LAND}^{caloric\ intake} > 0$$

$$\& \quad \beta_{LAND}^{food\ diversity} > 0$$

2.7 Model Diagnostics and Results

2.7.1 Model Diagnostics

Since the caloric intake and the food diversity exhibit the strongest dependence on the left tail of the distribution, we first carry out our empirical estimation using the Clayton Copula. The results are presented in six different models in Table 2.1. In each model, caloric intake per capita per day and food diversity function as dependent variables. The climate change index and ecological zones are included in Model 1. Model 2 adds the variable of infrastructure. Model 3 includes the social capital indicators as independent variables. The coping strategy proxies are analyzed in Model 4. Model 5 further accounts for agricultural income, and Model 6 controls for all explanatory variables of interest. All estimations use robust standard errors to address the heteroskadastic problem. As shown by the table, the signs and the significance levels of most of the variables are consistent across all models.

The AIC values, measuring the goodness of fit, gradually decrease from Model 1 to Model 6, indicating that Model 6 is of the best goodness of fit. In addition, the correlation between caloric intake and food diversity is confirmed by the highly significant Copula parameters.

2.7.2 Endogeneity

So far, we have treated all explanatory variables as exogenous factors. However, the food security proxies may exhibit reverse relationships with some explanatory variables. The first variable of concern is *REMIT*. The households who receive remittance are more likely to consume more food. Reversely, food shortages may drive household members to work outside (Crush, 2013). Therefore, the *REMIT* variable is potentially endogenous in the models. In this analysis, we use two instruments to conduct the Hausman test: the dummy variable, if there is any migrant in the household, and the amount of remittance received by other households in the same VDC. [7] The Hausman test result confirms that the endogeneity problem is existing. A similar argument can be applied to another variable in the model, *NUTRICHI,* because those who are eligible for receiving government support may with low food security level. We use two variables as instruments: population density in the VDC, and the amount of firewood collected

[7] We test the endogeneity problem and the validity of the instruments in the caloric intake model using "ivreg". The endogeneity of the remittance variable is confirmed by the p-value of 0.000. The strength and validity of the two instruments are confirmed by the F-statistics of 768.377 in the first-stage and the over-identification test with a p-value of 0.872.

by the household within a month.[8] Result shows that *NUTRICHI* does not have endogeneity issue.

We address the endogeneity problem of *REMIT* in two stages. In the first stage, we regress *REMIT* on all independent variables and the instruments. The predicted value of remittance (*REMITHAT*) is obtained in this stage. Afterwards, *REMITHAT* is used as the explanatory variable in the second stage of Copula estimation. Afterwards, we utilize the bootstrapped method to correct for the biased standard errors (Petrin and Train, 2009) [9] in the second stage. As shown by Karaca-Mandic and Train (2003), the standard errors obtained by using the bootstrapped method and the standard formulas of two-step estimators are very similar.

Table 2.3 reports the estimation results with bootstrapped robust standard errors. Models 1, 2, and 3 in Table 2.3 correspond with Model 4, 5, and 6 in Table 2.2, respectively, with regard to addressing the endogeneity problem of *REMIT*.

2.7.3 Results and Discussion

We also estimate Equation (2.6), which controls all variables of interest and addresses the endogeneity problem of *REMIT,* using the Product and Frank Copulas. The standard errors are corrected using the bootstrapped method. The Copula parameters are also positive and significantly different from zero at the 1% significance level with the Frank Copula. The signs and the significance level of all the variables are consistent across the three Copulas, with the Clayton Copula reporting the best goodness of fit, and the Product Copula reporting the worst goodness of fit. One of the possible explanations is that the correlation between caloric intake

[8] We use the same way to test the endogeneity and the validity of the instrument for *NUTRICHI* as *REMIT*. We fail to reject the null hypotheses that the NUTRICHI is exogenous with a p-value equaling to 0.215. And the strength and validity of the instruments are confirmed by the over-identification test with a p-value of 0.851.
[9] In this chapter, we use 500 resampling in bootstrap.

and food diversity is strongest when their values are low, which fits the property of the Clayton Copula. The AIC values and the significance levels of the Copula parameters provide the evidence of the validity of using the Copula approach to estimate our model. All hypotheses and results using the Clayton Copula estimation method are presented in Table 2.5.

Among the three models, the Frank Copula reports a relatively bigger coefficient for the climate change variable. Other slight differences are that the effects of *FARM* and *LAND* are strongest in the Clayton Copula estimation. In addition, we present the marginal effects of the significant determinants for the Clayton and Frank Copulas. Since Model 3 in Table 2.3 reports the best goodness of fit, the discussion will focus on this model in the following section.

The estimation results report that the coefficients of the climate change indicator are significantly different from zero at the 5% level in all the caloric models. They also show that climate change significantly affects food diversity in most of the models. The negative signs indicate that climate change is a negative determinant of both dietary quantity and quality. The marginal effects of climate change reported in Table 2.6 show that as the climate change indicator increases by 0.1, the weighted caloric intake for each individual will be 8.1 Calories less per day, while the number of food consumed by a particular household during a month will be 0.114 less on average. While the marginal effect of the climate indicator is subtle, it makes sense if we consider that the caloric intake is weighted and only equals to one third of original caloric amount at the most. In the past three decades, the increasing temperature as well as the uncertain trend of rainfall has been gradually obvious. The moderate rising temperature not only affects crops, but also increases the probability of glacier melting in the country. On the other hand, the monsoon rainfall, which is crucial to the fall cultivation, is anomalous (either extremely heavy or extremely light). While higher precipitation would result in higher agricultural production, it is noted that the excessive rainfall will adversely affect it. The precipitation from November to April has been declining, leading to losses of winter and spring agricultural production (Krishnamurthy et al, 2013). These erratic climate patterns have caused the food security crises in the country.

As expected, the coefficients of the ecological zone variables, *HILL* and *MOUTAIN*, are significant and negative in the diversity model. The results indicate that households living in the Hill and Mountain Zones consume less types of food, compared to their counterparts in the Terai area. In other words, the quality of food in the Hill and Mountain Zones is poorer than that in the Terai, with households in the Hill and Mountain Zones consume 2.515 and 3.434 less types of food during a month than those living in the Terai Zone. In all the caloric intake models, the coefficients of the *HILL* variables are significantly positive at the 5% level, which is contrary to the prior expectation and deserves explanation. Due to the dry climate condition and poor soil quality, households in the Hill Zone tend to grow the crops of stronger vitality such as potatoes (Nepal Ministry of Finance, 2013), which contain higher calories. Although we weighted the caloric intake by assigning lower weight to less-nutrient food, the excessive consumption of such food may still lead to high caloric intake. On the other hand, the Hill Zone covers the most agriculture land in Nepal, yielding the comparative agricultural production to the Terai area. However, the population density is less intensive, which may also contribute to higher daily caloric intake per capita. The marginal effect of the Hill Belt in the caloric model is around 118 in both Copulas, implying that compared to the people in the Terai Belt, those living in the Hill Belt are consuming118 Calories weighted calories more every day.

With regard to the social capital index, a positive effect of the agriculture user group is expected for all models. This indicates that engaging in the farmer user group is beneficial to enhancing household food security. The result is robust across all models. As the index increases by 1, the daily weighted caloric intake increases by around 20 Calories per individual. The result confirms that participating in the farmer group enables people to improve their food security through building stronger connections with their partners, as well as gaining more farming knowledge and techniques. However, the effect of engagement in the forest user group is reverse, which is consistent with the evidence reported by the World Food Program (WFO, 2006). As discussed above, households engaging in the forest group opt to focus on forestation activities instead of farming, which will negatively affect food security. The result implies that the positive effect of stronger social network is dominated by the negative effect.

Except for self-produced crops, market products are a supplement for households. The lack of infrastructure and prohibitive travel cost to get to the market restrict households' ability to obtain food from markets (Haile, 2005). In other words, the closer the household is to the paved road, the higher the probability that they are able to purchase food from the market. As expected, the coefficient of the distance to the paved road from the house is negative and significant at the 1% level. The marginal effect shows that as the distance to the paved road increases by 1 kilometer, the weighted caloric intake will be 9.714 Calories less for an individual during a day, and the food diversity for a household during a month will be 0.351 less. The result is consistent with other studies, which found that community infrastructure is a determinant of malnutrition status (Strauss and Thomas., 1998).

Comparing the results in Table 2.2 and Table 2.3, the effect of remittance is stronger when the endogeneity problem is solved. As reported by Model 3 in Table 2.3, the coefficient of *REMIT* is positive and statistically significant from zero at the 1% level, indicating that receiving remittance contributes to household food security. The marginal effects of *REMIT* in Table 2.6

show that as the amount of remittance received increase by 100 Nepalese Rupees (NRs), the daily weighted caloric intake per capita will increase by 230 Calories, and the types of food consumed by a household during a month will increase by 3. In addition, access to financial loans also helps households mitigate food insecurity problems. The coefficients of *CREDIT* in both the caloric and diversity models are positive and statistically significant at the 5% level. The coefficients of *NUTRICHI* are significant in all diversity models but insignificant in all of the caloric models. The results make sense because foods that the households obtain from the children nutrition program are of low calories, which will not significantly affect household members' caloric intake. However, it enriches the households' overall food diversity.

The effect of agricultural income, using the amount of agricultural land as the indicator, is positive and significantly different from zero at the 1% level in all diversity models, ranging from 0.047 to 0.076. By comparison, the effect of agricultural land on household food quantity is weaker, but still significant at the 10% level using the Clayton Copula estimation method. The marginal effects presented in Table 2.6 show that one more hectare of agricultural land will result in 74.853 more weighted Calories per person per day, and three more types of food consumed by a household during a month. The results imply that households tend to enrich crop variety instead of the production of a single crop if they have more agricultural land.

Other control variables of interest, including the head of household characteristics and the agricultural facility, are controlled for in the last model of both Table 2.2 and Table 2.3. One of the interesting results is *AGE* is positive in the caloric model and negative in the diversity model, indicating that the elders care more about food quantity than youngers. Another finding is that women are more capable of enhancing household food quality than men in rural Nepal. This finding is consistent with the result of Ibnouf (2009), which shows that compared to men, women contribute more to agricultural production, and thus, improve the household dietary quality in rural Sudan. We also find that the better educated head of household are more able to reduce food insecurity. As expected, compared to Brahmin or Chhetri that are the highest castes in Nepal, the Janjati, Dalit, and other castes tend to consume less food in terms of both quantity and quality. The effect is more obvious on dietary quality than quantity. Finally, agricultural equipment facilitates the cultivation process, and thus enhances households' food security level.

2.7.4 Model Selection

As discussed above, we estimate equation (6) using the Clayton, Frank, and Product Copulas. From the AIC values and the significant levels of the correlation parameters, we can tell that both the Clayton and Frank Copulas are preferred to the Product Copula. We further conduct a likelihood-ratio test to confirm our finding (Vuong, 1989). Since all Copulas used in this paper have the same degree of freedom, the test is carried out by comparing the pointwise log-likelihood (Kramer et al., 2010).

$$d_i = l_i^1 - l_i^2 \qquad (2.27)$$

where i denotes the individual observation, and l_i^1 and l_i^2 are the individual log-likelihood values of Model 1 and Model 2, respectively.

The mean of difference could be calculated with the following formula:

$$\bar{d} = \frac{1}{n}\sum_1^n d_i \qquad (2.28)$$

where n is the number of observation. The test statistic is obtained by the equation (2.29):

$$T_V = \frac{\sqrt{n} * \bar{d}}{\sqrt{\sum_1^n (d_i - \bar{d})^2}} \qquad (2.29)$$

We compare the statistics with the critical z-value. The results are presented in Table 2.7. From the table, we can tell that the Clayton and Frank Copulas are both significantly preferred to the Product Copula. However, we fail to reject that the Clayton and Frank Copulas are different from each other.

2.8 Conclusion

This analysis studies various determinants affecting household food security in rural Nepal. We adopt two indicators as food security measurements: caloric intake per capita per day and food diversity. Considering the correlation between the two variables, we utilize a Copula method to estimate the two models simultaneously. The validity of the method is confirmed by the significant Copula parameters in all models as well as the preference of both the Clayton and Frank Copulas to the Product Copula.

This research is a pioneering quantitative study analyzing impacts of climate change on household food security in the context of food utilization. Our results show that temperature and rainfall risk adversely affects households' food security levels in rural Nepal. It provides policy implications that the Nepalese government should educate households about mitigation strategies to adapt to climate change, such as crop diversity, early or late cultivation, improved seeds utilization, use of pesticides, and so on.

Although the social capital indices are aggregated at the district level, the result of positive effect of agricultural group still provides evidence about the benefits of such groups. The policy recommendation will be that the community government should encourage households to participate in the agriculture group if it exists. For those VDCs that have not formed an agriculture group, the governments should consider providing social networks for households to share agricultural information and resources. In addition, the negative effect of the forest user group indicates that the community government may educate households in the forest group to balance the activities of forestation and farming.

Another important finding is the negative effect of the distance to roads, implying the importance of the road construction. As reported by the 2012 Nepalese Economic Outlook, around 3.5 million people in Nepal still do not have access to roads. Evidently, road construction is urgent to improve the household food security and reduce poverty. Therefore, the Nepalese government should prioritize investment in transportation facilities, which is especially crucial for areas without road access.

In addition, the analysis has illustrated the importance of various coping strategies. The significant contribution of remittance found by this study indicates that government should seek ways to channel remittance into productive investment to foster local development. We also find that the availability of child nutrition programs and access to credit also positively related to food security, suggesting that Nepalese government should provide more government support to the households with low food security.

Table 2.1 Summary Statistics of Chapter 2

Variable	Definition	Mean	Standard Deviation	Minimum	maximum
Dependent Variables					
HHCAL	Caloric intake per day per capita.	736.431	353.796	202.7628	3790.292
DIVERSITY	Number of types of food consumed by household during a month.	26.158	5.125	3	40
Independent Variables					
TEMPRAIN	Temperature and rainfall risk index	0.359	0.207	0	1
MOUTAIN	Dummy variable. Indicator for region. Coded as 1 if household is located in Mountain belt.	0.513	0.5	0	1
HILL	Dummy variable. Indicator for region. Coded as 1 if household is located in Hill belt.	0.1	0.3	0	1
FARM	Social capital index. Coded as 1 if household is participating in agriculture community group.	0.366	0.555	0	2.504
FOREST	Social capital index. Coded as 1 if household is participating in forest conservation community group.	0.881	0.871	0	3.489
DROAD	Distance from the household to the paved road (in 100 km).	0.217	0.352	0	2.88
REMIT	Amount of remittance household received in one year (in logarithm).	5.602	5.001	0	17.732
CREDIT	Dummy variable. Code as 1 if household can access to loan outside	0.7	0.459	0	1
NUTRICHI	Dummy variable. Government support program for children. Coded as 1 if household can receive government support.	0.023	0.151	0	1
LAND	Indicator for agricultural income. Amount of agriculture land in hectare (in logarithm).	0.417	0.337	0	2.457
FEMALE	Dummy variable. Coded as 1 if gender of household head is female, 0 otherwise.	0.733	0.443	0	1
AGE	Age of household head (in 100)	0.47	0.141	0.11	0.95
EDUCATION	Dummy variable. Indicator for education. Coded as 1 if household head can read, 0 otherwise.	0.513	0.5	0	1
DALIT	Dummy variable. Indicator for cast. Coded as 1 if household is recognized as Dalit caste, 0 otherwise.	0.335	0.472	0	1
JANJATI	Dummy variable. Indicator for cast. Coded as 1 if household is recognized as Janjati caste, 0 otherwise.	0.141	0.348	0	1
OTHERCASTE	Dummy variable. Indicator for caste. Coded as 1 if household is identified by a caste other than Janjati, Dalit, and Brahmin or Chhetri, 0 otherwise	0.342	0.475	0	1
EQUIP	Dummy variable. Coded as 1 if household has equipment for agriculture, 0 otherwise	0.959	0.199	0	1
Observation	2971				

Source: Nepal household living standard survey and community survey in 2010.

Table 2.2 Regression Results for Clayton Copula

		Model I		Model II		Model III	
		calories	diversity	calories	diversity	calories	diversity
Climate	TEMPRAIN	-0.083*	-0.007	-0.103**	-0.014	-0.143***	-0.043**
		(0.043)	(0.017)	(0.045)	(0.019)	(0.046)	(0.019)
Ecological Belt	MOUNTAIN	-0.035*	-0.130***	-0.032	-0.128***	-0.006	-0.107***
		(0.019)	(0.007)	(0.019)	(0.007)	(0.020)	(0.007)
	HILL	0.092**	-0.198***	0.098***	-0.194***	0.163***	-0.134***
		(0.032)	(0.013)	(0.033)	(0.013)	(0.034)	(0.014)
Social capital	FARM			0.039**	0.017***	0.029**	0.009*
				(0.015)	(0.005)	(0.015)	(0.005)
	FOREST			-0.013	-0.004	-0.020	-0.009*
				(0.013)	(0.005)	(0.013)	(0.005)
Infra-sttru-cture	DROAD					-0.171***	-0.136***
						(0.031)	(0.015)
Coping strategies	REMIT						
	CREDIT						
	NUTRICHI						
Income	LAND						
	FEMALE						
	AGE						
	EDUCATION						
	DALIT						
	JANJATI						
	OTHERCASTE						
	EQUIP						
	CONSTANT	6.639***	3.35***	6.636***	3.346***	6.677***	3.377***
		(0.022)	(0.008)	(0.029)	(0.012)	(0.029)	(0.012)
	Theta	0.144***		0.143***		0.126***	
	Log likelihood	-30213.34		-30205.14		-30127.17	
	AIC	60446.69		60438.27		60286.33	
	Observation	2971		2971		2971	

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level.

Table 2.2 Regression Results for Climate Copula (continued)

		Model IV		Model V		Model VI	
		calories	diversity	calories	diversity	calories	diversity
Climate	TEMPRAIN	-0.139***	-0.037**	-0.132***	-0.038*	-0.124***	-0.044**
		(0.046)	(0.018)	(0.046)	(0.018)	(0.045)	(0.018)
Ecological Belt	MOUNTAIN	-0.002	-0.104***	-0.009	-0.108***	-0.0042	-0.097***
		(0.020)	(0.007)	(0.020)	(0.007)	(0.022)	(0.008)
	HILL	0.159***	-0.136***	0.143***	-0.141***	0.156***	-0.132***
		(0.034)	(0.014)	(0.034)	(0.014)	(0.035)	(0.014)
Social capital	FARM	0.027*	0.009*	0.028**	0.009*	0.031**	0.004
		(0.015)	(0.005)	(0.015)	(0.005)	(0.015)	(0.005)
	FOREST	-0.024*	-0.012**	-0.024*	-0.013**	-0.014	-0.013**
		(0.013)	(0.005)	(0.013)	(0.005)	(0.013)	(0.005)
Infrastructure	DROAD	-0.159***	-0.135***	-0.156***	-0.137***	-0.150***	-0.135***
		(0.032)	(0.015)	(0.032)	(0.015)	(0.033)	(0.014)
Coping strategies	REMIT	0.0058***	0.0040***	0.0055***	0.0037***	0.0038**	0.006***
		(0.0018)	(0.0007)	(0.0017)	(0.0007)	(0.0019)	(0.0007)
	CREDIT	0.030	0.040***	0.038**	0.043***	0.041**	0.037***
		(0.019)	(0.008)	(0.019)	(0.008)	(0.019)	(0.007)
	NUTRICHI	-0.002	0.063***	0.003	0.059**	0.014	0.050**
		(0.059)	(0.022)	(0.059)	(0.022)	(0.060)	(0.021)
Income	LAND			0.108***	0.075***	0.061**	0.048***
				(0.028)	(0.009)	(0.029)	(0.009)
	FEMALE					-0.034	0.047***
						(0.024)	(0.009)
	AGE					0.364***	-0.102***
						(0.075)	(0.028)
	EDUCATION					0.043*	0.068***
						(0.019)	(0.007)
	DALIT					-0.011	-0.029***
						(0.060)	(0.009)
	JANJATI					-0.042	-0.045***
						(0.029)	(0.011)
	OTHERCASTE					-0.085***	-0.037***
						(0.028)	(0.009)
	EQUIP					0.143*	0.020
						(0.075)	(0.019)
	CONSTANT	6.622***	3.324***	6.573***	3.295***	6.314***	3.276***
		(0.033)	(0.014)	(0.035)	(0.014)	(0.075)	(0.020)
	Theta	0.128**		0.120***		0.136***	
	Log likelihood	-30088.83		-30034.8		-29915.9	
	AIC	60221.66		60117.59		59907.8	
	Observation	2971		2971		2971	

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Moreover, the distance to road is measured in logarithm of distance divided by 10; the age of the household head is measured in 10.

Table 2.3 Regression Results for Clayton Copula with IV

		Model I		Model II		Model III	
		calories	diversity	calories	diversity	calories	diversity
Climate	TEMPRAIN	-0.119**	-0.038**	-0.120**	-0.039**	-0.110**	-0.044**
		(0.048)	(0.018)	(0.046)	(0.017)	(0.045)	(0.018)
Ecological Belt	MOUNTAIN	0.008	-0.105***	0.004	-0.109***	0.012	-0.096***
		(0.021)	(0.008)	(0.019)	(0.007)	(0.023)	(0.008)
	HILL	0.160***	-0.136***	0.154***	-0.142***	0.160***	-0.132***
		(0.034)	(0.015)	(0.034)	(0.013)	(0.037)	(0.013)
Social capital	FARM	0.021	0.009*	0.022	0.010*	0.025*	0.004
		(0.015)	(0.005)	(0.014)	(0.0053)	(0.014)	(0.005)
	FOREST	-0.029**	-0.012**	-0.029**	-0.013***	-0.019	-0.013***
		(0.013)	(0.005)	(0.013)	(0.004)	(0.014)	(0.005)
infrastructure	DROAD	-0.140***	-0.136***	-0.142***	-0.139***	-0.132***	-0.134***
		(0.034)	(0.016)	(0.034)	(0.016)	(0.034)	(0.015)
Coping strategies	REMITHAT	0.018***	0.0032***	0.017***	0.0024*	0.018***	0.006***
		(0.003)	(0.0012)	(0.003)	(0.0013)	(0.004)	(0.002)
	CREDT	0.029	0.040***	0.034*	0.043***	0.037**	0.037***
		(0.018)	(0.007)	(0.018)	(0.007)	(0.018)	(0.007)
	NUTRICHI	0.014	0.061**	0.014	0.059**	0.024	0.050**
		(0.060)	(0.022)	(0.060)	(0.023)	(0.063)	(0.022)
Income	LAND			0.096***	0.076***	0.041*	0.047***
				(0.026)	(0.008)	(0.025)	(0.009)
	FEMALE					0.026	0.050***
						(0.029)	(0.013)
	AGE					0.287***	-0.105***
						(0.081)	(0.031)
	EDUCATION					0.034*	0.068***
						(0.02)	(0.007)
	DALIT					-0.008	-0.029***
						(0.027)	(0.009)
	JANJATI					-0.051	-0.046***
						(0.034)	(0.012)
	OTHERCASTE					-0.082**	-0.037***
						(0.027)	(0.009)
	EQUIP					0.128**	0.020
						(0.062)	(0.020)
	CONSTANT	6.545***	3.330***	6.509***	3.303***	6.247***	3.281***
		(0.040)	(0.014)	(0.040)	(0.016)	(0.080)	(0.026)
	Theta	0.127**		0.119***		0.129***	
	Log likelihood	-30067.42		-30036.08		-29913	
	AIC	60178.84		60120.17		59911.9	
	Observation	2971		2971		2971	

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Moreover, the distance to road is measured in logarithm of distance divided by 10; the age of the household head is measure in 10.

Table 2.4 Regression result of the Frank Copula and the Product Copula

		Product Copula		Frank Copula	
		calories	diversity	calories	Diversity
Cim-ate	TEMPRAIN	-0.110**	-0.044**	-0.112**	-0.044**
		(0.044)	(0.018)	(0.046)	(0.019)
Ecological belt	MOUNTAIN	0.012	-0.096***	0.012	-0.097***
		(0.024)	(0.008)	(0.022)	(0.008)
	HILL	0.160***	-0.132***	0.159***	-0.133***
		(0.034)	(0.014)	(0.031)	(0.014)
Social capital	FARM	0.025	0.004	0.024	0.004
		(0.016)	(0.005)	(0.016)	(0.005)
	FOREST	-0.019	-0.013**	-0.020	-0.013**
		(0.014)	(0.005)	(0.013)	(0.005)
Infras tructu	DROAD	-0.132***	-0.134***	-0.131***	-0.134***
		(0.036)	(0.015)	(0.036)	(0.015)
Coping strategies	REMITHAT	0.018***	0.006***	0.018***	0.006***
		(0.004)	(0.001)	(0.004)	(0.001)
	CREDIT	0.037*	0.037***	0.038**	0.037***
		(0.020)	(0.007)	(0.019)	(0.007)
	NUTRICHI	0.024	0.050**	0.023	0.050**
		(0.061)	(0.023)	(0.059)	(0.023)
Inco me	LAND	0.041	0.047***	0.040	0.047***
		(0.028)	(0.009)	(0.029)	(0.008)
	FEMALE	0.026	0.050***	0.029	0.050**
		(0.028)	(0.011)	(0.028)	(0.023)
	AGE	0.287***	-0.105***	0.283***	-0.105**
		(0.079)	(0.029)	(0.076)	(0.029)
	EDUCATION	0.034*	0.068***	0.034*	0.068***
		(0.019)	(0.007)	(0.019)	(0.007)
	DALIT	-0.008	-0.029***	-0.009	-0.029***
		(0.029)	(0.009)	(0.027)	(0.009)
	JANJATI	-0.051	-0.046***	-0.055*	-0.046***
		(0.034)	(0.012)	(0.033)	(0.012)
	OTHERCASTE	-0.082***	-0.037***	-0.084***	-0.037***
		(0.028)	(0.009)	(0.027)	(0.009)
	EQUIP	0.128**	0.020	0.126**	0.020
		(0.061)	(0.020)	(0.059)	(0.020)
	CONSTANT	6.247***	3.281***	6.098***	3.278***
		(0.081)	(0.027)	(0.090)	(0.024)
	Theta	0		0.689***	
	Log Likelihood	-29947.5		-29932.2	
	AIC	59968.97		59940.39	
	Observation	2971		2971	

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Numbers in the parentheses are standard deviations. Moreover, the distance to road is measured in logarithm of distance divided by 10; the age of the household head is measure in 10.

Table 2.5 Hypothesis and Results

	Hypotheses		**Results**	
	Calories	diversity	calories	diversity
1 Climate	$\beta_{temprain} < 0$	$\beta_{temprain} < 0$	$\beta_{temprain} < 0$	$\beta_{temprain} < 0$
2 Ecological Zone	$\beta^{C}_{hill} < 0$, $\beta^{C}_{mountain} < 0$	$\beta^{D}_{hill} < 0$, $\beta^{D}_{mountain} < 0$	$\beta^{C}_{hill} > 0$	$\beta^{D}_{hill} < 0$, $\beta^{D}_{mountain} < 0$
3 Social Capital	$\beta_{farm} > 0$ $\beta_{forest} ? 0$	$\beta_{farm} > 0$ $\beta_{forest} ? 0$	$\beta_{farm} > 0$	$\beta_{forest} < 0$
4 Infrastructure	$\beta_{road} < 0$	$\beta_{road} < 0$	$\beta_{road} < 0$	$\beta_{road} < 0$
5 Copying Strategies	$\beta_{remit} > 0$ $\beta_{credit} > 0$ $\beta_{nutrichi} > 0$	$\beta_{remit} > 0$ $\beta_{credit} > 0$ $\beta_{nutrichi} > 0$	$\beta_{remit} > 0$ $\beta_{credit} > 0$	$\beta_{remit} > 0$ $\beta_{credit} > 0$ $\beta_{nutrichi} > 0$
6 Agricultural Income	$\beta_{land} > 0$	$\beta_{land} > 0$	$\beta_{land} > 0$	$\beta_{land} > 0$

Table 2.6 Marginal Effects of the Determinants in the Clayton Copula and the Frank Copula

		Clayton Copula		Frank Copula	
		calories	diversity	calories	Diversity
Cim- ate	TEMPRAIN	-8.085	-0.114	-8.222	-0.116
Ecologica l belt	MOUNTAIN		-2.515		-2.534
	HILL	117.882	-3.434	117.353	-3.480
Social capital	FARM	18.0184			
	FOREST		-0.340		-0.345
Infras tructu re	DROAD	-9.714	-0.351	-9.653	-0.348
Coping strategies	REMIT	229.923	2.981	231.899	3.260
	CREDIT	27.223	0.956	28.060	0.971
	NUTRICHI		1.317		1.337
Inco me	LAND	74.853	2.942	29.485	3.206
	FEMALE		1.302		1.295
	AGE	2.113	-2.754	2.083	-2.718
	EDUCATION	24.989	1.765	25.150	1.789
	DALIT		-0.761		-0.777
	JANJATI		-1.195	-40.725	-1.192
	OTHERCASTE	-60.274	-0.967	-61.576	-0.953
	EQUIP	94.526		93.155	
	Theta	0.129***		0.689***	
	Observation	2971		2971	

Note: This table only reports the marginal effects of the significant variables. The marginal effect of the temperature and rainfall risk is for every 0.1 change in the risk indicator. In addition, the marginal effect of the community user group index is for every 1 change in the indices. And the marginal effect of the remittance is for every 100 NRs change.

Table 2.7 Model Selection Result

		Model 2		
		Product	Clayton	Frank
	Product	—	-3.349	-2.830
Model1	Clayton	3.349	—	1.173
	Frank	2.830	-1.173	—

Note: If the value is greater than 1.96, then model 1 is preferred to mdel2 at the 5% level; if the value is less than -1.96, then model 2 is preferred to model 1 at the 5% level. Otherwise, no preferred Copula family is preferred.

Chapter 3: A Spatial Filtering Frontier Production Model for Panel Data: Effects of Climate Change on Rice Production in Rural Nepal

3.1 Introduction

Built on the framework of food security and climate change, this chapter analyzes the spatial effect of climate change on food production in rural Nepal. We utilize a Stochastic Frontier Production Model based on the Cobb-Douglas function, and analyze the factors affecting agricultural production inefficiency. The present study enriches the existing literature by examining the effects of climate conditions on crop production within the Stochastic Frontier Production framework. In addition, we adopt a flexible spatial econometric analysis method, spatial filtering technique, to address the spatial correlation of climatic conditions between adjacent neighborhoods (Areal et al., 2012).

The main data source is Nepal Living Standard Survey for the years 2003/2004 and 2010/2011, and climate data is from 36 ground weather stations in Nepal. We construct four climate indices, including extreme events of rainfall and temperature during the cropping season, and the mean rainfall and temperature during the monsoon season of Nepal. Specifically, we define temperatures above 32℃ as extremely high temperature, and the amount of rainfall exceeding three times the standard deviation within a district as variant rainfall. Because the length of climate data varies across the weather stations, we create the extreme climate indices based on the percentage of the days of extreme climate events.

We apply a maximum likelihood estimation method to analyze the model and find that variant rainfall during cropping season impedes rice growth, but the average monsoon rainfall is beneficial to rice production although the effect is insignificant. Moreover, we find that the average summer season temperature adversely affects rice production.

Another focus of this chapter is investigating factors affecting the technical inefficiency of rice production using a time-variant model. We divide the explanatory variables into three categories: infrastructural characteristics, community characteristics, and household characteristics. We find that technical inefficiency is existent in the model in both 2003 and 2010. Moreover, we find similar efficiency scores over these two years for both the extreme and average weather models, with mean scores of 0.630 and 0.622 in 2003 and 2010, respectively.

With respect to the individual factors, we find significant contribution of river and road network, as well as agricultural extension services and education level of household head in the extreme climate model. The Nepalese government should take these factors into account when they design policies to improve rice production, which is crucial to improve the level of food security and human well-being.

This chapter is organized as follows: The first section introduces the main objective of this study and provides an overall description of the method, data, and results. The second section introduces the relevant literature in the field. The third section describes the theoretical framework, followed by the introduction of the spatial filtering technique. Section 5 illustrates several data sources used in this study and proposes various hypotheses. Section 6 introduces the empirical models, followed by a discussion of the estimation results. The final section concludes and makes policy recommendations.

3.2 Literature Review

The existing literature estimating impacts of climate change on agricultural production can be divided into two broad streams. The first stream measures the effect of the predicted climatic change on simulated crop yields (e.g. Alcamo et al., 2006). The second stream investigates the impact of historical climate change on agricultural production. Krishnamurthy et al. (2013) analyze the relationship between crop production and average seasonal precipitation during the main growing season in Nepal from 1975 to 2005. They conclude that the amount of rainfall has a positive effect on crop production but do not find significant effect of temperature on production. We have already introduced numerous studies about these two streams in Chapter 2. In the present chapter, we will focus on the methods used to analyze climate conditions and agricultural production. We will focus on describing the Ricardian Cross-Sectional Model (RM) and the Production Function Approach.

3.2.1 Ricardian Method

The Ricardian method adopts a hedonic pricing model to assess impacts of climate change on agricultural profit or land value. Thapa and Joshi (2010) utilize the Ricardian method to estimate the impacts of the mean rainfall and temperature in each season on net farm income in Nepal using the 2003/2004 Nepal Living Standard Survey data. They find that spring and summer precipitation, as well as spring and fall temperature contribute to agricultural income; while fall and winter precipitation, as well as summer and winter temperature have adverse effects. Another example is Shakoor et al. (2011), in which the authors examine the effects of annual temperature and rainfall on farm net revenue in Pakistan using climate data from 1999 to 2010. Their results show that the impact of temperature is more severe than rainfall. Specifically, they find that as the average rainfall increases 8%, the agricultural profit will increase 377 Indian Rupees, and a 1°C increase in the mean temperature leads to a loss of 4188 Rupees in agricultural profit.

3.2.2 Stochastic Frontier Production Method

The Stochastic Frontier Production method considers the crop production as a function of agricultural inputs (Reinsborough, 2003). Isik and Devadoss (2006) utilize a Just-Pope stochastic production model to investigate mean, variance, and covariance of crop yields in Idaho. They use total rainfall within a year and mean temperature from April to November as the indices of climate change. They find that the mean crop yield is not affected by climate, but the variance of agriculture increases significantly with higher temperature and precipitation.

Recently, the spatial nature of weather events has driven scholars to incorporate spatial correlation into agricultural production within the context of Stochastic Frontier Production Model (Schlenker et al., 2006; Deschenes and Greenstone, 2006). For example, Deschenes and Greenstone (2006) adopt a Ricardian method to assess the future effect of year-to-year variation in temperature and precipitation on agricultural values, and find that the combination of these two climate proxies contributes to the U.S. agricultural sector (a $1.1 billion increase in agricultural profit). In order to confirm the validity of the result, they use the production model to investigate correlation between climate change and crop yields integrating the spatial distribution of climate. Their results show that higher precipitation is beneficial to crop yields, while hot temperature is harmful.

Another interest of the frontier model is the analysis of the determinants of technical efficiency of crop production (Battese and Coelli, 1995; Simwaka et al., 2013; Haider et al., 2011; Todsadee et al, 2012; Devkota and Upadhyay, 2013). For example, Simwaka et al. (2013) estimate factors affecting the technical efficiency of maize production using a two-year panel data for 2004/2005 and 2006/2007. They use two models of time-varying and time-invariant models. Their results show that fertilizer, labor, seeds, and age are significant determinants of technical efficiency in these two models.

Todsadee et al. (2012) investigate the variation in broiler production and the factors impacting technical efficiency in the northern region of Thailand with primary data collected in 2011. In their paper, they employ a Stochastic Frontier Production Model based on a trans-log function to estimate the model. Their results show that feed, bird stock, fixed cost, and total variable costs contribute to broiler output. They also find that 79% of the production is technically efficient, and suggest that appropriate adaptation strategies should be adopted to improve the broiler production. Another example is the study of agricultural production, including crop, fish, and livestock production in Khulna, Bangladesh by Haider et al. (2011). In this paper, the authors use a panel data set for 2007, 2008, and 2009 to examine the factors influencing technical efficiency in these three agricultural sectors. They use both OLS and MLE methods to estimate the model, and they find consistent results using the two methods. Their results also indicate that farmers' education level, usage of modern technology, access to agricultural information, and resource mobility are important determinants of technical efficiency during agricultural production. So far, the studies about the effects of climate change on crop yields using the Stochastic Frontier Production Model are very limited. We will contribute the existing literature by filling in this gap.

3.3 Theoretical Model

3.3.1 Stochastic Frontier Production Model

The theoretical framework of this chapter follows Battese and Coelli (1993)'s work in the frontier theory. We first start with a deterministic Frontier Production Model for panel data:

$$y_{it} = f(x_{it})TE_{it} \qquad (3.1)$$

where y_{it} is the actual agricultural output of household i at time t. x_{it} is a vector of inputs used by household i at time t. $f(x_{it})$ stands for the maximum feasible output using resources x_{it}, and TE_{it} is technical efficiency for household i at time t.

We rewrite Equation (3.1) in order to intuitively express the meaning of TE_{it}. We obtain the technical efficiency as a function of output and inputs:

$$TE_{it} = \frac{y_{it}}{f(x_{it})} \qquad (3.2)$$

Since the actual output is less than or equal to the feasible maximum output, the value of TE_{it} is in the range of $[0,1]$. If the actual output achieves the maximum feasible amount, then $TE_{it} = 1$. If there is a shortfall in the actual output from the maximum feasible amount, then $TE_{it} < 1$, which also means technical inefficiency.

Equation (3.1) ignores random shocks that are not controlled by humans, such as climate shocks. In order to capture the effect of the random shocks, we rewrite equation (3.1) as follows:

$$y_{it} = f(x_{it})\exp\{v_{it}\}TE_{it} \qquad (3.3)$$

The right hand side of Equation (3.3), $f(x_{it})\exp\{v_{it}\}TE_{it}$, is called the stochastic production frontier. The middle term, $\exp\{v_{it}\}$, represents the effect of random shocks (Angelici, 2011). Since $TE_{it} \leq 1$ and is nonnegative, we use an exponential term,$\exp\{-u_{it}\}$, to represent it, where u_{it} is greater than 0. Thus, Equation (3.3) can be rewritten as:

$$y_{it} = f(x_{it})\exp\{v_{it}\}\exp\{-u_{it}\} \qquad (3.4)$$

3.3.2 Cobb-Douglas Function

To estimate agricultural productivity, we use the Cobb-Douglas Production Function form for the generic function, $f(x_{it})$. In the Cobb-Douglas function, both y and x are expressed in the logarithmic form:

$$\ln(y_i) = ln(x_i) + \varepsilon_i \qquad (3.5)$$

To econometrically estimate Equation (3.5), we rewrite it and incorporates the technical efficiency. The stochastic production function based on a Cobb-Douglas function for panel data is specified as follows:

$$\ln y_{it} = \beta_0 + \sum_1^t \sum_1^i \beta_{it} ln x_{it} + CC_{jt} + v_{it} - u_{it} \qquad (3.6)$$

where y_{it} is the production of rice in the t^{th} period (t=2003, 2010) for the i^{th} household; X_{it} is a vector of inputs; CC_{jt} captures the climatic conditions for the j^{th} district. The first random error v_{it}, is assumed to be independently identically normally distributed with zero mean and constant variance $\mathrm{N}(0, \sigma_v^2)$. It is also assumed to be independent from u_{it}. The second component of the error term, u_{it}, represents technical inefficiency of production. We write u_{it} as a function of z_{it}, a vector of variables affecting technical inefficiency,.

$$u_{it} = z_{it}\gamma + \varepsilon_{it} \qquad (3.7)$$

where γ is the associated vector of parameters. ε_{it} denotes a vector of random errors, which captures the random part unexplained by the variables presented in Equation (3.7), and is assumed to be truncated normally distributed with zero mean and constant variance, σ_u^2 (Battese and Coelli, 1993).

3.4 Spatial Filtering

We use a spatial filtering technique to capture the spatial correlation in climate conditions among adjacent districts. Compared to the traditional spatial analysis models, such as spatial autoregressive model and spatial error model, spatial filtering is a relatively new method and much more flexible (Griffith, 2000 & 2007) since it solves the restrictions of traditional linear models in incorporating spatial effects and provides more robust and enhanced estimated results (Patuelli, et al., 2006). The procedure of spatial filtering consists of splitting spatial effects into spatial and non-spatial components to filter out spatially auto-correlated patterns.

Within this framework, scholars have developed four methods to capture the spatial structure of the data, including autoregressive linear operators (Haining, 1991), G statistics (Getis, 2010), interpoint distance matrix eigen-functions (Borcard and Legendre, 2002), and the eigenvectors created by Griffith (2000) based on the spatial weight matrix eigen-functions. This chapter follows Griffith's method and this section will introduce the process how the spatial filtering eigenvectors are produced (Griffith, 2006; Wang, 2013).

3.4.1 The Spatial Weight Matrix

The principle of the spatial filtering method is applying eigenvector(s) of a spatial weight matrix as the explanatory variable(s), which represents the spatial correlation between neighborhoods (Wang et al., 2013). These eigenvectors control for the stochastic spatial dependencies among neighborhoods.

The first step in the creation of the eigenvectors is to generate a spatial weight matrix, W, which is generally developed from a contiguity or a distance-based weight matrix. We utilize a distance-based weight matrix since the districts with data available are not next to each other. We use the software R to generate a certain distance (i.e., 39,240 meters) that ensures that all districts have at least one neighborhood. Afterwards, we assign number one to district i for the column of district j if i is within 39,240 meters from j, zero otherwise. Finally, we obtain a 46-by-46 regular symmetrically binary matrix.

3.4.2 Eigenvectors Generation

When the spatial weight matrix is obtained, we use the following formula to transform the spatial weight matrix (Griffith, 2000):

$$\Omega = (\mathrm{I} - ll^T/n)W(\mathrm{I} - ll^T/n) \qquad (3.8)$$

In Equation (3.8), Ω is called transformation matrix. W is the binary spatial weight matrix. I is an n-by-n identity matrix. l is an n-by-1 vector of ones, T denotes transpose operator, and n is the number of neighborhoods. Afterwards, we decompose the matrix, Ω and generate 46 eigenvectors associated with 46 eigenvalues (Griffith and Chun, 2014). The eigenvectors and eigenvalues are denoted as $\mathrm{E} = (E_1, E_2, \ldots, E_n)$ and $\delta = (EV_1, EV_2, \ldots, EV_n)$, respectively. Since the eigenvectors are orthogonal and uncorrelated (Griffith and Chun, 2014), we could apply more than one eigenvector in the regression.

3.4.3 Cobb-Douglas Frontier Model Incorporating Spatial Effect

After incorporating spatial correlation, the Cobb-Douglas Frontier model is developed based on Equation (3.7) and modified as:

$$\ln y_{it} = \beta_0 + \sum \beta_{it} ln x_{it} + \delta_k E_k + v_{it} - u_{it} \qquad (3.9)$$

$$u_{it} = z_{it}\gamma + \varepsilon_{it} \qquad (3.10)$$

where E_k is a vector of spatial filtering eigenvectors, and δ_k is the corresponding parameter. In this equation, E_k accounts for the spatial autocorrelation between the residuals and constants across 2003 and 2010.

In order to incorporate the technical change influencing agricultural production across different years, we add another year dummy variable in Equation (3.9) (Battese and Coelli, 1995). Thus, the final model is revised as follows:

$$\ln y_{it} = \beta_0 + \sum \beta_{it} lnx_{it} + \delta_k E_k + \delta_{k+1} T + v_{it} - u_{it} \quad (3.11)$$

3.5 Econometrics Models

Our agricultural production econometric analysis is based on the theoretical model given in Equations (3.10) and (3.11). We analyze how the agricultural production in rural Nepal is affected by a set of inputs, and the factors influencing technical efficiency of agricultural production.

3.5.1 Basic Econometric Model

The basic econometric model analyzes the factors affecting rice growth.

$$\ln agri_{ijt} = \beta_0 + \beta_1 lnlab_{it} + \beta_2 lnfert_{it} + \beta_3 lnseed_{it} + \beta_4 irrig_{it} + \beta_5 lnland_{it} + \beta_6 cc_{jt} + \beta_7 E_{kj} + v_{it} - u_{it} \quad (3.12)$$

In Equation (3.12), lab, $fert$, $irrig$, and $seed$ are inputs of labor, fertilizer, irrigation, and seed, respectively; cc represents the indices of climate condition; and E_{kj} is eigenvector k decomposed from the spatial weight matrix for district j. All inputs except for irrigation and climate conditions are expressed in logarithms.

In order to simplify Equation (3.12), we select a most appropriate eigenvector. As described by Griffith and Chun (2014), spatial variation is not explained by the eigenvectors whose MC values (for eigenvector, $E_j = \frac{n}{l^T C l} * \delta_j$) approach their expected MC values. Therefore, we exclude the eigenvectors with a MC value of less than 0.25, resulting in 14 feasible eigenvectors. Afterwards, only the third eigenvector, E_3, is selected from the 14 eigenvectors since it provides the best fit of the model with the highest significance level[10] (Griffith and Chun, 2014). Equation (3.12) is rewritten as:

$$\ln agri_{ijt} = \beta_0 + \beta_1 lnlab_{it} + \beta_2 lnfert_{it} + \beta_3 lnseed_{it} + \beta_4 irrig_{it} + \beta_5 lnland_{it} + \beta_6 cc_{jt} + \beta_7 E_{3j} + v_{it} - u_{it} \quad (3.13)$$

where E_{3j} is the third eigenvector decomposed from the spatial weight matrix for district j.

3.5.2 Technical Inefficiency Model

Based on Equation (3.9), we further analyze the technical inefficiency of agricultural production:

$$u_{ikjt} = \varphi_1 river_{jt} + \varphi_2 road_{jt} + \varphi_3 roadsq_{jt} + \varphi_4 scfarm_{jt} + \varphi_5 agrixt_{kt} + \varphi_6 hedu_{it} + \varphi_7 hgender_{it} + \varepsilon_{it} \quad (3.14)$$

where i, j, k, and t denote household, district, Village Development Committee (VDC), and time, respectively. We analyze the factors influencing the technical inefficiency, including the sum of the rivers ($river$) length within a district in 2003 and 2010, sum of the length of roads ($road$) within a district, the social capital index of farmer groups ($scfarm$) within a district, the availability of an agricultural extension office in a VDC ($agrixt$), and a vector of household

[10] The results of the regression analysis for choosing eigenvectors are provided in Appendix A.

demographic characteristics, including the education level of the head of household ($hedu$), and the gender of the head of household ($hgender$).

3.6 Data Description and Hypotheses

The main data source used in this chapter is the panel data of NLSS. NLSS collected panel data for three years: 1996, 2003, and 2010. We use data from the 2003 and 2010 waves. The reason is that the panel data of 2010 is composed of two parts: half from the cross-section sample and the second half from the panel sample of the 2003 wave, respectively. This means that we would lose half of the observations if we use panel data from all three waves. Climate data is rainfall and temperature records from 36 ground weather stations in Nepal.

3.6.1 Dependent Variable

The dependent variable is the amount of rice production in each household in the year 2003 and 2010 in rural Nepal. We focus on rice production for two main reasons. First, rice is the primary cereal crop in Nepal, representing 35% of the total cultivated area (Nepal Economic Outlook, 2012). But the rice production varies over the years due to random shocks such as unexpected monsoon rainfall. Hence, it is important to investigate the effects of climate on the growth of this crop. The second reason is that the variables of other common crops, such as wheat, millet, grains, potato, etc. contain too many missing observations in the NLSS survey.

During the data processing stage, we first drop the observations from urban areas. Afterwards, we convert all other quantity measurements into kilograms. We also drop the outliers of paddy production which is less than 10 kg and greater than 15,000 kg. These two actions result in a total sample size of 946 households, consisting of 473 observations for each year. The average rice production over these two years is 1869.7 kg per household, with a big variance across households from 19.2 kg to 14,929.6 kg. The overall rice production in 2010 (with a mean of

2,028.13 kg per household) is slightly higher than in 2003 (1,854.45 kg). The analysis of the factors driving the change in production is the primary interest of this analysis.

As discussed in the methodology section, we use the Stochastic Frontier Production Model to estimate rice production. Figure 3.1 presents the distribution of the rice production variable, in which a clear right-tailed skewness could be observed.

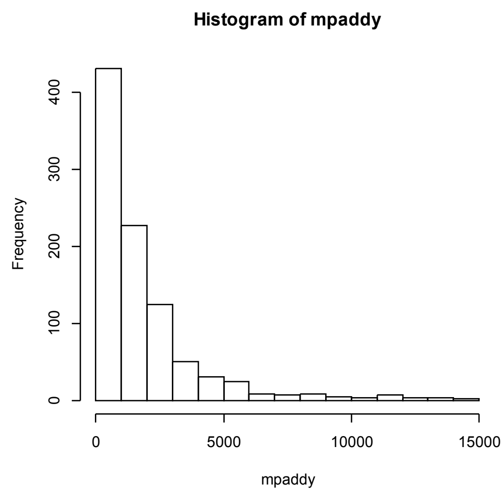


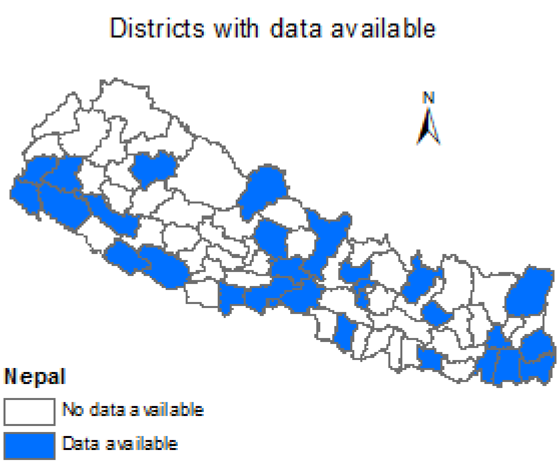
Figure 3.1 Distribution of Rice Production

3.6.2 Independent Variables

We divide our independent variables into two groups. The first group is a vector of inputs contributing to rice production, and the second group is the factors affecting technical inefficiency of rice production. The variables used as inputs include climate conditions, investments of capital, labor, fertilizers, seeds, irrigation, and cultivated land area.

3.6.2.1 Climate conditions

The climate indices are constructed using the rainfall and temperature records from 36 ground weather stations which cover 28 districts in Nepal. The original data include daily mean rainfall, as well as daily maximum and minimum temperature. We use the following steps to obtain the weather data for other districts. First, for the districts with more than one weather stations, we calculate the mean of the weather indices records. This procedure enables us to obtain data for 28 districts. Second, we use the software ArcGIS to identify the adjacent district for each district. Next, we use data from their adjacent district to calculate the climate data for those districts without weather data, saying district j. Specifically, if district j has only one adjacent district with climate data, we directly assign the existing climate data to district j. Otherwise, we extrapolate climate using spatial analysis in ArcGIS based on the average rainfall and temperature values from adjacent districts. Figure 3.2 illustrates the districts with original weather data, and Figure 3.3 shows all districts with data available after imputing missing climate data.



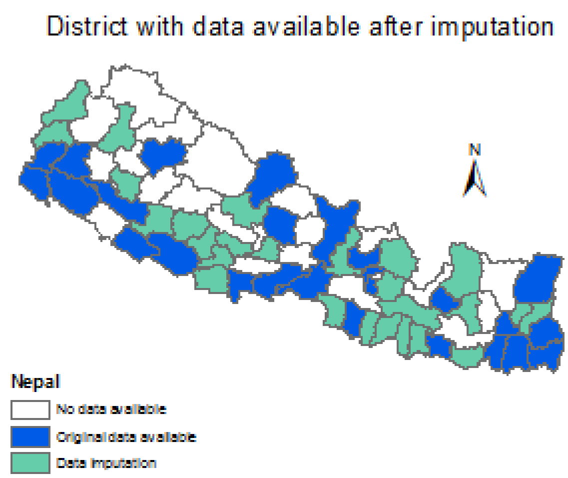


Figure 3.2 Districts with original data

Figure 3.3 Districts with original and imputing data

In this study, we construct four climate indices, including variant rainfall and extreme temperature during cropping seasons, and mean rainfall and temperature during monsoon season. With respect to the extreme weather, we use the percentage of days to overcome the heteroskadasticity problem resulting from the variant period of data across each weather station (i.e., ranging from 13 years (1996 to 2008) to 28 years (1971 to 2008)). For the districts with data more than 25 years, we use a period of the most recent 25 years to create the indices for both

2003 and 2010; otherwise, we use the data over all years. In addition, we follow previous studies (e.g., University of Reading, 2007) and define extreme temperature as that greater than 32℃. The threshold of extreme rainfall is defined as the triple of the standard deviation within a district. The first hypothesis we propose is that extreme climate events negatively contribute to the agricultural production.

Hypothesis 1: $\beta_{extr\_rain} = 0 \ v.s. \ \beta_{extr\_rain} < 0$

$\& \ \beta_{extr\_temp} = 0 \ v.s. \ \beta_{extr\_temp} < 0$

Given the information that rice is traditionally grown in flooded areas and in warm but not hot temperature, we hypothesize that the average monsoon rainfall has a positive impact on rice production while summer temperature[11] negatively affects the rice production.

Hypothesis 2: $\beta_{sumrain} = 0 \ v.s. \ \beta_{sumrain} > 0$,

$\& \ \beta_{sumtemp} = 0 \ v.s. \ \beta_{sumtemp} < 0$

3.6.2.2 Other Inputs

The inputs of capital, labor, fertilizers, and seeds are measured in Nepalese Rupees[12] (NRs). To construct the cost of capital, we sum up several types of capital investments included in the survey, namely the cost of agricultural machinery, payments for tractors, threshers, and other rented equipment, investments in the improvement and maintenance of land, machines, and

[11] Since the actual data of mean temperature is not available, we take the average of the maximum and minimum temperatures to construct daily average temperatures.
[12] One US dollars is approximately equal to 98 NRs.

buildings (Devkota and Upadhyay, 2013). As reported in Table 3.1, the average cost of capital is 1,734 NRs.

With respect to labor, we sum up the costs of home-labor and hired-labor, with a mean of 4,480 NRs. The information of cost of irrigation is absent in the NLSS survey; therefore, we follow Battese and Coelli (1995) and use the portion of irrigated land area as a proxy for irrigation input. A mean of 0.551 indicates that more than half of the agricultural land is irrigated in the sample. The measurement of land area is comparatively rougher. In NLSS, households do not report the exact land area for rice growth. Instead, they report the information of all vegetable planted on a specific land plot. To construct the land area variable, we sum up all land areas as long as this crop is grown on the land. Finally, all inputs, except for the irrigation proxy variable, are converted into logarithms.

3.6.3 Technical Inefficiency Factors

We divide the technical inefficiency factors into three categories: infrastructure characteristics, community characteristics, and household characteristics. The following section describes how we construct these key variables.

3.6.3.1 Infrastructure Characteristics

The infrastructure characteristics used in this analysis include the total length of roads (*Road*) and rivers (*River*) within a district. The total length of roads is calculated using Nepal road shapefiles for 2000 and 2009. As shown in Figure 3.4[13], there are several types of road in Nepal including main trail, foot path, graveled, high way, metaled, and railway. Recent literature has highlighted the importance of rural road construction, such as distance to paved road, to

[13] We only show the figure of road density for 2000 since the one for 2009 is very similar.

agricultural production in developing economies (Binam et al, 2004; Lanto, 2012). This is confirmed by the findings in the second chapter. In the present study, we also expect that road density contributes to technical efficiency in the process of agricultural production (negatively correlated with technical inefficiency).

Hypothesis 3:

$$\beta_{road} = 0 \; v.s. \beta_{road} < 0$$

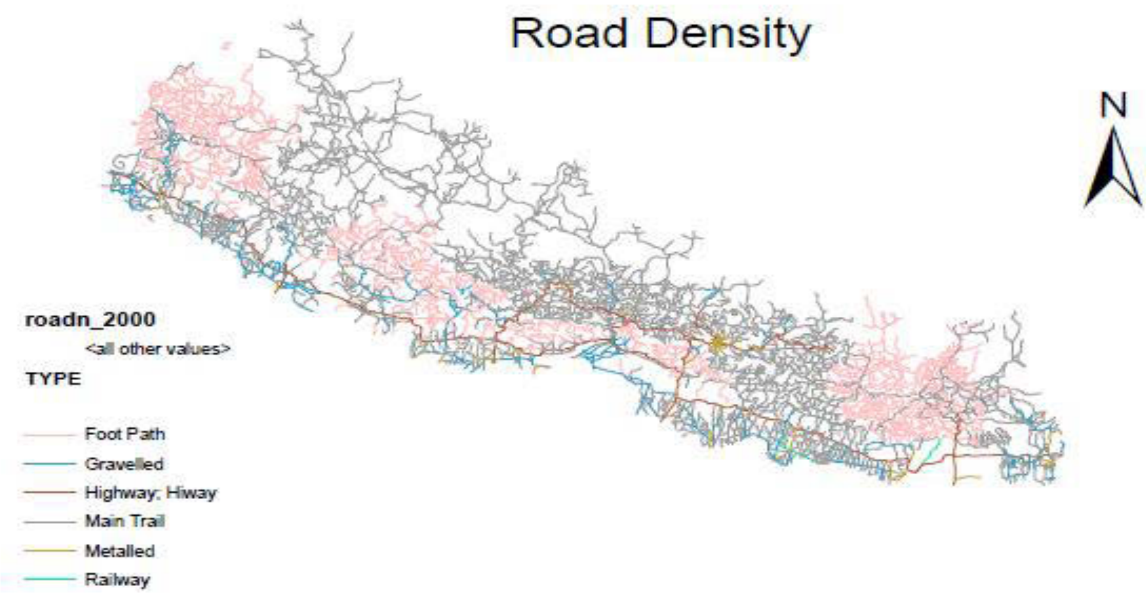


Figure 3.4 Road network in Nepal in 2010 used to calculate road density by District

The total length of rivers acts as a proxy for access to irrigation systems. On the one hand, availability of rivers provides the important connectivity with irrigation and fields. On the other hand, it lessens the irrigation costs for farmers. The variable of river length is calculated based on the whole district, with a mean of 821.3 km within a district.

Hypothesis 4:

$$\beta_{river} = 0 \; v.s. \beta_{river} < 0$$

3.6.3.2 Community characteristics

We use social capital (*Socialcap*) and availability of agricultural extension (*Agri_exten*) as indices of community characteristics. Using the same method as in the second chapter, we measure social capital by the extent of the farming groups at the district level. The availability of agricultural extension is controlled for since it provides farmers farming experience and weather information which benefit their agricultural activities and production. The variable is coded as 1 if the service is available in the village, and 0 otherwise. A mean of 0.11 for the variable indicates that such service is still scarce in Nepal. We hypothesize that both services positively contribute to technical efficiency.

Hypothesis 5:

$$\beta_{Socialcap} = 0 \; v.s. \beta_{Socialcap} < 0$$

Hypothesis 6:

$$\beta_{Agri\_exten} = 0 \; v.s. \beta_{Agri\_exten} < 0$$

3.6.3.3 Household Characteristics

Household characteristics are also controlled for in the model. We consider the gender of the household head (*Female*) and their education level (*Read*). The gender of the household heads is coded as 1 if the head is female, and 0 otherwise. We adopt "if the head of household can read" as an indicator of education level because the data on the actual education level is largely missing.

3.7 Results and Discussion

We use the maximum likelihood estimation method to estimate the Stochastic Frontier Production Model. In this section, we control for two categories of climate conditions indices in separate models: extreme climate conditions during cropping seasons and average climate during monsoon season.

3.7.1 Extreme Climate Model

Table 3.2 reports the model controlling for the indices of extreme climatic conditions. Model 2a is the basic model and Model 2b adds climate variables and the spatial eigenvector. Model 2c accounts for technical inefficiency and adds infrastructural characteristics. Model 2d adds community characteristics, and the final model (Model 2e) also controls for household characteristics. The AIC values reported at the bottom of the table indicate that the final model is of the best fit, therefore, the following discussions will focus on this model.

In Model 2e, the signs of the coefficients of all inputs are expected. Investments of capital, labor seed, fertilizer, land, and irrigation all contribute to rice production. Land amount is the most important input with an elasticity of 0.912. It indicates a 1% increase in land results in a 0.912% growth in rice production (18.14 kg). Besides, the rice production will increase by 0.033% (0.64 kg) and 0.039% (0.76 kg) with 1% increase in labor (42.7 NRs) and capital (17.13 NRs), respectively. The effects of inputs are robust across the five models, including both magnitudes of coefficients and significance levels.

With respect to extreme climate indices, the negative coefficient of *Temp32* indicates that extreme high temperature is negatively correlated rice growth. However, the effect is not statistically significant. The result is similar to previous studies that did not find significant effects of high temperature on crop production (Peng et al, 2004; Nagrajan et al, 2010). In addition, we find that the frequency of capricious rainfall in a district has an adverse impact on rice production, which is consistent from Model 2b to 2e. As reported by Table 3.2, 1% increase in the number of days with variant rainfall corresponds with a decrease of 0.28% (5.34 Kg per household) in rice production. Additionally, the highly significant coefficient of the eigenvector (*V3*) confirms that spatial correlation between adjacent districts.

Factors affecting technical inefficiency are of particular interest in the study. The results in Model 2e show that road, river, agricultural extension service, and the education level of the household head significantly contribute to technical efficiency. Coefficients of *River* and *Road* are as expected. The negative sign of *River* implies that the districts with more river systems are of higher production efficiency. This is because farmers are more accessible to water and their irrigation cost reduce if there is more river system. The finding is consistent with Edmonds (2002). On the other hand, the negative coefficient of *Road* implies that road network improves technical efficiency of rice production. The result is consistent with the finding in the second chapter.

Regarding the community characteristics, the social capital index is not a significant determinant although it is positively correlated with technical efficiency. However, we find a positive correlation between agricultural extension service and technical efficiency. The result is consistent with Elias et al. (2014)'s finding. They point out that such service provides farmers more technology and resources relating to agricultural production. Other factors found to significantly affect technical efficiency are the education level and gender of the household head. We find that more educated household heads are more efficient in rice production compared to their counterparts, and male-headed households are more efficient than female-headed households.

3.7.2 Average Rainfall and Temperature Model

We first conduct the analysis using the climate indicators of the monsoon season. The results are very close to those in the previous section. We estimate 5 sub-models in this subsection. Model 3a is the same as Model 2a, and Model 3b to 3e are consistent with Model 2b to 2e except for the climate change variables. In order to capture the nonlinear relationship between the climate conditions and rice production, we also control for the square term of the mean of rainfall and temperature variables. The AIC values reported on the bottom of Table 3.3 indicate that the final model is with the best fit. In this model, we find similar results for the input variables as the previous models in section 3.7.1. Specifically, all inputs except for seed are found to contribute to rice production. Moreover, in the estimation of technical efficiency, the signs of all coefficients are as expected, but the individual effects of the infrastructural characteristics, agricultural extension service, and education fade away.

The variables of particular interest in this model are climate change indices. Estimation results report positive and negative coefficients for *Msumrain* and *Msumrain2* (i.e., squre term of summer rainfall), respectively. Although the effects are insignificant, they still indicate that under some threshold, the monsoon rainfall is beneficial to rice growth while the effect becomes adverse above the threshold. On the other hand, the result of the average temperature is consistent with expectation. The combination of a negative coefficient and positive coefficient for *Msumtemp* and *Msumtemp2* (i.e., square term of summer temperature) suggest that summer weather impedes the rice production. After calculation, as summer temperature increases by 1℃, rice production will decrease by 0.48%, which means an average drop of 4,183 kg of rice production in one year in the sample.

We also analyze the effects of average temperature and rainfall over the whole cropping season on rice production (Table 3.4). The differences between Model 4 and Model 3e are that the effect of summer weather becomes insignificant. However, we find significantly positive effects of spring temperature and fall rainfall and adverse effects of fall temperature.

Although Model 4 reports a lower AIC value than that of Model 3e, the weather indices may be correlated in this model. After calculation, we find that the average temperatures of the three seasons are highly correlated with each other (Table 3.5). This may be the reason why the effect of the summer temperature becomes weaker in Model 4.

3.7.3 Technical Efficiency Analysis

In order to analyze whether the technical inefficiency of rice production is present, we propose the following hypothesis:

$$\gamma = \varphi = 0$$

where φ is the variance parameter of the efficiency model, and γ is a vector of parameters of the factors influencing technical efficiency. This null hypothesis states that technical inefficiency is not present in the model.

Following Battese and Coelli (1995), we conduct a likelihood-ratio test to compare the models with and without inefficiency based on Model 2e and 3e. The results presented in Table 3.4 indicate that the null hypothesis was rejected at the 5% level in both models and indicate that technical inefficiency is existent in the two models. It also indicates that although the individual effects of the variables in Model 3e are not significant, the combining effects of the infrastructural, community, and household characteristics contribute to the technical efficiency of rice production.

The average technical efficiency scores for the extreme weather and average weather models are quite similar across the studied years. For example, in the year 2003, the mean of technical efficiency scores is around 0.637 for the extreme weather model, and around 0.627 for the average weather model. This section will discuss the technical efficiency scores based on the former model which has a slightly lower AIC value.

As reported by Table 3.7.1, the technical efficiency scores range from 0.024 to 0.885 in year 2003 and from 0.019 to 0.911 in year 2010. This indicates that all households operated at least 2.4% and 1.9% below their respective mean efficiency levels in year 2003 and 2010.

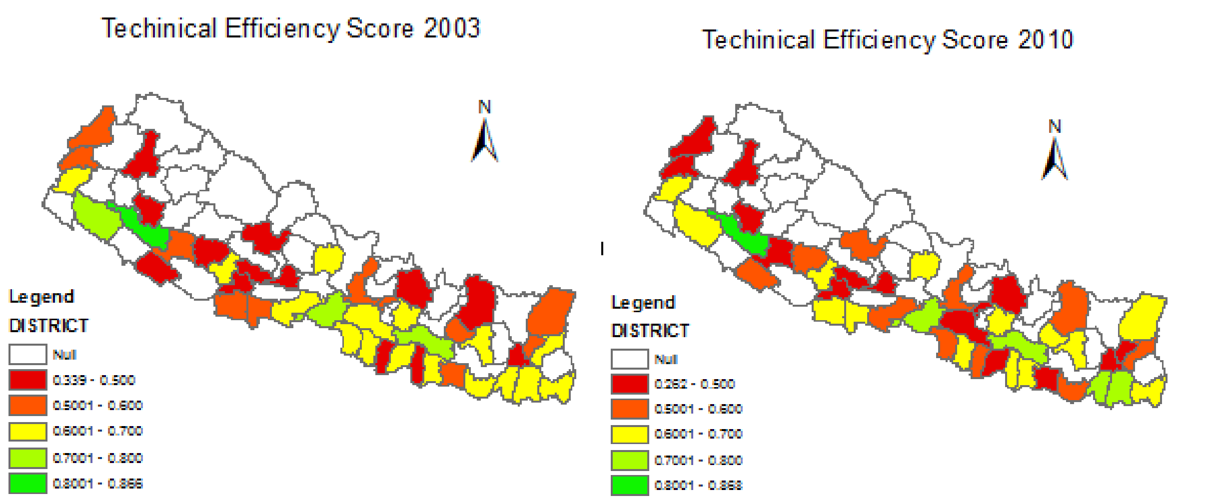
Table 3.7.1 Frequency distribution of technical efficiency of households in Nepal

Efficiency Score	Year 2003		Year 2010	
	No. of households	Percentage	No. of households	Percentage
0-0.5	73	0.159	92	0.203
0.5001-0.6	63	0.137	60	0.132
0.6001-0.7	125	0.272	99	0.219
0.7001-0.8	150	0.327	167	0.369
>0.8	48	0.105	35	0.077
Mean	0.637		0.622	
Max	0.885		0.911	
Min	0.024		0.019	
Total	459		453	

Source: Author calculation

In both years, fewest households have technical efficiency scores above 0.8. Only 10.5% and 7.7% of households achieved this high efficiency in 2003 and 2010. Moreover, the percentages of households whose technical efficiency scores are between 0.5 and 0.6 remain at the same level across the two years (i.e., 13.7% and 13.2%). The first slight difference is that the number of households whose technical efficiency scores below 0.5 increases in 2010 (from 15.9% to 20.3%), the second one is that the percentage of households with scores between 0.7 to 0.8 climbs from 32.7% in 2003 to 36.9% in 2010.

We also calculate the average technical efficiency scores of households at the district level. The technical efficiency scores at the district level range from 0.339 to 0.866 in the year 2003 and from 0.262 to 0.868 in the year 2010. As shown by Figure 3.5, among the 44 districts covered in the sample, 12 of them have scores improving to a better level in 2010, and 13 of them slip back to a worse level. For example, the biggest improvement is in the Mahottrari district, which improves from a level under 0.5 in 2003 to a level of 0.6~0.7 in 2010. Moreover, five districts improve from a level of 0.5~0.6 to a level of 0.6~0.7. However, the score of Kailali located in the Terai belt, becomes much lower in 2010. Finally, only Surkhet, which is located in the Terai belt, has a technical efficiency score of over 0.8 in both years.



Source: Authors' Calculation.

Figure 3.5 Technical Efficiency Score in 2003 and 2010

3.8 Conclusions

In this chapter, we utilize a Spatial Frontier Production Model based on a Cobb-Douglas function to analyze effects of climate change on rice production, and investigate the factors affecting technical efficiency of food production using the time-varying model with panel data from NLSS. This study contributes to the previous literature by considering climate condition as inputs within the Stochastic Frontier Production framework. It is also innovative in that it uses spatial filtering technique to capture the spatial effects caused by climate conditions.

We find that rainfall variation during the cropping season and the increase in the monsoon temperature lead to significant reduction in rice production. The results confirm the findings of the first chapter, and further indicate that households in rural Nepal are threatened by climate change. The danger of climate change is above significance since rain-fed rice is a primary food source and income in this country. We propose that rice farmers should be educated and trained to be experienced in managing climate risks to mitigate their vulnerability.

The study has also revealed that households in Nepal are not fully technically efficient in rice production. We find that river, road, agricultural extension service, and the education level and gender of the household head are factors influencing technical efficiency of rice production. These findings indicate that there is improvement for rice production in rural Nepal. An effective starting point to improve technical efficiency would be to integrate into farm, government, and community to raise farm households' capacities. On the one hand, the contribution of road network and river system indicates the benefits of infrastructural construction and water availability. We recommend that Nepalese government should help organize the infrastructure and irrigation development. On the other hand, community government should consider develop community social capital, which could be provided through agricultural extension service to farmers.

Table 3.1 Summary Statistics of Chapter 3

Variable	Definition	Mean	Standard Deviation	Minimum	maximum
Dependent Variables					
Rice	Quantity of rice production (in Kilogram)	1869.7	2255.091	19.2	14929.6
Independent Variables					
Labor	Input of cost of labor in the household (in logarithm)	4.711	4.176	0	12.143
Capital	Input of cost of capital in the household (in logarithm)	4.913	3.230	0	11.149
Fertilizer	Input of cost of fertilizer in the household (in logarithm)	6.085	3.138	0	11.562
Seed	Input of cost of seed in the household (in logarithm)	3.780	3.291	0	9.881
Port_irrig	Input of irrigation. Portion of land irrigated.	0.572	0.430	0	1
Land	Input of amount of land in the household (in logarithm)	-.0.814	1.118	-6.158	2.411
Temp32	Percentage of days in which maximum temperature exceeds 32℃ over 1971 to 2008 (at the district level)	0.259	0.240	0	0.814
Var_rain	Percentage of days in which average rainfall exceeds triple of standard deviation over 1971 to 2008 (at the district level)	0.032	0.013	0.007	0.072
Sumrain	Average monsoon rainfall over 1971 to 2008 at the district level (June to August)	18.569	8.553	5.626	30.014
Sumtermp	Average monsoon temperature at the district level over 1971 to 2008 (June to August)	26.484	3.515	19.471	30.014
Female	Dummy variable. Coded as 1 if gender of household head is female, 0 otherwise	0.147	0.354	0	1
Read	Dummy variable. Indicator for education. Coded as 1 if household head can read, 0 otherwise	0.541	0.499	0	1
Socialcap	Indicator of social capital. The extent of a farming group at the district level	0.508	0.582	0	2.540
Agri_exten	Dummy variable. Coded as 1 if there is agricultural extension service existing in the ward, 0 otherwise	0.108	0.310	0	1
River	Total length of river at the district level (in kilometer)	821.316	307.625	281.8	1607.3
Road	Total length of road at the district level (in kilometer)	558.978	199.83	26.456	1143.74
Observation	912				

Data source: Nepal living standard survey 2003/2004 and 2009/2010, Nepal shape files.
Note: the summary statistics are average values of panel data.

Table 3.2 Estimation Results (Extreme Climate Indices)

		Model 2a	Model 2b	Model 2c	Model 2d	Model 2e
	Basic Frontier Production Model					
Inputs	Labor	0.029***	0.029***	0.032***	0.032***	0.033***
		(0.008)	(0.008)	(0.008)	(0.008)	(0.007)
	Fertilizer	0.113***	0.110***	0.108***	0.11***	0.109***
		(0.011)	(0.011)	(0.010)	(0.010)	(0.010)
	Seed	0.016*	0.011	0.019**	0.018**	0.015*
		(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
	Capital	0.052***	0.053***	0.040***	0.040***	0.039***
		(0.010)	(0.010)	(0.010)	(0.010)	(0.009)
	Port_irrig	0.368***	0.371***	0.405***	0.383***	0.391***
		(0.072)	(0.071)	(0.066)	(0.064)	(0.064)
	Land	0.892***	0.888***	0.923***	0.924***	0.912***
		(0.088)	(0.088)	(0.079)	(0.080)	(0.078)
Climate	Temp32		-0.012	-0.097	-0.033	-0.051
			(0.187)	(0.167)	(0.153)	(0.165)
	Var_rain		-29.484**	-23.235***	-27.527***	-27.583**
			(11.405)	(9.124)	(9.015)	(9.485)
	E3		0.676**	0.748***	0.713***	0.693***
			(0.232)	(0.193)	(0.184)	(0.190)
	Time	-0.105	-0.090	-0.152	-0.125	-0.117
		(0.104)	(0.124)	(0.079)	(0.068)	(0.074)
	Constant	5.847***	6.799***	6.569***	6.716***	6.713***
		(0.113)	(0.387)	(0.306)	(0.310)	(0.322)
	Technical Inefficiency Model					
Infrastructure	River			-7942.200	-7374.100	-8666.100*
				(7162.700)	(5064.300)	(5005.600)
	Road			-3310.400	-2856.600	-3939.500*
				(2985.100)	(1960.700)	(2272.100)
Community	Socialcap				-205.780	-219.790
					(140.710)	(161.280)
	Agri_exten				-265.260	-75.339***
					(180.590)	(25.051)
Household	Female					644.170
						(435.860)
	Read					-96.682***
						(36.687)
	Constant2			-276.160	-265.260	-75.339
				(262.420)	(180.590)	(25.051)

Variance Parameters	SigmaSq	1.268***	1.213***	1066.300	1203.300	1085.9*
		(0.146)	(0.144)	(944.370)	(821.720)	(632.450)
	Gamma	0.600***	0.581***	0.992***	0.993***	0.992***
		(0.055)	(0.059)	(0.001)	(0.001)	(0.001)
	Log-likelihood	-1148.834	-1141.331	-1128.152	-1116.501	-1109.308
	AIC	2319.669	2310.662	2290.304	2271.003	2250.616
	N	921	921	912	912	912

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Numbers in the parentheses are standard deviations. The rice production and inputs except for portion of irrigated land are in logarithm. The river and road variables are in logarithm divided by 100.

Table 3.3 Estimation Results (Average Rainfall and Temperature during Monsoon Season)

		Model 3a	Model 3b	Model 3c	Model 3d	Model 2e
	Basic Frontier Production Model					
Inputs	Labor	0.029***	0.030***	0.033***	0.034***	0.034***
		(0.008)	(0.008)	(0.008)	(0.008)	(0.007)
	Capital	0.052***	0.051***	0.038***	0.037***	0.037***
		(0.010)	(0.010)	(0.009)	(0.010)	(0.010)
	Fertilizer	0.113***	0.103***	0.101***	0.103***	0.102***
		(0.011)	(0.011)	(0.010)	(0.010)	(0.010)
	Seed	0.016**	0.009	0.016*	0.015*	0.013**
		(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
	Port_irrig	0.368***	0.345***	0.373**	0.352***	0.358*
		(0.072)	(0.072)	(0.064)	(0.064)	(0.063)
	Land	0.892***	0.902***	0.936***	0.938***	0.927***
		(0.088)	(0.088)	(0.077)	(0.079)	(0.078)
Climate	Sumrain		0.004	0.020	-0.013	0.013
			(0.032)	(0.033)	(0.031)	(0.029)
	Sumrain_sq		-0.0003	-0.001	-0.001	-0.001
			(0.0008)	(0.001)	(0.001)	(0.001)
	Sumtemp		-0.491***	-0.458***	-0.484***	-0.480***
			(0.214)	(0.159)	(0.169)	(0.157)
	Sumtemp_sq		0.010**	0.010***	0.010***	0.010***
			(0.004)	(0.003)	(0.003)	(0.003)
	E3		0.819***	0.852***	0.849***	0.832***
			(0.242)	(0.190)	(0.197)	(0.199)
	T	-0.105	0.021	0.002	0.063	0.071
		(0.102)	(0.186)	(0.171)	(0.176)	(0.164)
	Constant1	5.847***	11.488***	10.915***	11.287***	11.229***
		(0.113)	(2.604)	(21.915)	(2.040)	(1.883)
	Technical Inefficiency Model					
Infrastructure	River			-5145.500	-2039.600	-4326.400
				(4613.400)	(1671.000)	(3126.800)
	Road			-2195.400	-829.130	-2085.200
				(1966.700)	(678.200)	(1506.200)
Community	Socialcap				-64.156	-104.050
					(54.386)	(71.419)
	Agri_exten				-164.140	-196.330
					(127.650)	(136.120)
Household	Female					411.360
						(286.500)
	Read					-69.142
						(50.410)
	Constant2			-657.720	-164.140	-196.330*

				(577.260)	(127.650)	(136.120)
Variance Parameters	SigmaSq	1.404***	1.202***	1030.900	470.930	776.920
		(0.127)	(0.141)	(914.260)	(376.320)	(552.780)
	Gamma	0.641***	0.583***	0.998***	0.989***	0.993***
		(0.042)	(0.058)	(0.002)	(0.002)	(0.034)
	Log-likelihood	-1148.834	-1138.601	-1124.202	-1112.69	-1105.24
	AIC	2319.669	2309.202	2286.404	2267.38	2256.480
	N	921	921	912	912	912

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Numbers in the parentheses are standard deviations. The rice production and inputs except for portion of irrigated land are in logarithm. The river and road variables are in logarithm divided by 100.

Table 3.4 Estimation Results (Average Rainfall and Temperature during Cropping Season)

	Model 4						
	Basic Frontier Production Model				*Technical Inefficiency Model*		
		Coefficient	S.E			Coefficient	S.E.
Inputs	Labor	0.036***	0.007	Household	River	-2670.700	2720.200
	Fertilizer	0.101***	0.011		Road	-1454.200	1480.400
	Seed	0.010	0.009	Community	Socialcap	-59.868	63.109
	Capital	0.039***	0.010		Agri_exten	-277.500	273.860
	Port_irrig	0.313***	0.063	Infrastructure	Female	360.170	374.680
	Land	0.885***	0.076		Read	-80.120	76.481
Climate	Spmrain	-0.018	0.381		Constant2	-277.500	273.860
	Spmrain_Sq	0.031	0.107				
	Spmtemp	0.826***	0.218				
	Spmtemp_Sq	-0.019***	0.005				
	Sumrain	0.008	0.038				
	Sumrain_Sq	0.000	0.001				
	Sumtemp	-0.210	0.512				
	Sumtemp_Sq	0.006	0.009				
	Fmrain	0.470***	0.087				
	Fmrain_Sq	-0.024***	0.005				
	Fmtemp	-1.180**	0.553				
	Fmtemp_Sq	0.022**	0.011				
	E3	0.517**	0.255				
	Time	-0.017	0.190				
	Constant1	12.487***	2.862				
Variance Parameters	SigmaSq	701.450	699.740				
	Gamma	0.996***	0.000				
	Log-likelihood		-1079.528				
	AIC		2221.055				
	N		912				

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. The rice production and inputs except for portion of irrigated land are in logarithm. The river and road variables are in logarithm divided by 100.

Table 3.5 Correlation between the average temperature during cropping season

	Spring Temperature	Summer Temperature	Fall Temperature
Spring Temperature	1	0.91	0.91
Summer Temperature	0.91	1	0.99
Fall Temperature	0.91	0.99	1

Source: Authors' Calculation.

Table 3.6 Technical Inefficiency Tests

	Null Hypothesis	Chi-square Value	Conclusion
Model 2e	No inefficiency effect ($\gamma = \varphi = 0$)	94.769	Reject Null
Model 3e	No inefficiency effect ($\gamma = \varphi = 0$)	101.31	Reject Null

Source: Authors' Calculation.

Chapter 4: Farmers' Perception of Climate Change and Willingness to Pay for Weather Index-Based Insurance in Bahunepati, Nepal

4.1 Introduction

Driven by the results in the previous two studies, we use the primary data collected from a household survey conducted in Bahunepati, Nepal to examine the effective mechanism to cope with climate change. We focus on analyzing the factors affecting farmers' willingness to pay (WTP) for the crop insurance products. We randomly selected 353 households to interview with an overall response rate of 72% for the survey. We designed two insurance products: Product A insures rice, and Product B adds five main livestock. This chapter is the first study that considers both crop and livestock in the research of studying weather index-based insurance. It also contributes to the literature by taking into account the rainfall distribution instead of total rainfall during the cropping season in the design of the insurance policy.

We construct two dependent variables in the model, willing to pay for Product A and B, and use a Biprobit method to estimate the two models simultaneously. The main independent variable of interest in the study is farmers' perception of climate change. We use two variables to measure this, perception of future climate change (ex-ante perception) and perception of past impacts of climate change (ex-post perception)[14]. Other factors influencing farmers' decision include existing adaption strategies, the amount of bids, gender, education level of the household head, household income, farming experience, etc. (Seo and Mendelsohn, 2008; Mertz et al., 2008; Deressa et al., 2009).

[14] For the following content of this chapter, we use Ex and Post Models for the abbreviation of the models with ex-ante perception variable and ex-post perception variable, respectively.

Estimation results indicate that people who perceive the continuity of climate change or experience adverse impacts of climate change tend to positively respond to the program. The results also show that the effects of other adaption strategies crowd out individuals' desire of the insurance mechanism. In addition, we find that females are equally in favor of the insurance products but less likely to purchase the products compared to males. This may suggest that women are less powerful in the decision-making of purchasing insurance products. Finally, we find that household income and respondents' education level positively affect WTPs while farming experience and household size have opposite effects.

With respect to the amount of WTP [15], we find that the median WTP for Product A is significantly lower than that of Product B in both Ex-ante and Ex-post models. Specifically, the median WTP for Product A is around 1,326 NRs[16] (1.28% of income) in the Ex-ante model while 1,400 NRs (1.36%) in the Ex-post model. In addition, the median WTP for Product B is around 2,342 NRs (2.27%) in the Ex-ante model and 2,207 NRs (2.14%) in the Ex-post model. Finally, the counterfactual analysis shows that males who perceive continuity of climate change will pay the highest amount for the insurance products while females who do not perceive continuity of climate change will pay the least amount.

4.2 Literature Review

While numerous literature focuses on the impacts of climate risk on farmers' willingness to pay, scholars also state that farmers' attitudes toward adaptation strategies largely depend on their perception about climate change (Gbetibouo, 2009). Numerous articles have studied this topic in the past decade (e.g., Mertz et al., 2008; Gbetibonu, 2009; Marc, 2011). Among the previous

[15] The amount of willingness to pay refers to the annual median amount in this chapter.
[16] One US dollars is approximately equal to 98 Nepalese Rupees (NR).

literature, they adopt various indicators for perception of climate change such as the perception about the trend of historical temperature and rainfall (Seo and Mendelsohn, 2008; Mertz et al., 2008; Deressa et al., 2009), perception about the previous impacts of climate change, perception about the future climate change (Akter and Bennett, 2012), among others. And conclusions suggest that the perception of future climate change is positively related to the use of any adaptation strategy (Marc, 2011). Instead of focusing on traditional mitigation strategies, this chapter analyzes a more effective adaptation tool, weather index-based insurance. To the authors' knowledge, this is a pioneering study examining the relationship between perception of climate change and weather index-based insurance in Nepal.

Other factors, such as agricultural extension service, age, farm size, and so on, are also controlled for to investigate farmers' willingness to pay for the weather index-based insurance (Abdullah, 2014). For example, a recent study about cocoa insurance in Nigeria finds that the availability of agricultural extension service is a favorable factor for the insurance (Falola et al., 2013). Ramasubramanian (2012) studies the weather insurance with coverage of all crops, taking India as a case study. The paper divides the willingness to join into four categories, definitely, rather, rather not, and definitely not willing to join (WTJ). She first uses an Ordered Probit method to estimate the WTJ model, and finds that age and mathematically literacy significantly affect respondents' WTJ. The results of the estimation of WTP with an interval regression model show that individual risk aversion level is the most important factor affecting individuals' decision making. The author also confirms that more risk-averse people is more likely to purchase the product, which iss opposite to the results in Gine et al. (2009)'s study in Rural India. Another example is from Abebe and Bogale (2014). Like Ramasubramanian (2002), they also start with a screening question before they propose the WTP question to the respondents when they study the insurance in Ethiopia. The authors use a Tobit method to estimate the model and find that agricultural income, information access, as well as public and private aid positively affect respondents' willingness to pay for the crop insurance.

4.3 Theoretical Model

The theoretical framework developed in this chapter follows the work of Long et al., (2013). Suppose U_0 and U_1 are the utility levels associated without and with the crop insurance for a farmer, respectively. The original utility level, U_0, is affected by the individual's income level (Y_0), the price (p_0) of a vector of goods (q_0), and a vector of the demographic characteristics (Z). On the other hand, U_1 is affected by the new income level after purchasing the insurance (Y_1), the price (p_0) of a vector of goods (q_0), the price (WTP) of the insurance (I), and a vector of the demographic characteristics (Z). Intuitively, the new income (Y_1) is equal to the original income subtracting the price of insurance, that is, $Y_1 = Y_0 - WTP$. The new vector of goods owned by an individual after purchasing the crop insurance, that is, q_1 is equal to q_0 plus the insurance product. The individual will purchase the insurance if his/her new utility is not lower than the original utility.

$$U_0(Y_0, p_0, q_0, Z) \leq U_1(Y_0 - WTP, p_0, q_1, Z) \quad (4.1)$$

We rewrite Equation (4.1) as of the following form:

$$U_0(Y_0, p_0, q_0, Z) \leq U_1(Y_0 - WTP, p_0, q_0 + 1, Z) \quad (4.2)$$

And the probability that the individual purchasing the insurance is equal to the probability that Equation (4.2) holds:

$$\Pr(yes) = \Pr(U_0(Y_0, p_0, q_0, Z) \leq U_1(Y_0 - WTP, p_0, q_0 + 1, Z)) \quad (4.3)$$

Households purchase agricultural insurance to protect them from the loss against climate change or other natural disasters, and payout will be made when the coverage condition is met. This means that households will get pay (G) which is associated with a potential loss (L). Therefore, Equation (4.2) could be revised as:

$$U_0(Y_0, p_0, q_0, Z) \leq U_1(Y_0 - WTP + G - L, p_0, q_0 + 1, Z) \quad (4.4)$$

So the probability of purchasing insurance is:

$$\Pr(yes) = \Pr(U_0(Y_0, p_0, q_0, Z) \leq U_1(Y_0 - WTP + G - L, p_0, q_0 + 1, Z) \quad (4.5)$$

We derive our econometric estimation model based on Equation (4.5):

$$\Pr(yes) = f(Y, p, L, Z) \quad (4.6)$$

Equation (4.6) indicates that households' willingness to pay is determined by the household income, the price of the insurance (bid), the loss suffered from climate change or natural disaster, and a vector of household characteristics. Except for the loss, other factors are straightforward to measure. In this study, we use the perception about climate change to as an indicator of L.

4.4 Survey Design

4.4.1 Study Area

This is a pilot study about weather index-based crop insurance conducted in a small village, Bahunepati, Nepal. The village is located in the Sindhupalchok district in the Hill Belt, and owns 9 wards. As of 2013, the number of households living in Bahunepati was 1096. Among a total population of 5703, 2873 were males (50.38%). In addition, it has a total area of 14.92 square kilometers, with an average latitude and longitude of 27.79 and 85.58 degree, respectively.

Farming is the main income generating activities in this area, contributing to the primary income source for around 88.8% of households. Crop-livestock mixed farming system is the main agricultural characteristic in Bahunepati. Among the five common crops, rice, millet, maize, wheat, and vegetables, rice is the widest grown crop. Goats, cows, buffalo, ducks, and chicken are the most important livestock raised by households.

4.4.2 Methods of sampling and data collection

We used three stages to select the sample. In the first stage, one third of households (353 households) covering all nine wards was decided to ensure a powerful sample size. Since the number of households in a ward is not evenly distributed, we selected one third of households in each ward ranging from 19 to 65 households in each ward in the second stage. Finally, a starting household was randomly selected in each ward. Afterwards, every third household was interviewed to ensure a representative sample.

The data was collected using a primary survey developed by the authors using the face-to-face interview method. The response rate is 72% for the whole survey and 100% for the bid questions. Ten well trained enumerators who spoke native Nepalese were hired to collect the data. The whole process was supervised and guided by the authors by communicating with a coordinator in Dhulikhel Hospital (Kathmandu University). The data collection process lasted for 8 weeks, from late August to late October, 2014. Afterwards, the enumerators spent four weeks on data entry, and finished the whole data collection process in late November, 2014.

There are two components of data collection, main survey and an experimental lottery game which was designed to test for individuals' risk tolerance level. In order to avoid bias in the bid answers due to the payout from the lottery game, the experiment was conducted after the survey questions.

4.4.3 Insurance Design

The whole survey covers ten sections, including demographic, social network, food security, farming, climate change, health, violence, saving, and the risk aversion lottery game. We used a popular method used to estimate the values of nonmarket goods (Yadavetal, 2012), the Contingent Valuation (CV) method to design the WTP questions. We also designed two insurance products in the survey: Product A only insures rice and B adds five common types of livestock, including buffalo, cows, goats, chicken, and ducks.

When we designed the insurance policies, we took account four key elements: amount of payoff, bids, cropping season, and cumulative rainfall level. The process of obtaining a reasonable criterion of each element is provided in Appendix D. And a brief description of the survey question is provided in Figure 4.1:

Weather index-based Crop Insurance

Objective: This insurance product is designed to protect farmers against deficient/excess cumulative rainfall during a cropping season

Coverage: This policy protects farmers against deficient/excess cumulative rainfall during a cropping season. If there is continuous heavy rainfall for 10 days or continuous no rainfall/little rainfall for 30 days, during the crop vegetative phase (months *March* to *June* and *July* to *November* after sowing), a payout would be made to the farmers. (In order to make the amount of rainfall more objective and easier to measure, the rainfall data is based on the record of the closest weather station to your village instead of the rain fell on your field. The standard is "if the rainfall for any 10 consecutive days is cumulatively above 120 millimeters or any 30 consecutive days is cumulatively below 10 millimeters).

Payout: For Product A, NPR 10000 per Ropani per year insured

For Product B, 10000 NPR per Ropani insured, 8100 NPR per cow insured, 26000 per buffaloes insured, 3800 per goat insured, and 380 per poultry (including ducks and chicken) insured.

Bids: NPR 100, 200, 350, 500, 700 and 1200

Figure 4.1 Description of the Weather index-based Crop Insurance

4.5 Data Description and hypotheses

In this section, we focus on introducing households' willingness to pay for the weather index-based crop insurance, which is used as the dependent variables in the econometric model.

4.5.1 Willingness to pay for the crop insurance

We have six bids, which were randomly selected by enumerators to propose to interviewers, for both Product A and B. Reflected by Figure 4.2, the proportion of saying yes to all bids of Product A is 76.1%. Comparatively, a relatively higher proportion of saying yes to Product B (77.7%) is reported. The numbers indicate that the bids may be too low. They also reflect the desire of such risk management strategy by farmers, which will be further discussed in the next subsection.

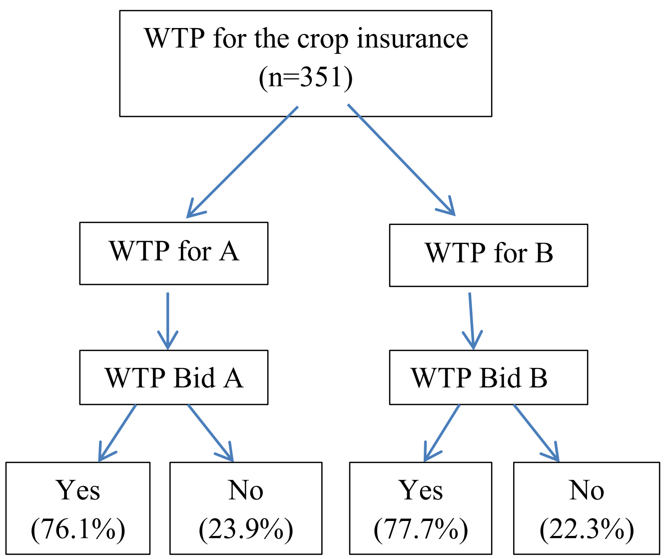


Figure 4.2 Willingness to pay for the weather index-based farming insurance

Figure 4.3 shows downward-sloping demand curves for the insurance products. It indicates that as the amount of bids increases, the probability of purchasing the insurance products decreases. It also displays that more respondents maintain a positive attitude toward Product B as the bid increases. Overall, the answers of respondents are consistent.

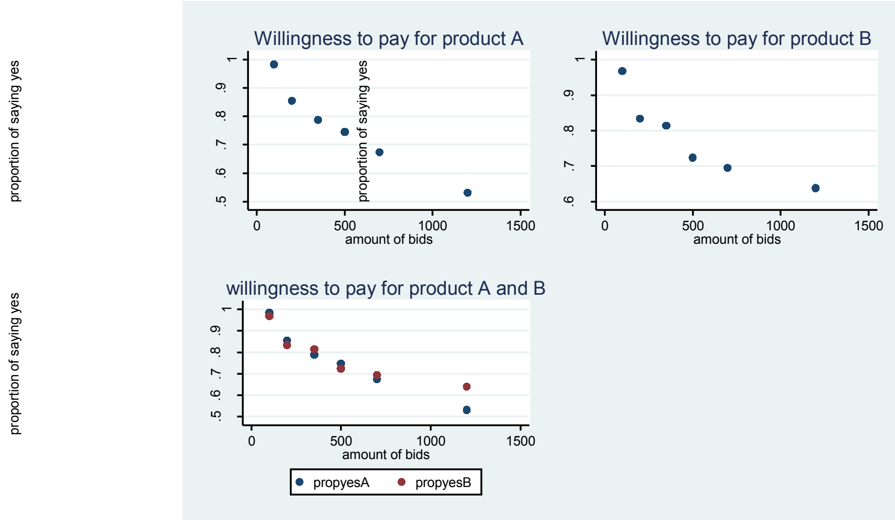


Figure 4.3 Willingness to pay for the weather index-based farming insurance

4.5.2 Preference of the insurance

Following the WTP questions, we asked the respondents their preference about the insurance. A question was proposed, "Do you think this weather index-based micro insurance program presented above is the best way to deal with the climate impact?" Respondents could choose from yes, somewhat, no, and don't know. Shown by Figure 4.4, a considerable proportion of respondents hold positive attitudes to the insurance (71.1% of respondents say yes and 16.2% of them say somewhat). Only a small proportion of them (12.7%) does not like this mechanism or do not know.

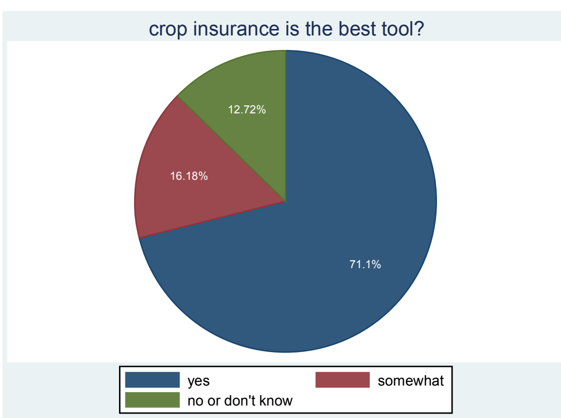


Figure 4.4 Crop insurance is the best tool

4.5.3 Independent variables

4.5.3.1 Households' perception of climate change

In the survey, we design two types of perception of climate change, ex-ante and ex-post perception. The ex-ante perception is constructed using the information that how household perceive climate change in the next 10 years. We first provide some background of the trend of rainfall and temperature in Nepal, and then ask respondents how they think that climate change is going to continue in the next 10 years if nothing is done to prevent it. Although Bahuneptati is a village vulnerable to climate change, especially drought, a relatively small portion of them perceives the continuity of climate change (31.27%). Given the fact that climate change is existent, ex-ante perception is also considered as an indicator for awareness of climate change in this study.

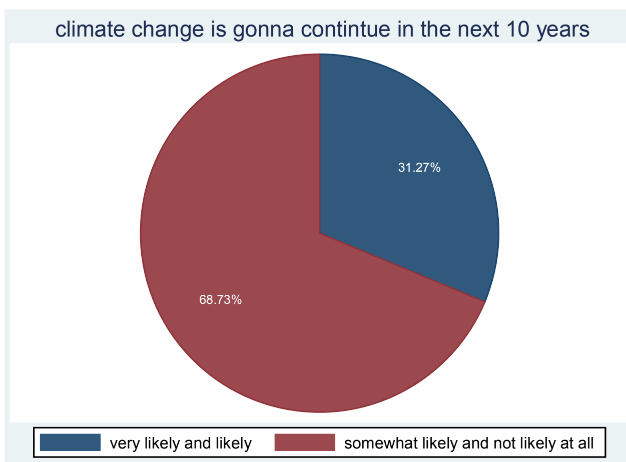


Figure 4.5 Respondents' perception about climate change

As to the ex-post perception, we use the information of past impacts of climate change to construct the variable. We proposed some statements about the impacts of climate change on households' livelihood in the past 5 years, and asked their degree of agreement on the statement. In this chapter, we focus on the agriculture-related impacts, including the impacts on weeds and pests on the fields and shortage of water and irrigation system. We sum up these two variables to construct a final index, ranging from 1 to 10. A mean of around 8 for the variable reflects that most households perceive that climate change caused impacts on their agricultural activities.

We hypothesize that the higher degree that households perceive climate change, the more likely they will be willing to pay for the insurance. Therefore, we propose the first hypothesis as followings:

Hypothesis 1:

$$\beta_{pclimate} > 0$$

$$\& \ \beta_{impclimate} > 0$$

where $pclimate$ is ex-ante perception, and $impclimate$ is ex-post perception.

4.5.3.2 Other Common Adaption Strategies

Among the 353 households (Figure 4.5) interviewed, 164 of them adopted at least one mitigation strategy (46.46%), and 189 of them didn't adopt any adaptation strategy (53.54%). A follow-up question about the type of strategies show that the common strategies adopted in Bahunepati is planting trees, followed by soil conservation and using improved seed. Very few households switched to different crop varieties and planted shorter cycle variety to cope with climate change (Figure 4.6). In addition, only 2 households out of 164 adopted 3 strategies, 16 of them adopted 2 types of strategies, and 146 of them only adopted one strategy.

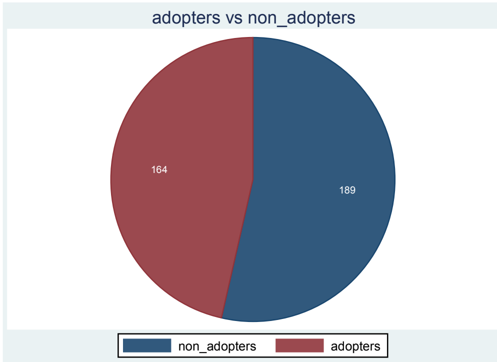


Figure 4.6 Adapters versus Non_adapters

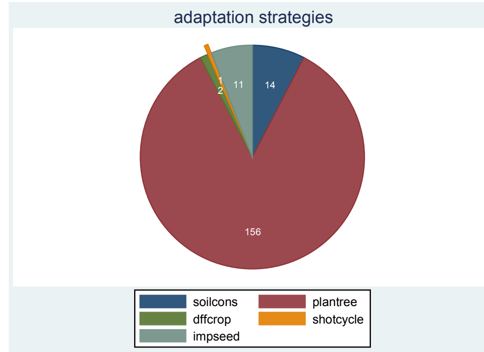


Figure 4.7 Distribution of common adaptation strategies

Hess (2003) suggests that crop insurance can serve as an important alternative ex-ante risk management tool for farmers to cope with climate change or natural hazards. Moreover, households who have identified more coping methods are more inclined to continue their own ways of coping, and thus will more likely to refuse to purchase the insurance (Ramasubramanian, 2012). Therefore, we propose that there will be some crowding-out effects.

Hypothesis 2:

$$\beta_{adapt} < 0$$

where $adapt$ is the dummy variable that if the household has adopted any adaptation strategies.

4.5.3.3. Gender Effect

Another focus of this chapter is analyzing the gender effect. We expect the gender effects from two points of view. On the one hand, women are more vulnerable to climate change and less capable to mitigate effects of climate change, which induces their tendency to adopt effective mechanism facing climate change (UNEP, 2004). From this perspective, we expect that women will more positively respond to the weather index-based insurance program. On the other hand, due to their lower social-economic status, women are less likely to participate in decision-making activities such as purchasing the insurance products. Overall, the effect of gender is ambiguous.

Hypothesis 3:

$$\beta_{female} ? 0$$

4.5.3.4 Other Control Variables

We also control for other variables including household income, household size, caste of household, education level, farming experience of the head of household, and household farming activities.

Table 4.1 illustrates the summary statistics and definitions for all variables. With respect to household income, we create two categories: 1 if household who earns a monthly income greater than 5000 NRs, and 0 otherwise. After calculation, households' average monthly income is around 10,300 NRs. We also regroup the caste into two categories: 1 if the household is Brahmin or Chherti which is a higher caste in Nepal, and 0 otherwise. For farming experience, we use the age of the head of household as an indicator. Another variable needs attention is the farming activities. Most of households focus on agricultural activities in Bahunepati. Around 85.3% of households grow paddy and 92.4% of them raise livestock.

4.6 Empirical Methodology and Models

4.6.1 Bivariate Probit Model

We use two dependent variables, whether a household is willing to pay for Product A (*WTPA*) and B (*WTPB*). Considering the correlation between two WTPs, we use a bivariate probit (Biprobit) method to jointly estimate the models.

Let y_1^* and y_2^* represent individuals' decisions of purchasing the two crop insurances. Each is generated by a probit equation and impacted by a set of variables. Moreover, the error term of each Probit model is correlated with each other.

$$y_1^* = X_1\beta_1 + \varepsilon_1 \qquad (4.7)$$

$$y_2^* = X_2\beta_2 + \varepsilon_2 \qquad (4.8)$$

where y_j^* is unobservable, and related to the binary dependent variable y_j. The error terms, ε_1 and ε_2 are assumed by be independent, identical distribution as standard bivariate normal.

$$y_j = \begin{cases} 1 \ \ if \ y_j^* > 0 \\ 0 \ \ if \ y_j^* \leq 0 \end{cases} \text{ where j=1,2} \qquad (4.9)$$

Under the assumption that the errors terms are correlated with the correlation parameter, ρ, the Log likelihood of the biprobit model could be derived as the following form (Meng and Schmidt, 1985),:

$$\ln L(\beta_1, \beta_2, \rho) = \sum_i^N \{y_{i1}y_{i2} lnF(X_i\beta_1, X_i\beta_2; \rho) + y_{i1}(1-y_{i2})\ln[\Phi(X_i\beta_1) - F(X_i\beta_1, X_i\beta_2; \rho)] + (1-y_{i1})y_{i2}\ln[\Phi(X_i\beta_2) - F(X_i\beta_1, X_i\beta_2; \rho)] + (1-y_{i1})(1-y_{i2})\ln[1 - \Phi(X_i\beta_1) - \Phi(X_i\beta_2) + F(X_i\beta_1, X_i\beta_2; \rho)]\} \qquad (4.10)$$

For each WTP, we estimate two models, ex-ante perception of climate change and ex-post perception of climate change. We substitute y_j^* with the probability of purchasing the insurance, and X_1 with a vector of independent variables corresponding with the decision. The econometrics models are of the following forms:

$$\Pr(\mathrm{WTP}_j) = \alpha_{0j} + \alpha_{1j}Bid_i + \alpha_{2j}pclimate_i + \alpha_{3j}adapt_i + \alpha_{4j}HC_i + \epsilon_{ij} \quad (4.11)$$

$$\Pr(\mathrm{WTP}_j) = \beta_{0j} + \beta_{1j}Bid_i + \beta_{2j}impclimate_i + \beta_{3j}adapt_i + \beta_{4j}HC_i + e_{ij}$$

(4.12)

Where $pclimate$ is perception of climate change in the next 10 years. $impclimate$ is the impact of climate change on households' agriculture. $adapt$ is the dummy variable of if household adopted any adaptation strategies before. HC is a vector of households demographics, such as respondents' age, education level, gender, household income, household size, and castes. α and β are two vectors of coefficients for model A (ex-ante perception) and model B (ex-post perception). i stands for household i; j stands for model j; and ε and e are the stochastic error terms.

4.6.2 Order Effects

There are two main designs in the order effect test, including exclusive list and inclusive list. The former design refers to that the following good is an alternative/substitute to the previous good, while the latter is that each subsequent good is described to be an addition or subtraction of the previous one (Bateman et al., 2001; Andersson and Svensson, 2000). For the exclusive list design, interviewers should ask the interviewees to forget about the first product when the second one is proposed. However, this action is not necessary in the inclusive list. Moreover, since the subsequent product is an alternative of the previous one, the WTPs to the products will not be affected by the order of the question. Nonetheless, the WTPs will be affected by the question orders in the inclusive list design since the following product is nested in the previous good (Bateman et al., 2001).

We use inclusive list to design the order of the products given that Product A is a subset of Product B. This kind of nested goods is also called categorical nesting (Carson and Mitchell, 1995). The economic theories expect that individuals will get higher utility from the larger product, i.e., the WTP for A is less than B, as well as that the WTP for the same insurance product is higher when the bigger product is introduced first (Carson and Mitchell, 1995; Bateman and Langford, 1996).

In order to test for the validity of WTPs, we create two versions of surveys. In version A, Product A is proposed to the respondents before Product B, and the order is reverse in version B. Afterwards, the whole sample is randomly and equally splitted into two subsamples, with one version for one subsample. Following Bennet et al. (1998) and Bateman et al. (2001), we controlled for the version dummy in the models.

$$\Pr\left(\mathrm{WTP}_j\right) = \alpha_{0j} + \alpha_{1j}Bid_i + \alpha_{2j}pclimate_i + \alpha_{3j}adapt_i + \alpha_{4j}HC_i + \alpha_{5j}top\_down_i + \epsilon_{ij} \quad (4.13)$$

$$\Pr\left(\mathrm{WTP}_j\right) = \beta_{0j} + \beta_{1j}Bid_i + \beta_{2j}impclimate_i + \beta_{3j}adapt_i + \beta_{4j}HC_i + \beta_{4j}top\_down_i + \varepsilon_{ij} \quad (4.14)$$

Where top_down is the dummy variable, with 1 representing that Product B is introduced first, and 0 otherwise. We expect that the coefficient of top_down is positive and significant, indicating that when the larger product (Product B) is introduced first, the respondents' WTP will be higher.

4.7 Results and Discussion

4.7.1 Model Identification

The primary concern of the model is the endogeneity problem of some independent variables. First, there may be some selection problem in the *Pclimate* variable since households who are more likely to perceive future climate change are those who are more aware of climate change and hence will be more likely to adopt the mitigation strategies. Therefore, there may be some unobserved heterogeneity characteristics driving both the perception of climate change and the willingness to pay for the insurance. Another variable of concern is the dummy variable of adaptation strategies (*Adapt*). Since crop insurance has not been implemented in Bahunepati and it is a new product introduced to the respondents, it is reasonable to assume that paying for the insurance does not affect households' decision of adopting other risk management strategies. However, it is possible that *Adapt* is affected by other independent variables in the model, such as household demographics.

In order to test for the endogeneity issues, we look for the instruments which affect the variables of concern but not correlated with the WTP variables. We use the social capital index[17] and the impact of climate change on households' education as instruments of *Pclimate*, and use social capital index and the reason why household did not adopt any adaptation strategies[18] as the instruments for *Adapt*. The validities of two groups of instruments are confirmed by the over-identifying test with the p-values of 0.560 and 0.458, respectively. Moreover, the Wald-test results indicate that there are no endogeneity problems of the *Pclimate* and *Adapt* variables.[19] Therefore, we estimate the econometrics models using the regular "Biprobit" method.

[17] Farmers get news and information about adaptation strategies and climate change through the institutions they engage in (i.e., social capital). Since crop insurance is a brand new product introduced to farmers, social capital won't affect their decision about willingness to pay. We constructed a dummy variable for the social capital index. If any of the household members engage in any community groups, then the index is equal to 1, 0 otherwise.

[18] We used the reason of no time to cope with climate change to avoid that WTP is potentially affected by some other reasons, such as no money.

[19] The p-values of the endogeneity tests are 0.133 and 0.403, respectively.

4.7.2 Results

4.7.2.1 Ex-ante perception of climate change

Table 4.2 reports the estimation results of the ex-ante perception of climate change on the WTP for the crop insurance. The first model only controls for perception of climate change (*Pclimate* and *Impclimate*), the dummy variable that if the household adopts any other coping strategy (*Adapt*), and the logarithm of the bids (*LnbidA* and *LnbidB*). Model 2b adds other control variables, including household demographic and the respondent's characteristics. Model 2c controls for the dummy variable of the household agricultural characteristics, the paddy dummy (*Paddy*) and the livestock dummy (*Livestock*). Model 2d adds a dummy variable of "*top_down*" (Product B is asked first) testing for order effects. Besides, each model jointly estimates two models, WTP for Product A and WTP for Product B. The AIC reported in Table 4.2 indicates that Model 2d is the best model. Table 4.3 presents the marginal effects. Models 3a to 3d are corresponding to Model 2a to 2d in Table 4.2. In this section, we focus on interpreting the coefficients and marginal effects of the variables in Model 2d and Model 3d.

The first variable of interest is the amount of bids. The coefficients are significantly negative at the 1% level, which is robust across all models. The result shows that people are less likely to pay for the crop insurance with a higher bid. The marginal effects of the bids indicate as the amount of bid increases by 1%, the probability of purchasing Product A decreases by 20% and 14.3% for Product B. This result makes sense since Product A is a subset of Product B, and the change in bids will have a smaller effect on Product B.

Although individuals positively respond to the insurance, they may be attracted by the high pay off of the insurance other than their awareness of climate change. The estimated results of the main variable, *Pclimate*, confirm that perception of climate change is a key factor affecting WTP.

The coefficients are consistent across the four models with significantly positive coefficients. They indicates that people who perceive the continuity of climate change in the next 10 years are more likely to purchase the crop insurance, compared to those who do not think climate change will continue/happen in the future. Moreover, the marginal effects of *Pclimate* indicate that the probability of purchasing Product A is 17.9% higher for the people with climate change perception, and 15.4% for Product B. This greater probability of purchasing Product A also indicates that Product B is less sensitive to climate change perception since it provides higher protection to households.

The coefficient of *Adapt* is negative and significant at the 5% level in Model 2d. It means that there is crowding-out effect of other adaptation strategies. One explanation is that farmers are more likely to continue their existing way of coping and resistant to switching to other strategies. It may be also because that these farmers do not have enough budget for other adaptation strategies. The result indicates that purchasing the crop insurance is also considered as a risk-management mechanism by households, which supports the second hypothesis. The marginal effect of *Adapt* shows that adopting other strategies crowds out a possibility of 7.2% of purchasing Product A and 10.1% of purchasing Product B.

Another variable of interest is gender effect. The significantly negative coefficient of the *Female* variable with the marginal effects of 0.132 and 0.101 indicate that compared to males, females are 13.2% and 10.1% less likely to purchase Product A and Product B, respectively. It implies that the negative effect of women's weak empowerment overcomes the positive effect of their tendency to adopt mitigation strategies. This is probability because women own little power to control over economic resources and it limits their ability to purchase insurance. Although we control for households income, the income source is probability contributed by male. Given that the insurance mechanism is equally welcomed by women (87.1%) and men (87.3%), it further confirms our hypothesis that facing decision making, there are more barriers for females. This result is consistent with the findings in Hill et al (2011)'s paper, in which females are found to be less likely to engage in adaptation activities.

Other variables, such as *Hhsize*, *Hhinc*, *Edu*, and *Paddy*, are also consistent with our expectation. Households with one more member are 0.8% and 1.1% less likely to purchase Product A and Product B, respectively. And household with an income of less than 5,000 NRs is 13.8% and 15.8% less likely to purchase Product A and Product B, respectively. With respect to *Edu*, it positively affects individuals' decision of purchasing Product A, but not Product B. Moreover, the coefficients of the farming activities are consistent with our assumption. The negative coefficients of *paddy* and *livestock* in Model 2d indicate households which grow the paddy and raise livestock are more experienced in farming and with better skills in coping with climate change, and thus less likely to purchase the crop insurances.

The coefficients of *Top_down* report the order effect. The significantly positive coefficients indicate that respondents reported a higher WTP if they were asked Product B first. The significant coefficients are due to the inclusive-list design, and indicate that the respondents' WTPs are valid.

4.7.2.2 Ex-post perception of climate change

Table 4.4 presents the estimation results of ex-post perception of climate change. Except for the climate change perception variable, other variables are the same as the ex-ante model from Model 2a to Model 2d in Table 4.2. The AIC values reported in Table 4.4 indicate that Model 4d is of the best goodness of fit. Besides, Table 4.5 presents the marginal effects. Models 5a to 5d in

Table 4.5 are corresponding to Model 4a to 4d in Table 4.4. In this section, we also focus on interpreting the coefficients and marginal effects of the variables in Model 4d and 5d.

The variables of interest in Models 4d and 5d are the same as the ex-ante perception model expect for climate change perception variable. The estimation results for the main variables are consistent with those in the ex-ante model. With respect to the amount of bids, the result indicates that the probability of purchasing Product A will decrease by 19.4% and 14.9% for Product B if the amount of bids increases by 1%.

For the key variable*, Impclimate*, the estimated results are consistent with those in all models of Product A, with the significance level strengthening from Model 4a to 4d for Product B. Specifically, people who have suffered from climate change are more likely to engage in the insurance program. As the impacts aggravates by one level, the probabilities to purchase Product A and B rise by 5.3% and 2.6%, respectively. Moreover, the probability of purchasing Product A is greater than Product B. This is also consistent with the ex-ante model.

The effects of *Adapt* gradually strengthen from model 4a to 4d. The marginal effects of -0.066 and -0.089 indicate that the households who already adapted to climate change are 6.6% and 8.9% less likely to purchase Product A and Product B, respectively. Moreover, the estimation result of the gender effect variable is consistent and robust across all models. The coefficients are significant at the 1% level with negative signs in all models, which indicate that women are less likely to participate in the insurance program than men.

Finally, the estimation results of *Hhsize*, *Hhinc*, *Edu*, *Paddy,* and *Top_down* are similar to the ex-ante model. It should be noted that the order effect hypothesis is also supported in the model. Respondents report a higher WTP if Product B is proposed before Product A.

4.8 Post Estimation

4.8.1 Willingness to Pay Estimation

We use the routine Delta method to estimate the mean and median willingness to pays based on the results of ex-ante and ex-post models (Models 2d and 4d). As shown in Table 4.6, the mean of willingness to pay for Product A is 1,794 NRs in the ex-ante model and 1,872 NRs in the ex-post model. Moreover, the medians of the willingness to pay for Product A (WTPA) in these two models are around 1,270 NRs and 1,325 NRs, respectively. Both the means and the medians are significantly different from 0 at the 1% level.

The means and medians of WTP for Product B in the ex-ante and ex-post models are also close to each other. Specifically, in the ex-ante model, the mean of WTP for Product B is 2,935 NRs while the median is 2066 NRs. Moreover, in the ex-post model, the mean of WTP is 3,156 NRs while the median is 2,221 NRs. However, the amount of WTPs may be underestimated due to the low bids proposed to interviewees.

We also calculate the proportion of the median WTPAs to income. After calculation, the ratios are 1.28% in the ex-ante model and 1.36% in the ex-post model. The proportion of WTPB is slightly higher than that of WTPA. Specifically, the median willingness to pay for B is 2.27% for ex-ante model and 2.14% for ex-post model.

In addition, we use the Wald test to test the null hypothesis that WTJA is equal to WTJB ($H_0: WTJA = WTJB$), versus the alternative hypothesis that WTJA is less than WTJB. We conduct the test for both the ex-ante and ex-post models. And we reject the null hypothesis with a p value of 0.000 in both models. It is concluded that households are more willing to pay for the insurance with the combination of paddy and livestock. The result makes sense when we consider that Product A is nested in Product B. And the utility that households obtain from Product B is be higher than that from Product A.

4.8.2 Counterfactual Analysis

We conduct the counterfactual analysis focusing on the future perception of climate change and gender effect in this section. The analysis is to estimate individuals' highest level of willingness to pay under several hypothetical scenarios. Specifically, we consider the change in the probabilities of saying yes to both insurance products and the median amount they are willing to pay assuming that: 1) all individuals are female versus males (*Female*=1 vs. *Female*=0); 2) all individuals are aware of climate change versus not (*Pclimate*=1 vs. *Pclimate*=0). Afterwards, we consider the combination of the above two scenarios: 3) all individuals are female and do not perceive the continuity of climate change (*Female=1, Pclimate=0*); 4) all individuals are female and do perceive the continuity of climate change (*Female=1, Pclimate=1*); 5) all individuals are male and do not perceive the continuity of climate change (*Female=0, Pclimate=0*); 6) all individuals are male and perceive the continuity of climate change (*Female=0, Pclimate=1*).

The probabilities and amount of counterfactual WTPs are estimated based on the final models (2d and 4d) with the "Margins" and "Delta" methods. We find that females are less likely to pay for the insurance products compared to males, holding everything else constant (76.5% versus 89.4%). The differences in median WTPA and WTPB between female and male are 1,033 NRs and 1,943 NRs, respectively. Moreover, people are more willing to engage in the insurance program if they perceive the continuity of climate change in the future (68.6% versus 86.6%). With respect to the latter four cases, we find that females who do not perceive the continuity of climate change in the future are least likely to purchase the insurance products (61.6%). The amount of WTPA and WTPB is 566 and 776 NRs, respectively. Comparatively, they are willingness to pay 1,268 and 2,121 NRs for Product A and B, respectively, if all of them perceive the continuity of climate change in the future. The highest probability and amount of WTPs is generated by males with the perception of future climate change. Under this scenario, they are willing to pay 2,598 and 4,782 NRs for Product A and Product B, respectively (Figure 4.7).

Although the interviewees were living in the same village where there was little climate variation across the area, their perception of climate change may be different which in turn affects their willingness to cope with climate change. The counterfactual analysis confirms that if everybody is aware of climate change, the implementation of insurance mechanism will be much more feasible. It also indicates that females are less empowered in decision-making, and facing more barriers to adopt mitigation strategies, compared to males.

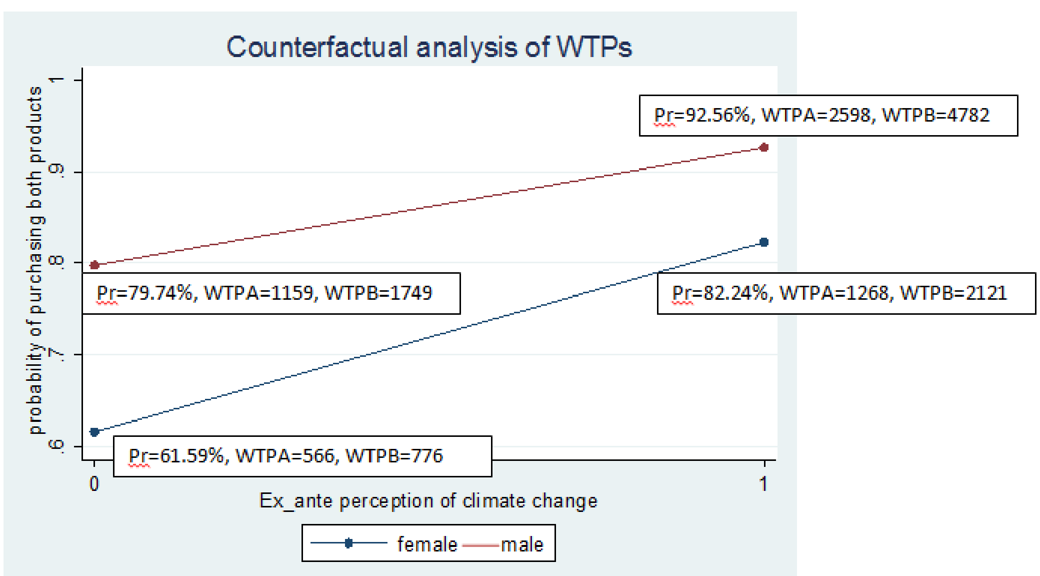


Figure 4.7 Counterfactual Analysis

4.9 Conclusion

This chapter analyzes the favorable factors and barriers of adopting adaptation strategies to fight against climate change using data collected from a primary survey conducted in Bahunepati, Nepal. One of the delighting findings is that a considerable proportion of households reported that they were actively engaging in coping with climate change. Among 353 households interviewed, 164 of them adopted at least one strategy (46.46%). Moreover, although the weather index-based insurance program is a new mechanism proposed to households in Bahunepati, the strategy is highly welcomed by household with the evidence that around 87% of them commended that it was the best protection tool against abnormal weather.

Our results confirm that the weather index-based base insurance is considered as a risk management tool, which is a key implication for policy makers. Especially in the present phase of recovery and reconstruction from earthquakes, Nepalese government should consider designing and carrying out more creative and effective protection tools such as the insurance program to protect households' livelihood.

The present study has been too limited in scope to take into account weather variability and other important factors such as access to extension service due to location limitation. However, their perception of climate change is still variate among individuals. Our findings support the view that awareness of climate change is positively linked to willingness to pay for the weather index-based insurance. Hence, enhancing households' knowledge about climate change through some service provision such as agricultural extension services, is an important policy suggestion.

In addition, the result that females are equally fond of but less likely to purchase the insurance products suggest that gender inequality, especially women's rightlessness in decision-making, is still a major impedement to the insurance program. Considering the important household and social responsibilities of female, government may provide programs and services, such as a microfinance program, to empower women.

One of the problems in the analysis is that in the WTP question, the probability of the positive response to the highest bid is very high, which causes a “fat-tail” distribution. While the distribution may reflect the true distribution of WTP, it may also implicate an overestimation of WTP. Several methods, such as nonparametric method and censoring the WTP distribution, have been introduced in the literature to solve the fat tail problem (Haltia et al., 2009). In the future study, I will use the pinched logit model introduced by Ready and Hu (1995) to address the problem. Specifically, the pinched logit model levels an upper finite limit to the distribution of WTP. For example, it considers that the WTP could not exceed people’s income level. In other words, it forces the probability of the positive response to the insurance products to be equal to zero if the bid is greater than income or some threshold. I will use both truncation points, including income and a threshold estimated from the model, to select a reasonable limit and mitigate the fat tail problem.

Table 4.1 Summary Statistics of Chapter 4

Variable	Definition	Mean	Std. Dev.	Min	Max
Dependent Variables					
WTJA	If the respondent is willing to purchase Product A, coded as 1 if yes, 0 otherwise	0.770	0.422	0	1
WTJB	If the respondent is willing to purchase Product B, coded as 1 if yes, 0 otherwise	0.787	0.410	0	1
Independent Variables					
Pclimate	Ex_ante perception of climate change. Coded as 1 if climate change is highly likely/likely to continue or happen in the next 10 years, 0 otherwise.	0.680	0.467	0	1
Impclimate	Ex_post perception of the impact of climate change on household agriculture.	2.311	1.204	0	10
Adapt	If household has adopted any adaptation strategies other than weather index-based insurance. Coded as 1 if yes, 0 otherwise	0.460	0.499	0	1
lnbidA	Logarithm of amount of bid for Product A	5.931	0.846	5	7
lnbidB	Logarithm of amount of bid for Product B	0.787	0.410	0	1
Hhinc	Monthly household income. Coded as 1 if less than 5000 NRs, 0 otherwise	0.657	0.476	0	1
Hhsize	Household size	5.827	4.234	1	65
Caste	The caste of the head of household. 1 if Brahmin or Chherti, and 0 otherwise	0.447	0.498	0	1
Female	The gender of the head of household. Coded as 1 if female, 0 otherwise	0.650	0.478	0	1
Edu	Education level of the head of household.	0.123	0.329	0	1
Age	Age of the head of household	39.580	12.650	2	87
Paddy	If household grows paddy. Coded as 1 if yes, 0 otherwise	0.857	0.351	0	1
Livestock	If household raises livestock. Coded as 1 if yes, 0 otherwise	0.940	0.238	0	1
top_down	Order of insurance product is proposed to respondents. Coded as 1 if Product B is proposed first, 0 otherwise.	0.513	0.501	0	1
n		298			

Source: Data collected by authors

Table 4.2 Estimation Result for Ex-ante Climate Change Perception

	Model 2a		Model 2b		Model 2c		Model 2d	
	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B
Pclimate	0.608***	0.585***	0.674***	0.636***	0.641***	0.581***	0.654***	0.586***
	(0.115)	(0.137)	(0.171)	(0.222)	(0.176)	(0.220)	(0.173)	(0.220)
Adapt	-0.188	-0.243	-0.323**	-0.383**	-0.372***	-0.486***	-0.287**	-0.405***
	(0.183)	(0.192)	(0.128)	(0.152)	(0.130)	(0.151)	(0.116)	(0.134)
ln(bidA)	-0.679***		-0.761***		-0.758***		-0.810***	
	(0.122)		(0.149)		(0.156)		(0.144)	
ln(bidB)		-0.496***		-0.546***		-0.542***		-0.583***
		(0.097)		(0.148)		(0.163)		(0.160)
Hhincome			0.553**	0.458*	0.542*	0.521*	0.624**	0.592**
			(0.256)	(0.274)	(0.280)	(0.281)	(0.268)	(0.276)
Hhsize			-0.035	-0.049**	-0.033	-0.047**	-0.031	-0.046**
			(0.028)	(0.022)	(0.024)	(0.021)	(0.023)	(0.021)
Caste			0.119	0.241	0.218	0.337	0.145	-0.270
			(0.325)	(0.375)	(0.361)	(0.399)	(0.376)	(0.408)
Female			-0.571***	-0.442**	-0.571***	-0.467**	-0.581***	-0.474**
			(0.201)	(0.204)	(0.207)	(0.201)	(0.203)	(0.196)
Edu			0.472**	0.271	0.438**	0.287	0.460**	0.310
			(0.224)	(0.274)	(0.218)	(0.289)	(0.215)	(.281)
Age			0.003	-0.004	4E-04	-0.005	0.002	-0.004
			(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.005)
Paddy					-0.301	-0.340*	-0.340	-0.382*
					(0.201)	(0.198)	(0.228)	(0.215)
Livestock						-0.378		-0.373
						(0.255)		(0.215)
Top_down							0.401**	0.364***
							(0.173)	(0.127)
Constant	4.564***	3.559***	5.119***	4.238***	5.480***	4.902***	5.501***	4.905***
	(0.649)	(0.533)	(0.885)	(0.763)	(0.974)	(0.910)	(0.939)	(0.884)
rho	0.976***		0.977***		0.983***		0.983***	
Log_Pseudo Likelihood	-205.698		-183.282		-176.528		-174.353	
AIC	427.396		382.565		369.057		364.7057	
N	321		308		298		298	

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Numbers in the parentheses are robust standard errors.

Table 4.3 Marginal Effects for Ex-ante Climate Change Perception

	Model 3a		Model 3b		Model 3c		Model 3d	
	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B
Pclimate	0.181***	0.169***	0.189***	0.174***	0.180***	0.160**	0.179***	0.158**
	(0.040)	(0.047)	(0.057)	(0.071)	(0.058)	(0.070)	(0.059)	(0.068)
Adapt	-0.052	-0.065	-0.082**	-0.096**	-0.096***	-0.124***	-0.072**	-0.101***
	(0.051)	(0.052)	(0.036)	(0.038)	(0.037)	(0.040)	(0.028)	(0.031)
ln(bidA)	-0.186***		-0.192***		-0.193***		-0.200***	
	(0.043)		(0.045)		(0.046)		(0.046)	
ln(bidB)		-0.132***		-0.135***		-0.136***		-0.143***
		(0.033)		(0.040)		(0.043)		(0.042)
Hhincome			0.150**	0.121*	0.148**	0.140*	0.168**	0.158**
			(0.065)	(0.070)	(0.073)	(0.072)	(0.070)	(0.071)
Hhsize			-0.009	-0.012**	-0.008	-0.012**	-0.008	-0.011**
			(0.006)	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)
Caste			0.030	0.059	0.055	0.083	0.036	-0.065
			(0.078)	(0.086)	(0.084)	(0.090)	(0.088)	(0.093)
Female			-0.133***	-0.103**	-0.134***	-0.109**	-0.132***	-0.108**
			(0.038)	(0.042)	(0.039)	(0.040)	(0.036)	(0.038)
Edu			0.099**	0.060	0.094**	0.064	0.095**	0.067
			(0.043)	(0.055)	(0.044)	(0.059)	(0.039)	(0.054)
Age			0.0009	-0.0009	0.0001	-0.001	0.0006	-0.0009
			(0.0013)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Paddy					-0.069*	-0.075**	-0.074*	-0.081**
					(0.036)	(0.036)	(0.039)	(0.035)
Livestock						-0.079*		-0.077*
						(0.046)		(0.043)
Top_down							0.100**	0.090**
							(0.049)	(0.037)
N	321		308		298		298	

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Numbers in the parentheses are standard deviations.

Table 4.4 Estimation Result for Ex-post Climate Change Perception

	Model 4a		Model 4b		Model 4c		Model 4d	
	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B
Impclimate	0.104**	0.010	0.103**	0.003	0.127**	0.022	0.205***	0.097**
	(0.046)	(0.035)	(0.051)	(0.022)	(0.055)	(0.030)	(0.062)	(0.040)
Adapt	-0.202	-0.248	-0.272	-0.324	-0.336*	-0.419**	-0.251**	-0.334***
	(0.222)	(0.228)	(0.208)	(0.209)	(0.191)	(0.191)	(0.106)	(0.121)
ln(bidA)	-0.630***		-0.675***		-0.680***		-0.743***	
	(0.097)		(0.111)		(0.124)		(0.119)	
ln(bidB)		-0.486***		-0.509***		-0.510***		-0.566***
		(0.077)		(0.107)		(0.126)		(0.123)
Hhincome			0.274	0.200	0.281	0.269	0.398	0.378
			(0.232)	(0.268)	(0.255)	(0.268)	(0.258)	(0.271)
Hhsize			-0.017*	-0.027*	-0.017*	-0.024*	-0.019*	-0.028*
			(0.011)	(0.014)	(0.009)	(0.014)	(0.010)	(0.016)
Caste			0.300	0.338	0.424	0.423	0.337	-0.340
			(0.294)	(0.319)	(0.317)	(0.325)	(0.330)	(0.338)
Female			-0.476***	-0.445**	-0.480***	-0.476**	-0.508***	-0.499***
			(0.153)	(0.180)	(0.163)	(0.171)	(0.152)	(0.169)
Edu			0.422**	0.377	0.364*	0.376	0.341*	0.357
			(0.169)	(0.278)	(0.186)	(0.300)	(0.184)	(.276)
Age			0.008	-0.009**	-0.012*	-0.011**	-0.009	-0.009**
			(0.007)	(0.004)	(0.007)	(0.005)	(0.006)	(0.004)
Paddy					-0.372**	-0.407**	-0.465**	-0.495**
					(0.177)	(0.181)	(0.204)	(0.209)
Livestock						-0.408*		-0.394
						(0.251)		(0.248)
Top_down							0.573***	0.538***
							(0.137)	(0.154)
Constant	3.827***	3.760***	4.557***	4.533***	4.842***	5.141***	4.319***	4.614***
	(0.692)	(0.441)	(0.962)	(0.620)	(0.965)	(0.736)	(0.943)	(0.652)
rho	0.979***		0.974***		0.981***		0.979***	
Log_Pseudo Likelihood	-232.312		-212.974		-203.598		-199.109	
AIC	480.6		441.9		423.2		414.2	
N	346		333		323		323	

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Numbers in the parentheses are robust standard errors.

Table 4.5 Marginal Effects for Ex-post Climate Change Perception

	Model 5a		Model 5b		Model 5c		Model 5d	
	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B
Impclimate	0.030**	0.003	0.028**	0.007	0.034**	0.006	0.053***	0.026**
	(0.013)	(0.010)	(0.014)	(0.006)	(0.014)	(0.008)	(0.016)	(0.011)
Adapt	-0.058	-0.070	-0.075	-0.088	-0.092*	-0.115**	-0.066**	-0.089***
	(0.066)	(0.067)	(0.062)	(0.061)	(0.056)	(0.059)	(0.031)	(0.035)
ln(bidA)	-0.180***		-0.184***		-0.185***		-0.194***	
	(0.040)		(0.039)		(0.041)		(0.041)	
ln(bidB)		-0.137***		-0.137***		-0.139***		-0.149***
		(0.031)		(0.034)		(0.037)		(0.036)
Hhincome			0.077	0.056	0.079	0.076	0.109	0.104
			(0.064)	(0.074)	(0.071)	(0.075)	(0.070)	(0.076)
Hhsize			-0.005*	-0.007*	-0.0045*	-0.007*	-0.005**	-0.007*
			(0.003)	(0.004)	(0.0023)	(0.004)	(0.002)	(0.004)
Caste			0.080	0.089	0.112	0.112	0.086	0.088
			(0.071)	(0.078)	(0.073)	(0.078)	(0.078)	(0.081)
Female			-0.122***	-0.114***	-0.122***	-0.121***	-0.123***	-0.123***
			(0.035)	(0.043)	(0.037)	(0.040)	(0.032)	(0.037)
Edu			0.098**	0.089	0.086**	0.089	0.078*	0.082
			(0.040)	(0.060)	(0.043)	(0.064)	(0.041)	(.056)
Age			-0.002	-0.002**	-0.0031*	-0.003**	-0.0025	-0.002**
			(0.002)	(0.001)	(0.0019)	(0.0013)	(0.0016)	(0.001)
Paddy					-0.089***	-0.097***	-0.103***	-0.109***
					(0.034)	(0.037)	(0.035)	(0.036)
Livestock						-0.093*		-0.087*
						(0.05)		(0.048)
Top_down							0.148***	0.141***
							(0.042)	(0.045)
N	346		333		323		323	

Note: *** denotes significant at the 1% level; ** denotes significant at the 5% level; and * denotes significant at the 10% level. Numbers in the parentheses are standard deviations.

Table 4.6 Willingness to Pay for Product A and Product B

		Mean	Median	Median (WTP) /Income	H0: WTJA = WTJB
Ex Model	Product A	3095.55 (1371.25,29360.74)	1326.01 (838.69,3332.99)	1.28%	P: 0.000
	Product B	13208.72 (2524.59,369458)	2341.82 (1137.91,18936.9)	2.27%	Conc. Reject
Post Model	Product A	4212.35 (868.993300.40)	1400.27 (1699.00, 33408.06)	1.36%	P: 0.000
	Product B	15200.08 (3173.68,207468)	2206.74 (1129.149437.08)	2.14%	Conc. Reject

Note: The numbers in the parentheses are lower bounds and upper bounds for the mean and median of WTPs.

Chapter 5 Conclusions and Policy Recommendations

5.1 Summary of Dissertation

This dissertation presents three analyses to study various decisions made by households, community, and government to cope with food insecurity and climate change in Rural Nepal. We start with introducing the overall food security and climate change status in Nepal, and followed by two studies analyzing the impacts of climate change on household food security. The final study examines an effective mechanism, weather index-based crop insurance, for smallholder famers to cope with climate change.

The second chapter investigates the determinants affecting individual caloric intake per capita per day and food diversity. We use a climate change indicator from a Practical Action report to capture the temperature and rainfall trend. The data analysis illustrates the significant correlation between individual caloric intake and household food diversity. We also solve the endogeneity problem of the remittance variable in two stages, and use a bootstrapping method to correct the standard errors in the second stage.

In the past three decades, the increasing temperature as well as the uncertain trend of rainfall has been gradually obvious. On the other hand, the monsoon rainfall, which is crucial to the fall cultivation, is anomalous (either extremely heavy or extremely light). These erratic climate patterns have caused the food security crises in the country. The negative results of the climate change indictor confirms that the increasing temperature and fluctuating rainfall has a substantial adverse impact on household food security in rural Nepal. This study also illustrates the importance of community social capital. The positive relationship between the farmer user group indicator and household food security proxies suggests that the participants are more likely to obtain farming knowledge and experience from their partners. Finally, we highlight the roles of infrastructure construction, government support, and remittance.

The third chapter utilizes a Spatial Frontier Production Model based on a Cobb-Douglas function to analyze effects of climate change on rice production, and investigate the factors affecting technical efficiency of agricultural production. We use the time-varying model with panel data from NLSS in 2003/2004 and 2010/2011. The results confirm the findings of the first chapter. Specifically, we find strong evidence that the increase in rainfall variation during the cropping seasons and the average monsoon temperature lead to significant reduction in rice production. The study also analyzes technical efficiency of rice production in Rural Nepal. We find that the technical inefficiency is existent in the models. In addition, results show that in rural Nepal, the overall technical efficiency scores are close in years 2003 and 2010. Specifically, the technical efficiency scores range from 0.024 to 0.885 in year 2003 and from 0.019 to 0.911 in year 2010. The study further points out, technical efficiency could be improved through infrastructural construction, agricultural extension service, education, and participation of male-headed households in farming activities.

Driven by the findings in the previous two studies, the final analysis examines the favorable factors and barriers of farmers' willingness to pay for a weather index-based crop insurance. We use data collected from a primary survey conducted in Bahunepati, Nepal in August 2014. We design two crop insurance products in the survey: Product A only insures rice and Product B adds five main livestock. One of the delighting findings is that the crop insurance was highly welcomed by households in Bahunepati. We find that around 87% of them commended that it was the best protection tool against abnormal weather. The estimation results with a Biprobit method illustrate a positive relationship between farmers' perception of climate change and their WTPs. Our result of negative effect of existing adaption strategies on WTPs confirms that weather index-based insurance is considered as a risk management tool. Finally, we find that the annually median WTPs are 1.6% and 3% of household income for product A and B, respectively.

5.2 Policy Recommendation

The three studies in this dissertation have important policy recommendations. The findings in the first study provide policy implications that the Nepalese government, which on the macro-level, should invest in the building resilient infrastructure, such as irrigation systems, to cope with climate change (i.e., mitigate effect of droughts). On the micro-level, the Nepalese government should educate households about mitigation strategies to adapt to climate change, such as crop diversity, early or late cultivation, improved seeds utilization, use of pesticides, and so on. In addition, we recommend that the community government should encourage households to participate in the agriculture group, and also educate farmers to balance the activities of forestation and farming. We also suggest that the Nepalese government should prioritize investment in transportation facilities, which is especially crucial for areas without road access. Finally, this research supports the importance of remittance and government support.

The second study further supports the importance of climate change education and mitigation. Policy makers should develop programs to educate and train farmers to be experienced in managing climate risks to mitigate their vulnerability. The factors found to affect technical efficiency of rice production provides policy recommendations of financial resources to the households who live in the hill and mountain areas. Also, investing irrigation development and agricultural service will also help households improve agricultural production and enhance their household food security.

The final study finds that the weather index-based crop insurance is highly welcome by households, indicating that Nepalese government should consider designing and carrying out such insurance program to protect households' livelihood. Also, we further emphasize the importance of enhancing households' knowledge about climate change. Government policy should consider some service provision such as extension services to educate farmers. Our results in this study also indicates women's rightlessness in decision-making, which impedes their participation in the insurance program. We suggest policy makers may provide programs and services such as a microfinance program to empower women.

5.3 Future Study

The future research will build on the findings in this dissertation and continue to focus on food security, climate change, human well-being improvement, and poverty reduction. First, the Frontier Production Model employed in the second study have seen the negative effect of climate change. There are a number of alternative methods related to this topic, and will be incorporated into my future study. For example, I will employ the Ricardian model to study the spatial effect of climate change on agricultural production revenue.

In the near future, I also would like to use the survey data for two projects. The first one is to provide some polices related to health implication. To be specific, prevalence of adverse health outcomes for small children and women may be associated with the nutritional deficiency caused by the general food insecurity status. Thus, I would like to analyze the impact of food insecurity on health outcome. I propose to use the body mass index (BMI) of children under 6 years old as health indices. With respect to women, I will use their perceived health status and actual visits of doctor.

The second project is to analyze factors influencing farmers' decision making in adopting mitigation strategies, and the impact of the adoption of mitigation strategies on household food security. Decision to engage in any form of mitigation strategy on the part of the rural residents hinges on a number of factors. For example, the way farmers perceive future climate risk or climate change and the individual risk tolerance level may have effect on decision making. Besides that, access to credit and information on climate change, including via extension to official, neighborhood and media tool, are factors influencing farmers' decision (Seo and Mendelsohn, 2008; Mertz et al., 2008; Deressa et al., 2009). The second step of the study will analyze whether adaptation to climate risk/climate change improve household food security. An endogenous selection model could be employed to study this problem. Overall, understanding the favorable factors and barriers to mitigation strategies would provide government programs and policies to help farmers avoid catastrophic loss, and thus result in agriculture production increase and poverty reduction.

Appendix A: Introduction of Gumbel and Gaussian Copulas

A.1 Gumbel Copula

The Gumbel Copula function is:

$$C(u_1, u_2;\ \theta) = \exp\{-((-\log u_1)^{\theta} + (-\log u_2)^{\theta})^{\frac{1}{\theta}}$$

The dependence parameter takes any real value on the range $[1, \infty]$, implying that it just allows for positive dependence, which is similar to the Clayton Copula. Nevertheless, as contrary to the Clayton Copula, the Gumbel Copula is more appropriate if the dependence is stronger on the high values (Trivedi and Zimmer, 2005).

$$C(u_1, u_2;\ \theta) = \exp\{-\big((-log u_1)^{\theta} + (-log u_2)^{\theta}\big)^{\frac{1}{\theta}} = \exp\{-((-\log\big(F(y_1)\big))^{\theta} + (-\log\big(F(y_2)\big))^{\theta})^{\frac{1}{\theta}}\}$$

1''

Taking derivative to Equation 1'' with respect to y_1, we get:

$$\frac{\partial C}{\partial y_1} = \exp\{-\left((-\log\big(F(y_1)\big))^{\theta} + (-\log\big(F(y_2)\big))^{\theta}\right)^{\frac{1}{\theta}} * \left(-\frac{1}{\theta}\right)\left((-\log\big(F(y_1)\big))^{\theta} + (-\log\big(F(y_2)\big))^{\theta}\right)^{\frac{1}{\theta}-1} * (\theta)(-\log\big(F(y_1)\big))^{\theta-1} * -\frac{1}{F(y_1)} * f(y_1)$$

$$= f(y_1)\frac{1}{F(y_1)}(-\log\big(F(y_1)\big))^{\theta-1}\left((-\log\big(F(y_1)\big))^{\theta} + (-\log\big(F(y_2)\big))^{\theta}\right)^{\frac{1}{\theta}-1}\exp\{-\left((-\log\big(F(y_1)\big))^{\theta} + (-\log\big(F(y_2)\big))^{\theta}\right)^{\frac{1}{\theta}}\}$$

2''

Therefore, the joint density is:

$$c(y_1,y_2;\theta)=f(y_1)\frac{1}{F(y_1)}\left(-\log\left(F(y_1)\right)\right)^{\theta-1}\{[\left(\left(-\log\left(F(y_1)\right)\right)^{\theta}\right.$$

$$+\left.\left(-\log\left(F(y_2)\right)\right)^{\theta}\right)^{\frac{1}{\theta}-1}\exp\left\{-\left(\left(-\log\left(F(y_1)\right)\right)^{\theta}+\left(-\log\left(F(y_2)\right)\right)^{\theta}\right)^{\frac{1}{\theta}}\right\}$$

$$-\left(\left(-\log\left(F(y_1)\right)\right)^{\theta}\right.$$

$$+\left.\left(-\log\left(F(y_2-1)\right)\right)^{\theta}\right)^{\frac{1}{\theta}-1}\exp\left\{-\left(\left(-\log\left(F(y_1)\right)\right)^{\theta}\right.\right.$$

$$\left.\left.+\left(-\log\left(F(y_2-1)\right)\right)^{\theta}\right)^{\frac{1}{\theta}}\right\}\}$$

3''

A.2 Gaussian Copula

Gaussian Copula function is:

$$C(u_1,u_2;\ \theta)=\Phi_G(\Phi^{-1}(u_1),\Phi^{-1}(u_2);\ \theta)$$

Where Φ is the cdf of the standard normal distribution. The dependent parameter θ is restricted on the range [-1,1]. The Gaussion is flexible since it permits both positive and negative dependence (Trivedi and Zimmer, 2005). Like Gumbel Copula, Gaussian Copula is more appropriate when the dependence is stronger on the right tail. The property is similar to the Gumbel Copula but opposite to the Clayton and Frank Copulas.

The Gaussian Copula function is:

$$C(u_1,u_2;\ \theta)=C(F(y_1),F(y_2);\theta)=\Phi_G\left\{\Phi^{-1}(u_1),\Phi^{-1}(u_2);\theta\right)$$

4''

In order to get the joint density function, we should get the expression of C_x first.

$$C_x(u_1,u_2;\ \theta)=\frac{\partial C}{\partial F(x)}=\frac{\partial C}{\partial u_1}=\frac{1}{(2_\pi)^{1/2}}\frac{1}{(1-\theta^2)^{\frac{1}{2}}}\int_{-\infty}^{\Phi^{-1}(u_2)}\exp\{-\theta t\,\Phi^{-1}(u_1)+\frac{1}{2}y^2\}dt$$

5''

The joint density of y_1 and y_2 is of the form:

$$c(u_1,u_2;\ \theta)=f(x)*[C_x(F(y_1),F(y_2),\theta)-C_x(F(y_1),F(y_2-1),\theta)]=f(y_1)*\frac{1}{(2_\pi)^{\frac{1}{2}}}\frac{1}{(1-\theta^2)^{\frac{1}{2}}}*\left\{\int_{-\infty}^{\Phi^{-1}(F(y_2))}\exp(-\theta t\,\Phi^{-1}(u_1)+\frac{1}{2}{y_2}^2)\right\}dt-\int_{-\infty}^{\Phi^{-1}(F(y_2-1))}\exp\{-\theta t\,\Phi^{-1}(u_1)+\frac{1}{2}{y_2}^2\}dt]$$

6''

Appendix B: Code

Stata Code

```
*******************************************Chapter 2********************************
clear
set more off
*set memory 500m

*calories model
cd D:\wenmei\data\nlss2010

/*education
use "D:\wenmei\data\2010\Stata9\xh10_s07.dta", clear
keep if v07_idc==1
keep  xhpsu xhnum v07_15 v07_17
gen id1=string(xhpsu)+string(xhnum)
destring id1,replace

*remittance
use "D:\wenmei\data\2010\Stata9\xh37_s16.dta", clear
drop if v16_16==.
keep xhpsu xhnum v16_05 v16_06 v16_07 v16_08b v16_16 v16_17
gen remittance=v16_16+v16_17
gen remit=log(remittance+1)
gen id1=string(xhpsu)+string(xhnum)
destring id1,replace
collapse (sum) remit, by(id1)
*getting information of household members who send money to the household(instruments of remittance)
use "D:\wenmei\data\newdata\rawremt.dta", clear
*replace those unknown with average education level
replace v16_05=9.5 if v16_05==97
rename v16_05 eduyearrem
collapse (mean) eduyearrem, by(id1)
*years leaving home
use "D:\wenmei\data\newdata\rawremt.dta", clear
rename v16_07 yearleft
collapse (mean) yearleft, by(id1)
*merge these three files
merge 1:1 id1 using "D:\wenmei\data\newdata\edurem.dta"
drop _merge
merge 1:1 id1 using "D:\wenmei\data\newdata\remit1.dta"
drop _merge

*To see the median and mean of each food item to check if the consumption is reasonable
use "C:\wenmei\data\2010\Stata9\xh05_s05.dta",clear
sum v05_03a if v05_idc==11 & v05_03b==1, detail    //one example


*calculate household calories intake
```

```
use "C:\wenmei\data\2010\Stata9\xh05_s05.dta",clear

*First step, I need to see the unit of each food item uses in a typical month since units used by different
household are not the same even for the same food item
tab v05_03b if v05_idc==11    //one example

use "C:\wenmei\data\2010\Stata9\xh05_s05.dta",clear

rename v05_03a homefoodq
rename v05_06a buyfoodq

*calculating the calories for homeproduction and purchase for a typical month
*before the food item quantity question, there is a question asking if they consume the food. If yes, then
go on with it, if no, the food quantity question is skiped and no zero entened in this question. So I just
guess the "." in the quantity variable is euqal to 0 since household doesn't consume it.
replace homefoodq=0 if homefoodq==.
replace buyfoodq=0 if buyfoodq==. | buyfoodq<0

gen chome11=homefoodq*365*10 if v05_idc==11 & v05_03b==1
replace chome11=homefoodq*365*36 if v05_idc==11 & v05_03b==6
replace chome11=homefoodq*365*4.5 if v05_idc==11 & v05_03b==7
replace chome11=homefoodq*365*1000 if v05_idc==11 & v05_03b==11
replace chome11=homefoodq*365*373 if v05_idc==11 & v05_03b==3


gen cbuy11=buyfoodq*365*10 if v05_idc==11 & v05_06b==1
replace cbuy11=buyfoodq*365*36 if v05_idc==11 & v05_06b==6
replace cbuy11=buyfoodq*365*4.5 if v05_idc==11 & v05_06b==7
replace cbuy11=buyfoodq*365*1000 if v05_idc==11 & v05_06b==11

gen chome12=homefoodq*350*10 if v05_idc==12 & v05_03b==1
replace chome12=homefoodq*350*720 if v05_idc==12 & v05_03b==5
replace chome12=homefoodq*350*36 if v05_idc==12 & v05_03b==6
replace chome12=homefoodq*350*4.5 if v05_idc==12 & v05_03b==7
replace chome12=homefoodq*350*5.4 if v05_idc==12 & v05_03b==8
replace chome12=homefoodq*350*1000 if v05_idc==12 & v05_03b==11
replace chome12=homefoodq*350*373 if v05_idc==12 & v05_03b==3

gen cbuy12=homefoodq*350*10 if v05_idc==12 & v05_06b==1
replace cbuy12=buyfoodq*350*720 if v05_idc==12 & v05_06b==5
replace cbuy12=buyfoodq*350*36 if v05_idc==12 & v05_06b==6
replace cbuy12=buyfoodq*350*4.5 if v05_idc==12 & v05_06b==7
replace cbuy12=buyfoodq*350*5.4 if v05_idc==12 & v05_06b==8
replace cbuy12=buyfoodq*350*1000 if v05_idc==12 & v05_06b==11

gen chome13=homefoodq*194*10 if v05_idc==13 & v05_03b==1
replace chome13=homefoodq*194*0.01 if v05_idc==13 & v05_03b==2
replace chome13=homefoodq*194*36 if v05_idc==13 & v05_03b==6
replace chome13=homefoodq*194*4.5 if v05_idc==13 & v05_03b==7
```

```
replace chome13=homefoodq*194*5.4 if v05_idc==13 & v05_03b==8

gen cbuy13=buyfoodq*194*10 if v05_idc==13 & v05_06b==1
replace cbuy13=buyfoodq*194*373 if v05_idc==13 & v05_06b==3
replace cbuy13=buyfoodq*194*0.01 if v05_idc==13 & v05_06b==2
replace cbuy13=buyfoodq*194*720 if v05_idc==13 & v05_06b==5
replace cbuy13=buyfoodq*194*36 if v05_idc==13 & v05_06b==6
replace cbuy13=buyfoodq*194*4.5 if v05_idc==13 & v05_06b==7
replace cbuy13=buyfoodq*194*5.4 if v05_idc==13 & v05_06b==8

gen chome14=homefoodq*85.7*10 if v05_idc==14 & v05_03b==1
replace chome14=homefoodq*85.7*0.01 if v05_idc==14 & v05_03b==2
replace chome14=homefoodq*85.7*720 if v05_idc==14 & v05_03b==5
replace chome14=homefoodq*85.7*36 if v05_idc==14 & v05_03b==6
replace chome14=homefoodq*85.7*4.5 if v05_idc==14 & v05_03b==7
replace chome14=homefoodq*85.7*5.4 if v05_idc==14 & v05_03b==8
replace chome14=homefoodq*85.7*1.8 if v05_idc==14 & v05_03b==9
replace chome14=homefoodq*85.7*373 if v05_idc==14 & v05_03b==3

gen cbuy14=buyfoodq*85.7*10 if v05_idc==14 & v05_06b==1
replace cbuy14=buyfoodq*85.7*0.01 if v05_idc==14 & v05_06b==2
replace cbuy14=buyfoodq*85.7*720 if v05_idc==14 & v05_06b==5
replace cbuy14=buyfoodq*85.7*36 if v05_idc==14 & v05_06b==6
replace cbuy14=buyfoodq*85.7*4.5 if v05_idc==14 & v05_06b==7
replace cbuy14=buyfoodq*85.7*1000 if v05_idc==14 & v05_06b==11
replace cbuy14=buyfoodq*85.7*1.8 if v05_idc==14 & v05_06b==9
replace cbuy14=buyfoodq*85.7*373 if v05_idc==14 & v05_06b==3

gen chome15=homefoodq*365*10 if v05_idc==15 & v05_03b==1
replace chome15=homefoodq*365*0.01 if v05_idc==15 & v05_03b==2
replace chome15=homefoodq*365*720 if v05_idc==15 & v05_03b==5
replace chome15=homefoodq*365*36 if v05_idc==15 & v05_03b==6
replace chome15=homefoodq*365*4.5 if v05_idc==15 & v05_03b==7


gen cbuy15=buyfoodq*365*10 if v05_idc==15 & v05_06b==1
replace cbuy15=buyfoodq*365*0.01 if v05_idc==15 & v05_06b==2
replace cbuy15=buyfoodq*365*720 if v05_idc==15 & v05_06b==5
replace cbuy15=buyfoodq*365*36 if v05_idc==15 & v05_06b==6
replace cbuy15=buyfoodq*365*4.5 if v05_idc==15 & v05_06b==7

gen chome16=homefoodq*366*10 if v05_idc==16 & v05_03b==1
replace chome16=homefoodq*366*0.01 if v05_idc==16 & v05_03b==2
replace chome16=homefoodq*366*720 if v05_idc==16 & v05_03b==5
replace chome16=homefoodq*366*36 if v05_idc==16 & v05_03b==6
replace chome16=homefoodq*366*4.5 if v05_idc==16 & v05_03b==7
replace chome16=homefoodq*366*373 if v05_idc==16 & v05_03b==3

gen cbuy16=buyfoodq*366*10 if v05_idc==16 & v05_06b==1
```

```
replace cbuy16=buyfoodq*366*0.01 if v05_idc==16 & v05_06b==2
replace cbuy16=buyfoodq*366*720 if v05_idc==16 & v05_06b==5
replace cbuy16=buyfoodq*366*36 if v05_idc==16 & v05_06b==6
replace cbuy16=buyfoodq*366*4.5 if v05_idc==16 & v05_06b==7
replace cbuy16=buyfoodq*366*1000 if v05_idc==16 & v05_06b==11
replace cbuy16=buyfoodq*366*373 if v05_idc==16 & v05_06b==3

gen chome17=homefoodq*378*10 if v05_idc==17 & v05_03b==1
replace chome17=homefoodq*378*720 if v05_idc==17 & v05_03b==5
replace chome17=homefoodq*378*36 if v05_idc==17 & v05_03b==6
replace chome17=homefoodq*378*4.5 if v05_idc==17 & v05_03b==7

gen cbuy17=buyfoodq*378*10 if v05_idc==17 & v05_06b==1
replace cbuy17=buyfoodq*378*0.01 if v05_idc==17 & v05_06b==2
replace cbuy17=buyfoodq*378*720 if v05_idc==17 & v05_06b==5
replace cbuy17=buyfoodq*378*36 if v05_idc==17 & v05_06b==6
replace cbuy17=buyfoodq*378*4.5 if v05_idc==17 & v05_06b==7
replace cbuy17=buyfoodq*378*5.4 if v05_idc==17 & v05_06b==8
replace cbuy17=buyfoodq*378*1000 if v05_idc==17 & v05_06b==11

gen chome21=homefoodq*75*10 if v05_idc==21 & v05_03b==1
replace chome21=homefoodq*75*0.01 if v05_idc==21 & v05_03b==2
replace chome21=homefoodq*75*36 if v05_idc==21 & v05_03b==6
replace chome21=homefoodq*75*4.5 if v05_idc==21 & v05_03b==7
replace chome21=homefoodq*75*5.4 if v05_idc==21 & v05_03b==8

gen cbuy21=buyfoodq*75*10 if v05_idc==21 & v05_06b==1
replace cbuy21=buyfoodq*75*0.01 if v05_idc==21 & v05_06b==2
replace cbuy21=buyfoodq*75*36 if v05_idc==21 & v05_06b==6
replace cbuy21=buyfoodq*75*4.5 if v05_idc==21 & v05_06b==7
replace cbuy21=buyfoodq*75*5.4 if v05_idc==21 & v05_06b==8

gen chome22=homefoodq*353*10 if v05_idc==22 & v05_03b==1
replace chome22=homefoodq*353*0.01 if v05_idc==22 & v05_03b==2
replace chome22=homefoodq*353*36 if v05_idc==22 & v05_03b==6
replace chome22=homefoodq*353*4.5 if v05_idc==22 & v05_03b==7

gen cbuy22=buyfoodq*353*10 if v05_idc==22 & v05_06b==1
replace cbuy22=buyfoodq*353*0.01 if v05_idc==22 & v05_06b==2
replace cbuy22=buyfoodq*353*720 if v05_idc==22 & v05_06b==5
replace cbuy22=buyfoodq*353*36 if v05_idc==22 & v05_06b==6
replace cbuy22=buyfoodq*353*4.5 if v05_idc==22 & v05_06b==7
replace cbuy22=buyfoodq*353*1000 if v05_idc==22 & v05_06b==11
replace cbuy22=buyfoodq*353*5.4 if v05_idc==22 & v05_06b==8
replace cbuy22=buyfoodq*353*373 if v05_idc==22 & v05_06b==3

gen chome23=homefoodq*137*10 if v05_idc==23 & v05_03b==1
replace chome23=homefoodq*137*0.01 if v05_idc==23 & v05_03b==2
replace chome23=homefoodq*137*36 if v05_idc==23 & v05_03b==6
```

```
replace chome23=homefoodq*137*4.5 if v05_idc==23 & v05_03b==7


gen cbuy23=buyfoodq*137*10 if v05_idc==23 & v05_06b==1
replace cbuy23=buyfoodq*137*0.01 if v05_idc==23 & v05_06b==2
replace cbuy23=buyfoodq*137*36 if v05_idc==23 & v05_06b==6
replace cbuy23=buyfoodq*137*4.5 if v05_idc==23 & v05_06b==7


gen chome24=homefoodq*321*10 if v05_idc==24 & v05_03b==1
replace chome24=homefoodq*321*0.01 if v05_idc==24 & v05_03b==2
replace chome24=homefoodq*321*36 if v05_idc==24 & v05_03b==6
replace chome24=homefoodq*321*4.5 if v05_idc==24 & v05_03b==7

gen cbuy24=buyfoodq*321*10 if v05_idc==24 & v05_06b==1
replace cbuy24=buyfoodq*321*0.01 if v05_idc==24 & v05_06b==2
replace cbuy24=buyfoodq*321*720 if v05_idc==24 & v05_06b==5
replace cbuy24=buyfoodq*321*36 if v05_idc==24 & v05_06b==6
replace cbuy24=buyfoodq*321*4.5 if v05_idc==24 & v05_06b==7


gen chome26=homefoodq*100*10 if v05_idc==26 & v05_03b==1
replace chome26=homefoodq*100*0.01 if v05_idc==26 & v05_03b==2
replace chome26=homefoodq*100*36 if v05_idc==26 & v05_03b==6
replace chome26=homefoodq*100*4.5 if v05_idc==26 & v05_03b==7
replace chome26=homefoodq*100*5.4 if v05_idc==26 & v05_03b==8


gen cbuy26=buyfoodq*100*10 if v05_idc==26 & v05_06b==1
replace cbuy26=buyfoodq*100*0.01 if v05_idc==26 & v05_06b==2
replace cbuy26=buyfoodq*100*36 if v05_idc==26 & v05_06b==6
replace cbuy26=buyfoodq*100*4.5 if v05_idc==26 & v05_06b==7
replace cbuy26=buyfoodq*100*373 if v05_idc==26 & v05_06b==3

gen chome31=homefoodq*68 if v05_idc==31 & v05_03b==9
replace chome31=homefoodq*68*12 if v05_idc==31 & v05_03b==10

gen cbuy31=buyfoodq*68 if v05_idc==31 & v05_06b==9
replace cbuy31=buyfoodq*68*12 if v05_idc==31 & v05_06b==10

gen chome32=homefoodq*30.5*33.8 if v05_idc==32 & v05_03b==4
replace chome32=homefoodq*30.5*33.8*0.568 if v05_idc==32 & v05_03b==7
replace chome32=homefoodq*30.5*33.8*0.682 if v05_idc==32 & v05_03b==8

gen cbuy32=buyfoodq*30.5*33.8 if v05_idc==32 & v05_06b==4
replace cbuy32=buyfoodq*30.5*33.8*4.544 if v05_idc==32 & v05_06b==6
replace cbuy32=buyfoodq*30.5*33.8*0.568 if v05_idc==32 & v05_06b==7
replace cbuy32=buyfoodq*30.5*33.8*0.68 if v05_idc==32 & v05_06b==8
```

```
gen cbuy33=buyfoodq*3350 if v05_idc==33 & v05_06b==1
replace cbuy33=buyfoodq*3.35 if v05_idc==33 & v05_06b==2
replace cbuy33=buyfoodq*3253 if v05_idc==33 & v05_06b==4

gen cbuy34=buyfoodq*356 if v05_idc==34 & v05_06b==1
replace cbuy34=buyfoodq*0.356 if v05_idc==34 & v05_06b==2


gen cbuy35=buyfoodq*24*10 if v05_idc==35 & v05_06b==1
replace cbuy35=buyfoodq*0.24 if v05_idc==35 & v05_06b==2
replace cbuy35=buyfoodq*24*9.51 if v05_idc==35 & v05_06b==4
replace cbuy35=buyfoodq*24*4.5 if v05_idc==35 & v05_06b==7
replace cbuy35=buyfoodq*24*5.4 if v05_idc==35 & v05_06b==8


gen chome41=homefoodq*331*10 if v05_idc==41 & v05_03b==1
replace chome41=homefoodq*331*0.01 if v05_idc==41 & v05_03b==2
replace chome41=homefoodq*45*2*33.814 if v05_idc==41 & v05_03b==4
replace chome41=homefoodq*45*2*33.814*4.544 if v05_idc==41 & v05_03b==6
replace chome41=homefoodq*45*2*33.814*0.568 if v05_idc==41 & v05_03b==7
replace chome41=homefoodq*45*2*33.814*0.682 if v05_idc==41 & v05_03b==8

gen cbuy41=buyfoodq*331*10 if v05_idc==41 & v05_06b==1
replace cbuy41=buyfoodq*331*0.01 if v05_idc==41 & v05_06b==2
replace cbuy41=buyfoodq*331*9.51 if v05_idc==41 & v05_06b==4
replace cbuy41=buyfoodq*331*36 if v05_idc==41 & v05_06b==6
replace cbuy41=buyfoodq*331*4.5 if v05_idc==41 & v05_06b==7
replace cbuy41=buyfoodq*331*9.51 if v05_idc==41 & v05_06b==8


gen cbuy42=buyfoodq*882*10 if v05_idc==42 & v05_06b==1
replace cbuy42=buyfoodq*882*0.01 if v05_idc==42 & v05_06b==2
replace cbuy42=buyfoodq*8115.36 if v05_idc==42 & v05_06b==4

gen chome43=homefoodq*8385.9 if v05_idc==43 & v05_03b==4
replace chome43=homefoodq*8385.9*0.568 if v05_idc==43 & v05_03b==7

gen cbuy43=buyfoodq*8385.9 if v05_idc==43 & v05_06b==4
replace cbuy43=buyfoodq*8385.9*0.568 if v05_idc==43 & v05_06b==7


gen chome51=homefoodq*77*10 if v05_idc==51 & v05_03b==1
replace chome51=homefoodq*77*0.01 if v05_idc==51 & v05_03b==2
replace chome51=homefoodq*77*720 if v05_idc==51 & v05_03b==5
replace chome51=homefoodq*77*36 if v05_idc==51 & v05_03b==6
replace chome51=homefoodq*77*4.5 if v05_idc==51 & v05_03b==7
replace chome51=homefoodq*77*373 if v05_idc==51 & v05_03b==3

gen cbuy51=buyfoodq*77*10 if v05_idc==51 & v05_06b==1
```

```
replace cbuy51=buyfoodq*77*0.01 if v05_idc==51 & v05_06b==2
replace cbuy51=buyfoodq*77*720 if v05_idc==51 & v05_06b==5
replace cbuy51=buyfoodq*77*36 if v05_idc==51 & v05_06b==6
replace cbuy51=buyfoodq*77*4.5 if v05_idc==51 & v05_06b==7


gen chome52=homefoodq*43*10 if v05_idc==52 & v05_03b==1
replace chome52=homefoodq*43*0.01 if v05_idc==52 & v05_03b==2
replace chome52=homefoodq*43*36 if v05_idc==52 & v05_03b==6
replace chome52=homefoodq*43*5.4 if v05_idc==52 & v05_03b==8

gen cbuy52=buyfoodq*43*10 if v05_idc==52 & v05_06b==1
replace cbuy52=buyfoodq*43*0.01 if v05_idc==52 & v05_06b==2
replace cbuy52=buyfoodq*43*720 if v05_idc==52 & v05_06b==5
replace cbuy52=buyfoodq*43*36 if v05_idc==52 & v05_06b==6
replace cbuy52=buyfoodq*43*1000 if v05_idc==52 & v05_06b==11

gen chome53=homefoodq*29*10 if v05_idc==53 & v05_03b==1
replace chome53=homefoodq*29*0.01 if v05_idc==53 & v05_03b==2

gen cbuy53=buyfoodq*29*10 if v05_idc==53 & v05_06b==1
replace cbuy53=buyfoodq*29*0.01 if v05_idc==53 & v05_06b==2


gen chome59=homefoodq*101*10 if v05_idc==59 & v05_03b==1
replace chome59=homefoodq*101*0.01 if v05_idc==59 & v05_03b==2
replace chome59=homefoodq*101*36 if v05_idc==59 & v05_03b==6
replace chome59=homefoodq*101*4.5 if v05_idc==59 & v05_03b==7

gen cbuy59=buyfoodq*101*10 if v05_idc==59 & v05_06b==1
replace cbuy59=buyfoodq*101*0.01 if v05_idc==59 & v05_06b==2
replace cbuy59=buyfoodq*101*36 if v05_idc==59 & v05_06b==6
replace cbuy59=buyfoodq*101*4.5 if v05_idc==59 & v05_06b==7
replace cbuy59=buyfoodq*101*10 if v05_idc==59 & v05_06b==9

gen chome54=homefoodq*18*10 if v05_idc==54 & v05_03b==1
replace chome54=homefoodq*18*0.01 if v05_idc==54 & v05_03b==2
replace chome54=homefoodq*18*5.4 if v05_idc==54 & v05_03b==8
replace chome54=homefoodq*18*1.5 if v05_idc==54 & v05_03b==9

gen cbuy54=buyfoodq*18*10 if v05_idc==54 & v05_06b==1
replace cbuy54=buyfoodq*18*0.01 if v05_idc==54 & v05_06b==2
replace cbuy54=buyfoodq*18*5.4 if v05_idc==54 & v05_06b==8
replace cbuy54=buyfoodq*18*1.5 if v05_idc==54 & v05_06b==9

gen chome56=homefoodq*17.4*10 if v05_idc==56 & v05_03b==1
replace chome56=homefoodq*17.4*0.01 if v05_idc==56 & v05_03b==2

gen cbuy56=buyfoodq*17.4*10 if v05_idc==56 & v05_06b==1
```

```
replace cbuy56=buyfoodq*17.4*0.01 if v05_idc==56 & v05_06b==2


gen chome57=homefoodq*17*10 if v05_idc==57 & v05_03b==1
replace chome57=homefoodq*17*0.01 if v05_idc==57 & v05_03b==2


gen cbuy57=buyfoodq*17*10 if v05_idc==57 & v05_06b==1
replace cbuy57=buyfoodq*17*0.01 if v05_idc==57 & v05_06b==2


gen chome61=homefoodq*97*10 if v05_idc==61 & v05_03b==1
replace chome61=homefoodq*97*1.18 if v05_idc==61 & v05_03b==9
replace chome61=homefoodq*97*1.18*12 if v05_idc==61 & v05_03b==10

gen cbuy61=buyfoodq*97*10 if v05_idc==61 & v05_06b==1
replace cbuy61=buyfoodq*97*0.01 if v05_idc==61 & v05_06b==2
replace cbuy61=buyfoodq*97*1.18 if v05_idc==61 & v05_06b==9
replace cbuy61=buyfoodq*97*1.18*12 if v05_idc==61 & v05_06b==10

gen chome62=homefoodq*47*10 if v05_idc==62 & v05_03b==1
replace chome62=homefoodq*47*0.01 if v05_idc==62 & v05_03b==2
replace chome62=homefoodq*62 if v05_idc==62 & v05_03b==9
replace chome62=homefoodq*62*12 if v05_idc==62 & v05_03b==10

gen cbuy62=buyfoodq*47*10 if v05_idc==62 & v05_06b==1
replace cbuy62=buyfoodq*47*0.01 if v05_idc==62 & v05_06b==2
replace cbuy62=buyfoodq*47*1000 if v05_idc==62 & v05_06b==11
replace cbuy62=buyfoodq*62 if v05_idc==62 & v05_06b==9
replace cbuy62=buyfoodq*62*12 if v05_idc==62 & v05_06b==10

gen chome63=homefoodq*65*10 if v05_idc==63 & v05_03b==1
replace chome63=homefoodq*65*1000 if v05_idc==63 & v05_03b==11
replace chome63=homefoodq*135 if v05_idc==63 & v05_03b==9
replace chome63=homefoodq*135*12 if v05_idc==63 & v05_03b==10

gen cbuy63=buyfoodq*65*10 if v05_idc==63 & v05_06b==1
replace cbuy63=buyfoodq*65*0.01 if v05_idc==63 & v05_06b==2
replace cbuy63=buyfoodq*65*1000 if v05_idc==63 & v05_06b==11
replace cbuy63=buyfoodq*135 if v05_idc==63 & v05_06b==9
replace cbuy63=buyfoodq*135*12 if v05_idc==63 & v05_06b==10

gen chome64=homefoodq*52*10 if v05_idc==64 & v05_03b==1
replace chome64=homefoodq*95 if v05_idc==64 & v05_03b==9
replace chome64=homefoodq*52*1000 if v05_idc==64 & v05_03b==11

gen cbuy64=buyfoodq*52*10 if v05_idc==64 & v05_06b==1
replace cbuy64=buyfoodq*52*0.01 if v05_idc==64 & v05_06b==2
replace cbuy64=buyfoodq*95 if v05_idc==64 & v05_06b==9
```

```
replace cbuy64=buyfoodq*95*12 if v05_idc==64 & v05_06b==10

gen chome65=homefoodq*50*10 if v05_idc==65 & v05_03b==1
replace chome65=homefoodq*448 if v05_idc==65 & v05_03b==9

gen cbuy65=buyfoodq*50*10 if v05_idc==65 & v05_06b==1
replace cbuy65=buyfoodq*50*0.01 if v05_idc==65 & v05_06b==2
replace cbuy65=buyfoodq*50*1000 if v05_idc==65 & v05_06b==11
replace cbuy65=buyfoodq*448 if v05_idc==65 & v05_06b==9

gen chome66=homefoodq*39.3*10 if v05_idc==66 & v05_03b==1
replace chome66=homefoodq*157.2 if v05_idc==66 & v05_03b==9

gen cbuy66=buyfoodq*39.3*10 if v05_idc==66 & v05_06b==1
replace cbuy66=buyfoodq*39.3*0.01 if v05_idc==66 & v05_06b==2
replace cbuy66=buyfoodq*157.2 if v05_idc==66 & v05_06b==9

gen chome71=homefoodq*200*10 if v05_idc==71 & v05_03b==1
replace chome71=homefoodq*2 if v05_idc==71 & v05_03b==2

gen cbuy71=buyfoodq*200*10 if v05_idc==71 & v05_06b==1
replace cbuy71=buyfoodq*2 if v05_idc==71 & v05_06b==2

gen chome72=homefoodq*234*10 if v05_idc==72 & v05_03b==1
replace chome72=homefoodq*234*0.01 if v05_idc==72 & v05_03b==2


gen cbuy72=buyfoodq*234*10 if v05_idc==72 & v05_06b==1
replace cbuy72=buyfoodq*234*0.01 if v05_idc==72 & v05_06b==2

gen chome73=homefoodq*100*10 if v05_idc==73 & v05_03b==1

gen cbuy73=buyfoodq*100*10 if v05_idc==73 & v05_06b==1
replace cbuy73=buyfoodq if v05_idc==73 & v05_06b==2

gen chome74=homefoodq*223*10 if v05_idc==74 & v05_03b==1
replace chome74=homefoodq*2.23 if v05_idc==74 & v05_03b==2


gen cbuy74=buyfoodq*223*10 if v05_idc==74 & v05_06b==1
replace cbuy74=buyfoodq*2.23 if v05_idc==74 & v05_06b==2


gen cbuy91=buyfoodq*381*10 if v05_idc==91 & v05_06b==1
replace cbuy91=buyfoodq*381*0.01 if v05_idc==91 & v05_06b==2


gen chome92=homefoodq*380*10 if v05_idc==92 & v05_03b==1
replace chome92=homefoodq*380*0.01 if v05_idc==92 & v05_03b==2
```

```
replace chome92=homefoodq*380*4.5 if v05_idc==92 & v05_03b==7

gen cbuy92=buyfoodq*380*10 if v05_idc==92 & v05_06b==1
replace cbuy92=buyfoodq*380*0.01 if v05_idc==92 & v05_06b==2
replace cbuy92=buyfoodq*380*4.5 if v05_idc==92 & v05_06b==7
*replace cbuy92=buyfoodq*85.7*1.8 if v05_idc==92 | v05_06b==9

gen cbuy93=buyfoodq*88*10 if v05_idc==93 & v05_06b==1
replace cbuy93=buyfoodq*88*0.01 if v05_idc==93 & v05_06b==2
*replace cbuy93=buyfoodq*88*1.8 if v05_idc==93 | v05_06b==9

*replace .(who didn't consume a certain food item) with 0
replace chome11=0 if chome11==.
replace chome12=0 if chome12==.
replace chome13=0 if chome13==.
replace chome14=0 if chome14==.
replace chome15=0 if chome15==.
replace chome16=0 if chome16==.
replace chome17=0 if chome17==.
replace chome21=0 if chome21==.
replace chome22=0 if chome22==.
replace chome23=0 if chome23==.
replace chome24=0 if chome24==.
replace chome26=0 if chome26==.
replace chome31=0 if chome31==.
replace chome32=0 if chome32==.
replace chome41=0 if chome41==.
replace chome43=0 if chome43==.
replace chome51=0 if chome51==.
replace chome52=0 if chome52==.
replace chome53=0 if chome53==.
replace chome59=0 if chome59==.
replace chome54=0 if chome54==.
replace chome56=0 if chome56==.
replace chome57=0 if chome57==.
replace chome61=0 if chome61==.
replace chome62=0 if chome62==.
replace chome63=0 if chome63==.
replace chome64=0 if chome64==.
replace chome65=0 if chome65==.
replace chome66=0 if chome66==.
replace chome71=0 if chome71==.
replace chome72=0 if chome72==.
replace chome73=0 if chome73==.
replace chome74=0 if chome74==.
replace chome92=0 if chome92==.
replace cbuy11=0 if cbuy11==.
replace cbuy12=0 if cbuy12==.
replace cbuy13=0 if cbuy13==.
```

```
replace cbuy14=0 if cbuy14==.
replace cbuy15=0 if cbuy15==.
replace cbuy16=0 if cbuy16==.
replace cbuy17=0 if cbuy17==.
replace cbuy21=0 if cbuy21==.
replace cbuy22=0 if cbuy22==.
replace cbuy23=0 if cbuy23==.
replace cbuy24=0 if cbuy24==.
replace cbuy26=0 if cbuy26==.
replace cbuy31=0 if cbuy31==.
replace cbuy32=0 if cbuy32==.
replace cbuy33=0 if cbuy33==.
replace cbuy34=0 if cbuy34==.
replace cbuy35=0 if cbuy35==.
replace cbuy41=0 if cbuy41==.
replace cbuy42=0 if cbuy42==.
replace cbuy43=0 if cbuy43==.
replace cbuy51=0 if cbuy51==.
replace cbuy52=0 if cbuy52==.
replace cbuy53=0 if cbuy53==.
replace cbuy59=0 if cbuy59==.
replace cbuy54=0 if cbuy54==.
replace cbuy56=0 if cbuy56==.
replace cbuy57=0 if cbuy57==.
replace cbuy61=0 if cbuy61==.
replace cbuy62=0 if cbuy62==.
replace cbuy63=0 if cbuy63==.
replace cbuy64=0 if cbuy64==.
replace cbuy65=0 if cbuy65==.
replace cbuy66=0 if cbuy66==.
replace cbuy71=0 if cbuy71==.
replace cbuy72=0 if cbuy72==.
replace cbuy73=0 if cbuy73==.
replace cbuy74=0 if cbuy74==.
replace cbuy91=0 if cbuy91==.
replace cbuy92=0 if cbuy92==.
replace cbuy93=0 if cbuy93==.

*The following part is to calculating calories for differnet categories of homeproduction
* Carbohudrate (rice/gram/beans)
gen homecalcar=chome11+chome12+chome13+chome14+chome15+chome16+chome17
*pulses
gen homecalpul=chome21+chome22+chome23+chome24+chome26
*Protein(eggs/milk/fish/meat)
gen homecalpro=chome31+chome32+chome71+chome72+chome73+chome74
*Cooking oils
gen homecaloil=chome41+chome43
*Vegetables
gen homecalveg=chome51+chome52+chome53+chome59+chome54+chome56+chome57
```

```
*Fruit
gen homecalfru=chome61+chome62+chome63+chome64+chome65+chome66

*calculating calories for differnet categories of food purchased in the mkt
* Carbohudrate (rice/gram/beans)
gen buycalcar=cbuy11+cbuy12+cbuy13+cbuy14+cbuy15+cbuy16+cbuy17
*Pulses
gen buycalpul=cbuy21+cbuy22+cbuy23+cbuy24+cbuy26
*Protein(eggs/milk/fish/meat)
gen buycalpro=cbuy31+cbuy32+cbuy33+cbuy34+cbuy35+cbuy71+cbuy72+cbuy73+cbuy74
*Cooking oils
gen buycaloil=cbuy41+cbuy42+cbuy43
*Vegetables
gen buycalveg=cbuy51+cbuy52+cbuy53+cbuy54+cbuy56+cbuy57+cbuy59
*Fruit
gen buycalfru=cbuy65+cbuy61+cbuy62+cbuy63+cbuy64+cbuy66
*sweets and confectionery
gen buycalsweet=cbuy91+cbuy92+cbuy93


*In order to get the calories of each food item for each household, I need to generate a unique id for each
food item in a household. Therefore, the first step is generating an id for different categories of food
* Carbohudrate (rice/gram/beans)
gen idc=1 if
v05_idc==11|v05_idc==12|v05_idc==13|v05_idc==14|v05_idc==15|v05_idc==16|v05_idc==17
*pulses
replace idc=7 if v05_idc==21|v05_idc==22|v05_idc==23|v05_idc==24|v05_idc==26
*Protein(eggs/milk/fish/meat)
replace idc=2 if
v05_idc==31|v05_idc==32|v05_idc==33|v05_idc==34|v05_idc==35|v05_idc==71|v05_idc==72|v05_idc
==73|v05_idc==74
*Cooking oils
replace idc=3 if v05_idc==41|v05_idc==42|v05_idc==43
*Vegetables
replace idc=4 if
v05_idc==51|v05_idc==59|v05_idc==52|v05_idc==53|v05_idc==54|v05_idc==55|v05_idc==56|v05_idc
==57
*Fruit
replace idc=5 if v05_idc==61|v05_idc==62|v05_idc==63|v05_idc==64|v05_idc==65|v05_idc==66
*sweets and confectionery
replace idc=6 if v05_idc==91|v05_idc==92|v05_idc==93

gen calcar=homecalcar+buycalcar
gen calpul=homecalpul+buycalpul
gen calpro=homecalpro+buycalpro
gen caloil=homecaloil+buycaloil
gen calveg=homecalveg+buycalveg
gen calfru=homecalfru+buycalfru
gen calsweet=buycalsweet
```

```
*The following items dropped are those which is general categories
drop if v05_idc== 18| v05_idc==25 | v05_idc==27| v05_idc==36| v05_idc==44| v05_idc==55|
v05_idc==58| v05_idc==67| v05_idc==68| v05_idc==75| v05_idc==82| v05_idc==83| v05_idc==84|
v05_idc==85| v05_idc==86| v05_idc==94| v05_idc==101| v05_idc==102| v05_idc==103| v05_idc==104|
v05_idc==111| v05_idc==112| v05_idc==113| v05_idc==114| v05_idc==121| v05_idc==122|
v05_idc==123| v05_idc==124| v05_idc==131| v05_idc==132| v05_idc==133| v05_idc==990|
v05_idc==90| v05_idc==81

*Generating a unique id for a unique category, saying protein, for a household
gen id2 = string( xhpsu) + string( xhnum) + string(idc)
destring id2, replace
save calcat, replace


***This part is to calculate the calories of each categories for each household

*get categories of carbohydrate for each household

use  "C:\wenmei\data\nlss2010\calcat.dta",clear

keep  xhpsu xhnum idc id2 calcar calpul calpro caloil calveg calfru calsweet
keep if idc==1
collapse (sum) calcar, by(id2)

*Generating the id1 is to create a common id across these files and other datasets.
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\calcarbohydrate.dta"
drop _merge
save calcarbohydrate, replace

**get categories of pulses for each household
keep if idc==7
*collapse (sum) calpul, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\calpul.dta"
drop _merge
save calpul, replace

**get calories of protein for each household
keep if idc==2
collapse (sum) calpro, by(id2)
```

```
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\calprotein.dta"
drop _merge
save calprotein, replace

*get calories of oil for each household
keep if idc==3
*collapse (sum) caloil, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\caloil.dta"
drop _merge
save caloil, replace

*get calories of vegetable for each household

keep if idc==4
*collapse (sum) calveg, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\calvegetable.dta"
drop _merge
save calvegetable, replace

*get calories of fruit for each household

keep if idc==5
*collapse (sum) calfru, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\calfruit.dta"
drop _merge
save calfruit, replace

*get calories of sweets for each households
```

```
keep if idc==6
*collapse (sum) calsweet, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\calsweet.dta"
drop _merge
save calsweet, replace


***This part is to calculate the diversity of food(may not be needed)
*Calculating the number of food of each categories consumed by household(diversity)
use "C:\wenmei\data\2010\Stata9\xh05_s05.dta",clear
drop if v05_idc>=100  //drop the food of no nutrition, e.g. cigarrette
replace v05_03a=0 if v05_03a==.
replace v05_06a=0 if v05_06a==.
gen diversitycat=1 if v05_03a>0 | v05_06a>0
replace diversitycat=0 if diversitycat==.  //replace the food that is not consumed with 0
drop if v05_idc== 18| v05_idc==25 | v05_idc==27| v05_idc==36| v05_idc==44| v05_idc==55|
v05_idc==58| v05_idc==67| v05_idc==68| v05_idc==75| v05_idc==82| v05_idc==83| v05_idc==84|
v05_idc==85| v05_idc==86| v05_idc==94| v05_idc==101| v05_idc==102| v05_idc==103| v05_idc==104|
v05_idc==111| v05_idc==112| v05_idc==113| v05_idc==114| v05_idc==121| v05_idc==122|
v05_idc==123| v05_idc==124| v05_idc==131| v05_idc==132| v05_idc==133| v05_idc==990|
v05_idc==90| v05_idc==81

*generating different ids for different categories for each household(same as above)
* Carbohudrate (rice/gram/beans)
gen idc=1 if
v05_idc==11|v05_idc==12|v05_idc==13|v05_idc==14|v05_idc==15|v05_idc==16|v05_idc==17
*pulses
replace idc=7 if v05_idc==21|v05_idc==22|v05_idc==23|v05_idc==24|v05_idc==26
*Protein(eggs/milk/fish/meat)
replace idc=2 if
v05_idc==31|v05_idc==32|v05_idc==33|v05_idc==34|v05_idc==35|v05_idc==71|v05_idc==72|v05_idc
==73|v05_idc==74
*Cooking oils
replace idc=3 if v05_idc==41|v05_idc==42|v05_idc==43
*Vegetables
replace idc=4 if
v05_idc==51|v05_idc==59|v05_idc==52|v05_idc==53|v05_idc==54|v05_idc==55|v05_idc==56|v05_idc
==57
*Fruit
replace idc=5 if v05_idc==61|v05_idc==62|v05_idc==63|v05_idc==64|v05_idc==65|v05_idc==66
*sweets and confectionery
replace idc=6 if v05_idc==91|v05_idc==92|v05_idc==93

gen id2 = string( xhpsu) + string( xhnum) + string(idc)
```

```
destring id2, replace
save diversitycat, replace

*generate the diversity of carbohydrate for each household

keep if idc==1
*collapse (sum) diversitycat, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\diversitycar.dta"
drop _merge
save diversitycar, replace

*calculate the diversity of pulses for each household
keep if idc==7
*collapse (sum) diversitycat, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\diversitypul.dta"
drop _merge
save diversitypul, replace


*generate the diversity of protein for each household

keep if idc==2
*collapse (sum) diversitycat, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\diversitypro.dta"
drop _merge
save diversitypro, replace

*generate the diversity of cooking oil for each household

keep if idc==3
*collapse (sum) diversitycat, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
```

```
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\diversityoil.dta"
drop _merge
save diversityoil, replace

*generate the diversity of vegetables for each household

keep if idc==4
*collapse (sum) diversitycat, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\diversityveg.dta"
drop _merge
save diversityveg, replace

*generate the diversity of fruit for each household

keep if idc==5
*collapse (sum) diversitycat, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\diversityfru.dta"
drop _merge
save diversityfru, replace

*generate the diversity of sweet for each household

keep if idc==6
*collapse (sum) diversitycat, by(id2)

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (mean) id2, by(id1)

merge 1:1 id2 using "C:\wenmei\data\nlss2010\diversitysweet.dta"
drop _merge
save diversityswe, replace*/


***This several lines of codes is to calculate a general calories of all food for one household
/*gen
hhomecal=chome11+chome12+chome13+chome14+chome15+chome16+chome17+chome21+chome22+
```

```
chome23+chome24+chome26+chome31+chome32+chome41+chome43+chome51+chome52+chome53+
chome59+chome54+chome56+chome57+chome61+chome62+chome63+chome64+chome65+chome66+
chome71+chome72+chome73+chome74
gen
hbuycal=cbuy11+cbuy12+cbuy13+cbuy14+cbuy15+cbuy16+cbuy17+cbuy21+cbuy22+cbuy23+cbuy24+
cbuy26+cbuy31+cbuy32+cbuy33+cbuy34+cbuy35+cbuy41+cbuy42+cbuy43+cbuy51+cbuy52+cbuy53+c
buy54+cbuy56+cbuy57+cbuy59+cbuy65+cbuy61+cbuy62+cbuy63+cbuy64+cbuy66+cbuy71+cbuy72+c
buy73+cbuy74+cbuy91+cbuy92+cbuy93

gen calories30=hhomecal+hbuycal

gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (sum) calories30, by(id1)



*Calculating the number of food consumed by household(diversity) (General situation, maybe not very
good)
use "C:\wenmei\data\2010\Stata9\xh05_s05.dta",clear
drop if v05_idc>=100
replace v05_03a=0 if v05_03a==.
replace v05_06a=0 if v05_06a==.
gen diversity=1 if v05_03a>0 | v05_06a>0
replace diversity=0 if diversity==.
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (sum) diversity, by(id1)


*credits, if any household member can have loans outside
use "D:\wenmei\data\2010\Stata9\xh00_s00.dta", clear
keep  xhpsu xhnum v15_01
rename v15_01 credit
replace credit=0 if credit==2
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
save credit, replace

*transfers, amount of remittance
use "D:\data\Stata9\xh37_s16.dta", clear
keep  xhpsu xhnum v16_16 v16_17
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
replace v16_16=0 if v16_16==.
replace v16_17=0 if v16_17==.
gen remittance=v16_16+v16_17
collapse (sum) remittance, by(id1)
```

```
use "D:\data\Stata9\xh39_s17b.dta", clear
keep  xhpsu xhnum v17_20a v17_20b
replace v17_20a=0 if v17_20a==.
replace v17_20b=0 if v17_20b==.
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
gen remitotherrec=v17_20a+v17_20b
collapse (sum) remitotherrec, by(id1)

merge 1:1 id1 using "D:\data\incdata\remit.dta"
drop _merge
save transfer, replace
replace remitotherrec=0 if remitotherrec==.
replace remittance=0 if remittance==.

#this is the amount of remittance
gen transfers=remittance+remitotherrec
gen remit=log(transfer+1)
save transfer, replace
*amount of land
use "D:\data\Stata9\xh20_s13a1.dta", clear
keep  xhpsu xhnum v13_04u v13_04rb v13_04ak v13_04pd
gen la=v13_04rb+v13_04ak+v13_04pd
gen lar=la*5476 if v13_04u==1
replace lar=la*72900 if v13_04u==2
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
collapse (sum) lar, by(id1)
save landamount, replace

*if the household received remittance from other household members(dummy variable)
use "D:\wenmei\data\2010\Stata9\xh37_s16.dta"
keep v16_13 xhpsu xhnum
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
rename v16_13 remithousmem
replace remithousmem=0 if remithousmem==2
collapse (sum) remithousmem,by(id1)
replace remithousmem=1 if remithousmem>=1
*instruments
*age of the dwelling & no of firewood the household collects
use "D:\wenmei\data\2010\Stata9\xh02_s02.dta", clear
keep xhpsu xhnum v02_10 v02_36 v02_37a v02_37b v02_37c
gen bage=2013-v02_10+100
replace v02_37c=1 if v02_37a==3
gen firewood=v02_37b*v02_37c
replace firewood=0 if v02_36==2
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
```

```
save instrument, replace

*population
use "D:\wenmei\data\nlss2010\rural\xr70_sr0.dta", clear
keep  r0_dist r1_04
rename r0_dist district
rename r1_04 population
collapse (sum) population, by(district)

*household head education
use "D:\wenmei\data\2010\Stata9\xh10_s07.dta", clear
keep if  v07_idc==1
keep  xhpsu xhnum v07_02 v07_03
rename v07_02 read
rename v07_03 write
replace read=0 if read==2
replace write=0 if write==2
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace



/*merge datafiles
use "C:\wenmei\data\nlss2010\head.dta",clear
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
sort id1
save merge1,replace

use "C:\wenmei\data\nlss2010\education.dta",clear
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
sort id1
save nlss20101,replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge1.dta"
drop _merge
save merge2, replace

use "C:\wenmei\data\nlss2010\calories30.dta"
sort id1
save nlss20102,replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge2.dta"
drop _merge
save merge3, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\dryland.dta"
drop _merge
```

```
save merge4, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\wetland.dta"
drop _merge
save merge5, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\borrow.dta"
drop _merge
save merge6, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\lend.dta"
drop _merge
save merge7, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\livenow.dta"
drop _merge
save merge8, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\live12.dta"
drop _merge
save merge9, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\livebuy.dta"
drop _merge
save merge10, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\hhincome.dta"
drop _merge
save merge11, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversity.dta"
drop _merge
save merge12, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\child.dta"
drop _merge
save merge13, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversity.dta"
drop _merge
save merge14, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\calcarbohydrate.dta"
drop _merge
save merge15, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\calpul.dta"
drop _merge
save merge16, replace
```

```
merge 1:1 id1 using "C:\wenmei\data\nlss2010\calprotein.dta"
drop _merge
save merge17, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\calvegetable.dta"
drop _merge
save merge18, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\calfruit.dta"
drop _merge
save merge19, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\caloil.dta"
drop _merge
save merge20, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\calsweet.dta"
drop _merge
save merge21, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversitycar.dta"
drop _merge
save merge22, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversitypul.dta"
drop _merge
save merge23, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversitypro.dta"
drop _merge
save merge24, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversityoil.dta"
drop _merge
save merge25, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversityveg.dta"
drop _merge
save merge26, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversityfru.dta"
drop _merge
save merge27, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\diversityswe.dta"
drop _merge
save merge28, replace
```

```
merge 1:1 id1 using "C:\wenmei\data\nlss2010\old.dta"
drop _merge
save merge29, replace

use "C:\wenmei\data\nlss2010\poverty.dta", clear
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
sort id1
save poverty1, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge29.dta"
drop _merge
save merge30, replace

use "C:\wenmei\data\nlss2010\foodaid.dta", clear
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
sort id1
save foodaid1,replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge30.dta"
drop _merge
save merge31, replace

use "C:\wenmei\data\nlss2010\000.dta", clear
gen id1= string( xhpsu) + string( xhnum)
destring id1, replace
sort id1
save nlss20100,replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge31.dta"
drop _merge
save merge32, replace

use "C:\wenmei\data\2010\Stata9\xh02_s02.dta", clear
keep  xhpsu xhnum v02_02a v02_31a v02_31b v02_31c v02_31d
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
sort id1
save nlss20101, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge32.dta"
drop _merge
save merge33, replace

use "C:\wenmei\data\2010\Stata9\xh33_s15a.dta", clear
keep  xhpsu xhnum v15_05
rename v15_05 borrowwho
replace borrowwho=1 if borrowwho==1
```

```
replace borrowwho=0 if borrowwho>=2
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
collapse (sum) borrowwho, by(id1)
replace borrowwho=1 if borrowwho>=1
save borrowwho, replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge33.dta"
drop _merge
replace borrowwho=0 if borrowwho==.
save merge34, replace


*use "C:\wenmei\data\nlss2010\district.dta", clear
gen dist=v00_dist

rename dist district*


merge 1:1 id1 using "C:\wenmei\data\nlss2010\district.dta"
drop _merge
drop v00_dist
save merge35, replace

use "C:\wenmei\data\2010\Stata9\xh00_s00.dta", clear
keep  xhpsu xhnum v13_02 v13_65 v17_11 v13_74
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
sort id1
save nlss20103,replace

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge35.dta"
drop _merge
save merge36, replace


*use "C:\wenmei\data\nlss2010\climate.dta", clear
drop if v1==.
gen dist=v1

save climate1, replace

use "C:\wenmei\data\nlss2010\climate1.dta"
merge 1:m dist using "C:\wenmei\data\nlss2010\merge36.dta"
drop _merge
rename dist district
save merge37, replace

merge m:m district using "C:\wenmei\data\nlss2010\socialcapital1.dta"
```

```
drop _merge
save merge38, replace

use "C:\wenmei\wenmei\data\nlss2010\road.dta"
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
sort id1

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge38.dta"
drop _merge
save merge39, replace

use "C:\wenmei\data\nlss2010\agri.dta"
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
sort id1

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge39.dta"
drop _merge
save merge40, replace

use "C:\wenmei\data\nlss2010\mkt.dta"
gen id1 = string( xhpsu) + string( xhnum)
destring id1, replace
sort id1

merge 1:1 id1 using "C:\wenmei\data\nlss2010\merge40.dta"
drop _merge
save merge41, replace

 merge 1:1 id1 using "D:\data\land\landamount.dta"
 drop _merge
 save merge41, replace

  merge 1:1 id1 using "D:\wenmei\data\nlss2010\instruments.dta"
 drop _merge
 save merge41, replace

  merge 1:1 id1 using "D:\wenmei\data\nlss2010\credit.dta"
 drop _merge
 save merge41, replace
 */

rename v18_101 foodaid
rename v18_102 nutrichild
rename v18_103 nutrimom
rename v18_104 foodwork
rename v18_105 cashwork
rename v13_02 ownagri
```

```
rename v13_65 ownlive
rename v17_11 remitother
rename v07_11 heducation
rename v01_03 age
rename v01_02 gender
rename v01_06 married
rename v01_08 hcast
rename v15_14 loanown
rename v02_31a telephone
rename v02_31b mophone
rename v02_31c tv
rename v02_31d internet
rename v02_02a totalroom
rename v13_74 equipment

replace belt=0 if belt==1
replace belt=1 if belt==2
replace belt=2 if belt==3
replace nutrichild=0 if nutrichild==2
replace gender=0 if gender==1
replace gender=1 if gender==2
replace ownagri=0 if ownagri==2
replace remitother=0 if remitother==2
replace ownlive=0 if ownlive==2
replace foodaid=0 if foodaid==2
replace nutrimom=0 if nutrimom==2
replace loanown=0 if loanown==2
replace foodwork=0 if foodwork==2
replace cashwork=0 if cashwork==2
replace telephone=0 if telephone==2
replace mophone=0 if mophone==2
replace tv=0 if tv==2
replace internet=0 if internet==2
replace equipment=0 if equipment==2

replace livenow=0 if livenow==.
replace livebuy=0 if livebuy==.
replace amountlend=0 if amountlend==.
replace amountborrow=0 if amountborrow==.
replace remitother=0 if remitother==.
replace borrowwho=0 if borrowwho==.

*merging casts according to census 2001
gen cast1=0 if hcast==1|hcast==2|hcast==14|hcast==20|hcast==48|hcast==65|hcast==49|hcast==27
replace cast1=1 if
hcast==76|hcast==58|hcast==59|hcast==26|hcast==30|hcast==38|hcast==43|hcast==56|hcast==35|hcast=
=63|hcast==72|hcast==94|hcast==9|hcast==16|hcast==18|hcast==19|hcast==25|hcast==28|hcast==31|hcas
t==77|hcast==34|hcast==37|hcast==44|hcast==47|hcast==50|hcast==55|hcast==64|hcast==33
```

```
replace cast1=2 if
hcast==87|hcast==8|hcast==12|hcast==15|hcast==79|hcast==84|hcast==102|hcast==17|hcast==22|hcast=
=23|hcast==39|hcast==40|hcast==41|hcast==54|hcast==70|hcast==75
replace cast1=3 if hcast==6
replace cast1=4 if
hcast==85|hcast==89|hcast==97|hcast==99|hcast==103|hcast==101|hcast==93|hcast==61|hcast==68|hcast
==57|hcast==32|hcast==5|hcast==36|hcast==42|hcast==45|hcast==60|hcast==67|hcast==62|hcast==78|hc
ast==71|hcast==90|hcast==98|hcast==46|hcast==92|hcast==3|hcast==74|hcast==10|hcast==24|hcast==29|
hcast==66|hcast==69|hcast==13|hcast==86|hcast==91|hcast==80|hcast==95|hcast==82|hcast==100|hcast
==81|hcast==4|hcast==11|hcast==21|hcast==52|hcast==53

replace cast1=5 if hcast==7|hcast==83
replace cast1=6 if hcast==73|hcast==96|hcast==88|hcast==51

gen hhcast=0 if cast1==0
replace hhcast=1 if cast1==2
replace hhcast=3 if cast1==4
replace hhcast=4 if cast1==1|cast1==3|cast1==5|cast1==6


***********************************Chapter 3*************************************
*social capital
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\social2010.dta",clear
****************************2010 social capital*******************************
use "C:\wenmei\wenmei\wenmei\firstchapterdata\NLSS Data\NLSS_III_2010_2011\rural\xr70_sr0.dta",
clear
merge 1:m xhpsu using "C:\wenmei\wenmei\wenmei\firstchapterdata\NLSS
Data\NLSS_III_2010_2011\rural\xr87_sr4b.dta"
keep if _merge==3
keep   xhpsu r0_dist r0_vdc r4_14 r4_15 r4_16 r4_17 r4_18
ren r0_dist district
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\social2010.dta",replace

use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\social2010.dta",clear
*for farmer's group
keep if r4_14==1
ren r4_15 groupyear
ren r4_16 hhno
ren r4_17 pwomen
ren r4_18 meetingno
egen sgyear=sum(groupyear), by(district)
egen shhno=sum(hhno), by(district)
egen spwomen=sum(pwomen), by(district)
egen smeetno=sum(meetingno), by(district)
egen maxgyear=max(sgyear)
egen maxhhno=max(shhno)
egen maxpwomen=max(spwomen)
egen maxmeetno=max(smeetno)
egen mingyear=min(sgyear)
```

```
egen minhhno=min(shhno)
egen minpwomen=min(spwomen)
egen minmeetno=min(smeetno)
gen farmyear=(sgyear-mingyear)/(maxgyear-mingyear)
gen farmhhno=(shhno-minhhno)/(maxhhno-minhhno)
gen farmpwom=(spwomen-minpwomen)/(maxpwomen-minpwomen)
gen farmmeetno=(smeetno-minmeetno)/(maxmeetno-minmeetno)
gen dscfarm=farmyear+farmhhno+farmpwom+farmmeetno
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scfarmfull1.dta",replace
 keep district dscfarm
 collapse (mean) dscfarm, by(district)
  save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scfarm1.dta",replace


*for water's group
keep if r4_14==2
ren r4_15 groupyear
ren r4_16 hhno
ren r4_17 pwomen
ren r4_18 meetingno
egen sgyear=sum(groupyear), by(district)
egen shhno=sum(hhno), by(district)
egen spwomen=sum(pwomen), by(district)
egen smeetno=sum(meetingno), by(district)
egen maxgyear=max(sgyear)
egen maxhhno=max(shhno)
egen maxpwomen=max(spwomen)
egen maxmeetno=max(smeetno)
egen mingyear=min(sgyear)
egen minhhno=min(shhno)
egen minpwomen=min(spwomen)
egen minmeetno=min(smeetno)
gen wateryear=(sgyear-mingyear)/(maxgyear-mingyear)
gen waterhhno=(shhno-minhhno)/(maxhhno-minhhno)
gen waterpwom=(spwomen-minpwomen)/(maxpwomen-minpwomen)
gen watermeetno=(smeetno-minmeetno)/(maxmeetno-minmeetno)
gen dscwater=wateryear+waterhhno+waterpwom+watermeetno
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scwaterfull1.dta",replace
 keep district dscwater
 collapse (mean) dscwater, by(district)
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scwater1.dta",replace

use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\social2010.dta",clear
*for forest's group
keep if r4_14==3
ren r4_15 groupyear
ren r4_16 hhno
ren r4_17 pwomen
ren r4_18 meetingno
```

```
egen sgyear=sum(groupyear), by(district)
egen shhno=sum(hhno), by(district)
egen spwomen=sum(pwomen), by(district)
egen smeetno=sum(meetingno), by(district)
egen maxgyear=max(sgyear)
egen maxhhno=max(shhno)
egen maxpwomen=max(spwomen)
egen maxmeetno=max(smeetno)
egen mingyear=min(sgyear)
egen minhhno=min(shhno)
egen minpwomen=min(spwomen)
egen minmeetno=min(smeetno)
gen forestyear=(sgyear-mingyear)/(maxgyear-mingyear)
gen foresthhno=(shhno-minhhno)/(maxhhno-minhhno)
gen forestpwom=(spwomen-minpwomen)/(maxpwomen-minpwomen)
gen forestmeetno=(smeetno-minmeetno)/(maxmeetno-minmeetno)
gen dscforest=forestyear+foresthhno+forestpwom+forestmeetno
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scforestfull1.dta",replace
 keep district dscforest
 collapse (mean) dscforest, by(district)
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scforest1.dta",replace

 *credit group
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\social2010.dta",clear
*for credut's group
keep if r4_14==4
ren r4_15 groupyear
ren r4_16 hhno
ren r4_17 pwomen
ren r4_18 meetingno
egen sgyear=sum(groupyear), by(district)
egen shhno=sum(hhno), by(district)
egen spwomen=sum(pwomen), by(district)
egen smeetno=sum(meetingno), by(district)
egen maxgyear=max(sgyear)
egen maxhhno=max(shhno)
egen maxpwomen=max(spwomen)
egen maxmeetno=max(smeetno)
egen mingyear=min(sgyear)
egen minhhno=min(shhno)
egen minpwomen=min(spwomen)
egen minmeetno=min(smeetno)
gen credityear=(sgyear-mingyear)/(maxgyear-mingyear)
gen credithhno=(shhno-minhhno)/(maxhhno-minhhno)
gen creditpwom=(spwomen-minpwomen)/(maxpwomen-minpwomen)
gen creditmeetno=(smeetno-minmeetno)/(maxmeetno-minmeetno)
gen dsccredit=credityear+credithhno+creditpwom+creditmeetno
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\sccreditfull1.dta",replace
 keep district dsccredit
```

```
 collapse (mean) dsccredit, by(district)
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\sccredit1.dta",replace

use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\social2010.dta",clear
*for women's group
keep if r4_14==5
ren r4_15 groupyear
ren r4_16 hhno
ren r4_17 pwomen
ren r4_18 meetingno
egen sgyear=sum(groupyear), by(district)
egen shhno=sum(hhno), by(district)
egen spwomen=sum(pwomen), by(district)
egen smeetno=sum(meetingno), by(district)
egen maxgyear=max(sgyear)
egen maxhhno=max(shhno)
egen maxpwomen=max(spwomen)
egen maxmeetno=max(smeetno)
egen mingyear=min(sgyear)
egen minhhno=min(shhno)
egen minpwomen=min(spwomen)
egen minmeetno=min(smeetno)
gen womenyear=(sgyear-mingyear)/(maxgyear-mingyear)
gen womenhhno=(shhno-minhhno)/(maxhhno-minhhno)
gen womenpwom=(spwomen-minpwomen)/(maxpwomen-minpwomen)
gen womenmeetno=(smeetno-minmeetno)/(maxmeetno-minmeetno)
gen dscwomen=womenyear+womenhhno+womenpwom+womenmeetno
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scwomenfull1.dta",replace
 keep district dscwomen
 collapse (mean) dscwomen, by(district)
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scwomen1.dta",replace
 merge 1:1 district using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\sccredit1.dta"
 drop _merge
 merge 1:1 district using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scforest1.dta"
 drop _merge
 merge 1:1 district using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scwater1.dta"
 drop _merge
 merge 1:1 district using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scfarm1.dta"
 drop _merge

 replace  dscwomen=0 if dscwomen==.
 replace dsccredit=0 if dsccredit==.
 replace dscforest=0 if dscforest==.
 replace dscwater=0 if dscwater==.
 replace dscfarm=0 if dscfarm==.
 save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\scapital031.dta",replace

 merge 1:m district using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20106.dta"
 replace  dscwomen=0 if dscwomen==.
```

```
 replace dsccredit=0 if dsccredit==.
 replace dscforest=0 if dscforest==.
 replace dscwater=0 if dscwater==.
 replace dscfarm=0 if dscfarm==.
 keep if _merge==3
 drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20107.dta",replace




***********************************Chapter 3*************************************
*********************************Input generation***********************************
clear
set more off
********************inputs 2010*************************
use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2010\xh27_s13d2.dta", clear
keep xhpsu xhnum v13d2_en v13_64

*gen unique id for household in order to be consistent with 1996 and 2003
gen WWW=xhpsu*10 if xhnum<10
replace WWW=xhpsu if xhnum>=10
gen WWWHH=string(WWW)+string(xhnum)
destring WWWHH, replace
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", replace

*seed
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==1
ren v13_64 seed
replace seed=0 if seed==.
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\seed10.dta", replace

*fertilizer
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==2
ren v13_64 fertilizer
replace fertilizer=0 if fertilizer==.
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\fertilizer10.dta", replace

*labor
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==3
ren v13_64 labor
replace labor=0 if labor==.
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\labor10.dta", replace

*irrigation
```

```
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==4
ren v13_64 irrigation
replace irrigation=0 if irrigation==.
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\irrigation10.dta", replace

*impland
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==8
ren v13_64 landimp
replace landimp=0 if landimp==.
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\landimp10.dta", replace

*repequip
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==9
ren v13_64 equip
replace equip=0 if equip==.
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\equip10.dta", replace

*tractor
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==12
ren v13_64 tractor
replace tractor=0 if tractor==.
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\tractor10.dta", replace

*thresher
use "D:\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==13
ren v13_64 thresher
replace thresher=0 if thresher==.
save "D:\chapter2data\paneldata\panel\2010\thresher10.dta", replace

*other machine
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\expediture10.dta", clear
keep if v13d2_en==14
ren v13_64 othmachine
replace othmachine=0 if othmachine==.
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\othmachine10.dta", replace

*capital
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\thresher10.dta"
drop _merge
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\tractor10.dta"
drop _merge
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\equip10.dta"
drop _merge
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\landimp10.dta"
```

```
drop _merge
gen capital=landimp+equip+tractor+thresher+othmachine
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\capital.dta", replace
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\irrigation10.dta"
drop _merge
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\labor10.dta"
drop _merge
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\fertilizer10.dta"
drop _merge
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\seed10.dta"
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\input.dta", replace



***************************create the file for main paddy"*********************
*main paddy
use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2010\xh22_s13b.dta", clear
keep xhpsu xhnum v13_35cc v13_37a v13_37b
keep if v13_35cc==2
gen mpaddy=v13_37b if v13_37a==1
replace mpaddy=v13_37b*37.324 if  v13_37a==3
replace mpaddy=v13_37b*0.5514 if v13_37a==4
replace mpaddy=v13_37b*2.4 if v13_37a==6
replace mpaddy=v13_37b*72 if v13_37a==5
replace mpaddy=v13_37b*100 if v13_37a==11

*gen unique id for household in order to be consistent with 1996 and 2003
gen WWW=xhpsu*10 if xhnum<10
replace WWW=xhpsu if xhnum>=10
gen WWWHH=string(WWW)+string(xhnum)
destring WWWHH, replace
collapse (sum) mpaddy, by(WWWHH)
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\mpaddy.dta",replace

/*************paddy area****************************
use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2010\xh20_s13a1.dta", clear
keep   xhpsu xhnum v13_plt1 v13_04u v13_04rb v13_04ak v13_04pd v13_11 v13_13a v13_13b v13_13c
v13_13d v13_14 v13_16a v13_16b v13_16c v13_16d

*gen unique id for household in order to be consistent with 1996 and 2003
gen WWW=xhpsu*10 if xhnum<10
replace WWW=xhpsu if xhnum>=10
gen WWWHH=string(WWW)+string(xhnum)
destring WWWHH, replace
keep if   v13_11==1| v13_14==1
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\land0.dta",replace

use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\land0.dta",clear
```

```
keep if  v13_16a==2| v13_16b==2| v13_16c==2| v13_16d==2
gen paddyarea= (v13_04rb*400+v13_04ak*20+v13_04pd)*0.001693114 if  v13_04u==2
*ropani
replace paddyarea= (v13_04rb*64+v13_04ak*4+v13_04pd)*0.000794875 if  v13_04u==1
collapse (sum) paddyarea, by(WWWHH)

merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\mpaddy.dta"
keep if _merge==3
drop _merge
*save "C:\wenmei\wenmei\chapter2data\panel\2010new\paddy1.dta",replace
save "C:\wenmei\wenmei\chapter2data\panel\2010new\paddy2.dta",replace

*******************merge with inputs**************************
use "C:\wenmei\wenmei\chapter2data\panel\2010new\paddy2.dta",clear
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\input.dta"
keep if _merge==3
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy2",replace

*******************get the portion of irrigated portion of land*************
use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2010\xh20_s13a1.dta", clear
keep if  v13_16a==2| v13_16b==2| v13_16c==2| v13_16d==2
keep if v13_07==1
gen irrparea= (v13_04rb*400+v13_04ak*20+v13_04pd)*0.001693114 if  v13_04u==2
*ropani
replace irrparea= (v13_04rb*64+v13_04ak*4+v13_04pd)*0.000794875 if  v13_04u==1
gen WWW=xhpsu*10 if xhnum<10
replace WWW=xhpsu if xhnum>=10
gen WWWHH=string(WWW)+string(xhnum)
destring WWWHH, replace
collapse (sum) irrparea, by(WWWHH)
save "C:\wenmei\wenmei\chapter2data\panel\2010new\irrigatedland.dta", replace
merge 1:1 WWWHH using "
replace irripaddy==0 if irripaddy==.
gen irriport=  irripaddy/paddyarea
drop _merge
save "C:\wenmei\wenmei\chapter2data\panel\2010new\irrigportion.dta",replace*/
use "C:\wenmei\wenmei\chapter2data\panel\2010new\irrigatedland1.dta",clear
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010\input.dta"
keep if _merge==3
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20103",replace

**********merge with district level data and household characteristics**************
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20103",clear
merge 1:m WWWHH using "C:\wenmei\wenmei\chapter2data\panel\2010\panel2010newdata.dta"
keep if _merge==3
drop _merge
gen time=2010
```

```
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20104.dta",replace

*******************merge with urban and belt***********************
use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2010\xh00_s00.dta", clear
keep  xhpsu xhnum v00_dist v00_vdc
gen WWW=xhpsu*10 if xhnum<10
replace WWW=xhpsu if xhnum>=10
gen WWWHH=string(WWW)+string(xhnum)
destring WWWHH, replace
ren v00_dist district
ren v00_vdc vdc
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\geographic2010.dta",replace
merge 1:1 WWWHH using
"C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20104.dta"
keep if _merge==3
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20105.dta",replace


********************************2003 panel*************************
*****************************getting paddy area******************
use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2003\Z11A1B.dta", clear
**create a unique id for each plot****************
gen plotid=string(WWWHH)+string(PNO)
destring plotid,replace
*bihga
gen paddyarea= (V11A1B_03A*400+V11A1B_03B*20+V11A1B_03C)*0.001693114 if
V11A1B_03D==2
*ropani
replace paddyarea= (V11A1B_03A*64+V11A1B_03B*4+V11A1B_03C)*0.000794875 if
V11A1B_03D==1

keep  paddyarea plotid V11A1B_06 WWWHH
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea1.dta",replace


use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2003\Z11A1C.dta", clear
keep if  V11A1C_12A==2 |V11A1C_12B==2 |V11A1C_12C==2 |V11A1C_12D==2 |V11A1C_15A==2
|V11A1C_15B==2 |V11A1C_15C==2 |V11A1C_15D==2
gen plotid=string(WWWHH)+string(PNO)
destring plotid,replace

merge 1:1 plotid using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea1.dta"
drop _merge
keep  plotid WWWHH WWW HH V11A1B_06 paddyarea
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea2.dta",replace

***************creating the irrigated area *************************
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea2.dta",clear
```

```
collapse (sum)  paddyarea,by(WWWHH)
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea3.dta",replace

use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea2.dta",clear
keep if  V11A1B_06==1
collapse (sum)  paddyarea,by(WWWHH)
ren paddyarea irrparea
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea4.dta",replace

merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea3.dta"
replace irrparea=0 if irrparea==.
gen irriport= irrparea/paddyarea
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea5.dta",replace


****************paddy production*************************
use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2003\Z11B1.dta", clear

*get information for main paddy
keep   WWWHH CCD V11B1_03B V11B1_03A  CCD
keep if CCD==2

*uniform to kilogram
gen mpaddy=V11B1_03B if V11B1_03A==1
replace mpaddy=V11B1_03B*37.34 if  V11B1_03A==3
replace mpaddy=V11B1_03B*72 if V11B1_03A==5
replace mpaddy=V11B1_03B*2.4 if V11B1_03A==6
collapse (sum) mpaddy, by(WWWHH)
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy2003.dta",replace
merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea5.dta"
keep if _merge==3
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy20031.dta",replace

*********************inputs******************************
use "C:\wenmei\wenmei\chapter2data\paneldata\PANEL2003\Z11D.dta", clear
keep  WWWHH WWW HH  V11D_01 V11D_09 V11D_10 V11D_11 V11D_12 V11D_13 V11D_16
V11D_17 V11D_19 V11D_20 V11D_21 V11D_22
ren V11D_01 agriinc
ren V11D_09 seed
ren V11D_10 fertilizer
ren V11D_11 labor
ren V11D_12 irrigation
ren V11D_16 landimp
ren V11D_17 equip
ren V11D_19 tractor
ren V11D_20 thresher
ren V11D_21 othmachine
```

```
replace seed=0 if seed==.
replace fertilizer=0 if fertilizer==.
replace labor=0 if labor==.
replace irrigation=0 if irrigation==.
replace landimp=0 if landimp==.
replace equip=0 if equip==.
replace tractor=0 if tractor==.
replace thresher=0 if thresher==.
replace othmachine=0 if othmachine==.
gen capital=landimp+equip+tractor+thresher+othmachine
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\input2003.dta",replace

merge 1:1 WWWHH using
"C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy20031.dta"
keep if _merge==3
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy20032.dta",replace

****************merge with household characteristics (in R)************************
use "C:/wenmei/wenmei/chapter2data/panel/2003/panel2003newdata.dta",clear
merge 1:1 WWWHH using
"C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy20032.dta"
keep if _merge==3
drop _merge
gen time=2003
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy20033.dta",replace


******************************2003 cross section*******************************
use "C:\wenmei\wenmei\wenmei\firstchapterdata\NLSS Data\NLSS_II\HH\Z11A1B.dta", clear
**create a unique id for each plot***************
gen plotid=string(WWWHH)+string( V11A1B_PNO)
destring plotid,replace
*convert all units to hectares
*bihga
gen paddyarea= (V11A1B_03A*400+V11A1B_03B*20+V11A1B_03C)*0.001693114 if
V11A1B_03D==2
*ropani
replace paddyarea= (V11A1B_03A*64+V11A1B_03B*4+V11A1B_03C)*0.000794875 if
V11A1B_03D==1

keep  paddyarea plotid  V11A1B_06 WWWHH
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea11.dta",replace

use "C:\wenmei\wenmei\wenmei\firstchapterdata\NLSS Data\NLSS_II\HH\Z11A1C.dta", clear
keep if  V11A1C_12A==2 |V11A1C_12B==2 |V11A1C_12C==2 |V11A1C_12D==2 |V11A1C_15A==2
|V11A1C_15B==2 |V11A1C_15C==2 |V11A1C_15D==2
gen plotid=string(WWWHH)+string(V11A1C_PNO)
destring plotid,replace
```

```
merge 1:1 plotid using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea11.dta"
drop _merge
keep  plotid WWWHH WWW HH V11A1B_06 paddyarea
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea21.dta",replace

***************creating the irrigated area ***************************
use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea21.dta",clear
collapse (sum)  paddyarea,by(WWWHH)
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea31.dta",replace

use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea21.dta",clear
keep if  V11A1B_06==1
collapse (sum)  paddyarea,by(WWWHH)
ren paddyarea irrparea
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea41.dta",replace

merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea31.dta"
replace irrparea=0 if irrparea==.
gen irriport= irrparea/paddyarea
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea51.dta",replace

*****************************mpaddy production*****************
use "C:\wenmei\wenmei\wenmei\firstchapterdata\NLSS Data\NLSS_II\HH\Z11B1.dta", clear
keep WWWHH  V11B1_CCD V11B1_03A V11B1_03B
keep if V11B1_CCD==2
gen mpaddy=V11B1_03B if V11B1_03A==1
replace mpaddy=V11B1_03B*0.001 if  V11B1_03A==2
replace mpaddy=V11B1_03B*37.324 if  V11B1_03A==3
replace mpaddy=V11B1_03B*0.5514 if V11B1_03A==4
replace mpaddy=V11B1_03B*72 if V11B1_03A==5
replace mpaddy=V11B1_03B*2.4 if V11B1_03A==6
collapse (sum) mpaddy, by(WWWHH)
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy2003crosssection.dta",replace

merge 1:1 WWWHH using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\parea51.dta"
keep if _merge==3
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy2003cs.dta",replace
********************************inputs**************************
*inputs
 use "C:\wenmei\wenmei\wenmei\firstchapterdata\NLSS Data\NLSS_II\HH\Z11D.dta", clear
 keep  WWWHH WWW HH  V11D_01 V11D_09 V11D_10 V11D_11 V11D_12 V11D_13 V11D_16
V11D_17 V11D_19 V11D_20 V11D_21 V11D_22
ren V11D_01 agriinc
ren V11D_09 seed
ren V11D_10 fertilizer
ren V11D_11 labor
```

```
ren V11D_12 irrigation
ren V11D_16 landimp
ren V11D_17 equip
ren V11D_19 tractor
ren V11D_20 thresher
ren V11D_21 othmachine
replace seed=0 if seed==.
replace fertilizer=0 if fertilizer==.
replace labor=0 if labor==.
replace irrigation=0 if irrigation==.
replace landimp=0 if landimp==.
replace equip=0 if equip==.
replace tractor=0 if tractor==.
replace thresher=0 if thresher==.
replace othmachine=0 if othmachine==.
gen capital=landimp+equip+tractor+thresher+othmachine
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\inputs.dta",replace
merge 1:1 WWWHH using
"C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy2003cs.dta"

keep if _merge==3
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy2003cs1.dta",replace
****************************merge with household characteristics(in R)********************
merge 1:1 WWWHH using "C:/wenmei/wenmei/chapter2data/panel/2003/panel2003newcrossdata.dta"
keep if _merge==3
drop _merge
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy2003cs2.dta",replace

****************************2003 social capital******************************
 *********social capital at the district level, similar codes as 2010, available upon requested

use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20107.dta",clear
ren paddyarea2 paddyarea
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20107.dta",replace

use "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy2003cs4.dta",clear
append using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2010new\mpaddy20107.dta"
save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy2003final.dta",replace
append using "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy20035.dta"

save "C:\wenmei\wenmei\chapter2data\paneldata\panel\2003new\mpaddy201003final.dta",replace

*******************************Climate indices sample*******************************
//rainfall 104, district
insheet using "C:\wenmei\wenmei\chapter2data\rainfall\104.csv",clear
ren v1 rainfall
destring rainfall, force replace
drop if _n==1
```

```
generate date=td(01jan1971)+ _n-1
format date %td
gen dmo=mofd(date)
format dmo %tm
gen month=month(date)
gen year=year(date)
gen quarter=1 if month==2|month==3|month==4
replace quarter=2 if month==5|month==6|month==7
replace quarter=3 if month==8|month==9|month==10
replace quarter=4 if month==11|month==12|month==1
save "C:\wenmei\wenmei\chapter2data\rainfall\seasonraifall\r104.dta",replace

*******************************Chapter 4 Code**************************************
clear
set more off
insheet using "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\chapter_3.csv",clear
drop if hhno==.

//version A
gen version_1=1 if version=="A"
replace version_1=2 if version=="B"
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\chapter_3.dta",replace

//got policy A, version A
use "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\chapter_3.dta",clear
keep if version_1==1
gen bidA=bids_f21

//WTJ
gen fbidA=f21
keep bidA fbidA version_1 hhno
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versA.dta",replace

//got policy A in version B
use "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\chapter_3.dta",clear
keep if version_1==2
gen bidA=bids_f24

//WTJ
gen fbidA=f24
keep bidA fbidA version_1 hhno
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versA1.dta",replace
```

```
append using "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versA.dta"
replace bidA=1200 if bidA==120
egen tfbidA=count(1),by(bidA)
drop if tfbidA==2
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versA_final.dta",replace

//generating properties
use "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versA_final.dta",clear
keep if fbidA==1
replace bidA=1200 if bidA==120
egen fbidAyes=count(1), by(bidA)
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versAyes1.dta",replace
merge 1:1 hhno using "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versA_final.dta"
drop _merge
gen propyesA=fbidAyes/tfbidA
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versA_finalA.dta",replace

//got policy B, version A
use "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\chapter_3.dta",clear
keep if version_1==1
gen bidB=bids_f24

//WTJ
gen fbidB=f24
keep bidB fbidB version_1 hhno
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidB_versB.dta",replace

//got policy B in version B
use "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\chapter_3.dta",clear
keep if version_1==2
gen bidB=bids_f21

//WTJ
gen fbidB=f21
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidB_versB1.dta",replace
append using "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidB_versB.dta"
replace bidB=1200 if bidB==120
drop if bidB==358
```

```
egen tfbidB=count(1),by(bidB)
drop if tfbidB==2
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidB_versB_final.dta",replace

//generating properties
use "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidB_versB_final.dta",clear
keep if fbidB==1
replace bidB=1200 if bidB==120
egen fbidByes=count(1), by(bidB)
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidB_versByes1.dta",replace
merge 1:1 hhno using "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidB_versB_final.dta"
drop _merge
gen propyesB=fbidByes/tfbidB
scatter propyesB bidB
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidB_versB_finalB.dta",replace
merge 1:1 hhno using "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\bidA_versA_finalA.dta"
drop _merge
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\finalchapter3_1.dta",replace

//paddy
insheet using "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\agriculture_information.csv",clear
keep if d8==1  //keep paddy
gen paddy==1
keep hhno paddy
merge 1:1 hhno using "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\finalchapter3.dta"
drop _merge
save "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word
ducument\finalchapter3.dta",replace

/*analysis*/
use "C:\wenmei\wenmei\wenmei\living standard survey data\chapter 3\word ducument\finalchapter3.dta",
clear
use "E:\dissertation\word ducument\finalchapter3.dta",clear

*age of the responsent
gen rage=a3
gen lrage=log(rage)

*gender of the respondent
gen female=1 if a2==2
```

```
replace female=0 if a2==1

*hhincome
gen hhinc=1
replace hhinc=. if a16>10
replace hhinc=0 if a16<2

*farmer
gen farmer1=a9
destring farmer1, force replace
gen farmer=0
replace farmer =1 if farmer1==3

*household size
gen hhsize=a1

*education, distinguished at middle school (8th grade)
gen edu=1 if a7>3
replace edu=0 if a7<4

*perception of cliamte change
gen pclimate=0 if f9==1|f9==2  //notlikely and somewhat
replace pclimate=1 if f9==3|f9==4 //likely and highly likely

*risk tolerace, risk aversed
gen riskaversed=1 if j1==1|j1==2
replace riskaversed=0 if j1==3

*agricultural land
gen unit=d4_a
destring unit, force replace
replace unit=1 if unit==.
replace unit=. if unit==0|unit>
replace d4_c=0 if d4_c==.
replace d4_d=0 if d4_d==.
gen agriland= (d4_b*400 + d4_c*20 + d4_d)*0.001693114 if  unit==2
*ropani
replace agriland= (d4_b*64 + d4_c*4 + d4_d)*0.000794875 if  unit==1

*bid
gen lnbidA=log(bida)
gen lnbidB=log(bidb)

*WTJ
gen WTJA=1 if fbida==1
replace WTJA=0 if fbida==2
gen WTJB=1 if fbidb==1
replace WTJB=0 if fbidb==2
```

```
*top_down
gen top_down=1 if version_1==2
replace top_down=0 if version_1==1

//livestock
gen livestock=1 if d21==1
replace livestock=0 if d21==2

//graph of WTP
scatter propyesa bida, ytitle("proportion of saying yes") xtitle("amount of bids") title("Willingness to pay for product A") saving(productA)
scatter propyesb bidb, ytitle("proportion of saying yes") xtitle("amount of bids") title("Willingness to pay for product B") saving(productB)
twoway (scatter propyesa bida) (scatter propyesb bidb), ytitle("proportion of saying yes") xtitle("amount of bids") title("willingness to pay for product A and B") saving(productA_B)
gr combine productA.gph productB.gph productA_B.gph

//caste
gen caste=1 if a11==1|a11==2   //Brahmin or Chherti
replace caste=0 if a11>2
//impact of climate change (post-experience)
//a and d are related to agriculture; b, c, and e are related to non-agriculture
//drop unreasonable answers
replace f2_a=. if f2_a>5
replace f2_b=. if f2_b>5
replace f2_c=. if f2_c>5
replace f2_d=. if f2_d>5
replace f2_e=. if f2_e>5

gen impagclimate=f2_a+f2_d
gen impnonagclimate=f2_b+f2_c+f2_e
gen edufemale=edu*female
tab f2_b, gen(impedu)

//adaptation strategies
gen adapstrat=1 if f12_1==1
replace adapstrat=2 if f12_2==2
replace adapstrat=3 if f12_3==3
replace adapstrat=4 if f12_4==4
replace adapstrat=5 if f12_5==5
replace adapstrat=6 if f12_6==6
replace adapstrat=7 if f12_7==7
replace adapstrat=8 if f12_8==8
replace adapstrat=9 if f12_9==9
replace adapstrat=10 if f12_10==10
replace adapstrat=11 if f12_11==11
replace adapstrat=12 if f12_12==12
replace adapstrat=13 if f12_13==13
replace adapstrat=14 if f12_14==14
```

```
replace adapstrat=15 if f12_15==15
replace adapstrat=16 if f12_16==16
replace adapstrat=17 if f12_17==17
replace adapstrat=18 if f12_18==18
replace adapstrat=19 if f12_19==19
gen soilcons=1 if f12_1==1
replace soilcons=0 if soilcons==.
gen plantree=1 if f12_2==2
replace plantree=0 if plantree==.
gen dffcrop=1 if f12_5==5
replace dffcrop=0 if dffcrop==.
gen shotcycle=1 if f12_7==7
replace shotcycle=0 if shotcycle==.
gen impseed=1 if f12_12==12
replace impseed=0 if impseed==.
gen numstrat=soilcons+plantree +dffcrop+shotcycle+impseed
gen noadat=1 if impseed==0&shotcycle==0&dffcrop==0&plantree==0&soilcons==0
replace noadat=0 if noadat==.
gen adoption=1 if noadat==0
replace adoption=0 if noadat==1

//pie graph for adoption
tab adoption, gen(climateadoption)
label var climateadoption1 "non_adopters"
label var climateadoption2 "adopters"
graph pie climateadoption1 climateadoption2, plabel(_all  sum, color(white))  title("adopters vs
non_adopters")

//distribution of adpatation strategies
*graph pie soilcons plantree dffcrop shotcycle impseed, pie(4,explode) plabel(_all sum, color(white))
title("adaptation strategies")

//like the crop insurance or not?
gen like=1 if f28==1
replace like=2 if f28==2
replace like=3 if f28==3|f28==99
tab like, gen(likecropins)
label var likecropins1 "yes"
label var likecropins2 "somewhat"
label var likecropins3 "no or don't know"
graph pie likecropins1 likecropins2 likecropins3,  plabel(_all percent, color(white))  title("crop insurance
is the best tool?")

///should also consider the knowledge of climate change
gen knowclimate=f1_a+f1_b+f1_c+f1_d+f1_e
//adaptation strategies
gen adapt=1 if f11==1|f11==3|f11==4|f11==6
replace adapt=0 if f11==2|f11==99
```

```
//independent variables
//organization group, social capital
gen socapital=1 if b4_a==1
replace socapital=0 if b4_a==2


//education of the household head
gen hedu=a8
destring hedu, force replace
replace hedu=0 if hedu<=3
replace hedu=1 if hedu>=4

//degree of impact
gen impclimatec=f10
replace impclimatec=. if impclimatec==99

//analysis policy A, testing for endogeneity
//no endogeneous problem
tab f13_4, gen(noadpreason)
gen adapt1=1 if numstrat>0
replace adapt1=0 if numstrat==0
ivprobit WTJB (pclimate= riskaversed impedu2 impedu3 impedu4 impedu5) lnbidB  account fertland
socapital  edu hhinc hhsize female caste lrage paddy livestock top_down tdbidB, twostep
overid, depvar(WTJB)
replace noadpreason3=0 if noadpreason3==.      //not enough time
ren noadpreason3 notime
replace noadpreason4=0 if noadpreason4==.     //not knowing what to do
replace noadpreason5=0 if noadpreason5==.     //not necessary
ivprobit WTJA pclimate lnbidA adapt1 (adapt1=socapital notime) hhinc hhsize caste female edu rage
paddy top_down, twostep
overid, depvar(WTJA)
ivprobit WTJB pclimate lnbidB adapt1 (adapt1=socapital notime) hhinc hhsize caste female edu rage
paddy livestock top_down, twostep
overid, depvar(WTJB)

//risk management: account, socapital, number of strategies adopted
biprobit (WTJA=pclimate numstrat account lnbidA) (WTJB=pclimate numstrat account lnbidB),
cluster(wardno)
estat ic
probit adapt1 pclimate lnbidA account socapital notime hhinc hhsize caste female edu rage paddy
top_down

predict adapt1A,xb
probit adapt1 pclimate lnbidB account socapital notime hhinc hhsize caste female edu rage paddy
livestock top_down
predict adapt1B,xb

*counterfactual analysis
margins, predict(p11) at(pclimate=(0 1)) atmeans  //gender and perception
```

```
matrix b=r(b)'
matrix list b
*female
matrix fem=(0\1)
matrix list fem
matrix f=fem,b
matrix list f
svmat f, names(f)

*plot
graph twoway (connect  c1  (connect c3 c1 if fem==1), ///
            xlabel(0 1) legend(order(1 "female" 0 "male" )) ///
                        xtitle(Ex_ante perception of climate change) ytitle(probability of purchasing
both products) ///
                        title(Counterfactual analysis of WTPs)

*drop if WTJA==.|WTJB==.|lnbidA==.|lnbidB==.| pclimate==.|  adapt1==.|  hhinc==.|  hhsize==.|
caste==.|  female==.|  edu==.|  rage==.|  paddy==.|  top_down==.|  livestock==.
biprobit (WTJA=lnbidA pclimate adapt1 hhinc hhsize caste female edu rage paddy top_down)
(WTJB=lnbidB pclimate adapt1 hhinc hhsize caste female edu rage paddy livestock top_down),
cluster(wardno)

*margins, predict(p11) at(pclimate=(0 1)) atmeans
*margins, predict(p11) at(female=(0 1)) atmeans
biprobit (WTJA=lnbidA impagclimate adapt1 hhinc hhsize caste female edu rage paddy top_down)
(WTJB=lnbidB impagclimate adapt1 hhinc hhsize caste female edu rage paddy livestock top_down),
cluster(wardno)

*counterfactual analysis
margins, predict(p11) at(female=(0 1) pclimate=(0 1)) atmeans  //gender and perception
matrix b=r(b)'
matrix list b
*perception of climate change
matrix per_climate=(0\1)#(1\1)
matrix list per_climate
*female
matrix fem=(1\1)#(0\1)
matrix list fem
matrix c=per_climate,fem,b
matrix list c
svmat c, names(c)
*plot
graph twoway (connect c3 c1 if fem==0) (connect c3 c1 if fem==1), ///
            xlabel(0 1) legend(order(1 "female" 0 "male" )) ///
                        xtitle(Ex_ante perception of climate change) ytitle(probability of purchasing
both products) ///
                        title(Counterfactual analysis of WTPs)

//perception about past impact
```

```
biprobit (WTJA=impagclimate adapt1 lnbidA ) (WTJB=impagclimate adapt1 lnbidB ), cluster(wardno)
estat ic
*mfx compute, predict(pmarg1)
*mfx compute, predict(pmarg2)
wtpcikr lnbidA impagclimate adapt1, reps(50000) eq(WTJA) expo
wtpcikr lnbidB impagclimate adapt1, reps(50000) eq(WTJB) expo
biprobit (WTJA=impagclimate adapt1 lnbidA hhinc hhsize caste female edu rage) (WTJB=impagclimate
adapt1 lnbidB hhinc hhsize caste female edu rage), cluster(wardno)
estat ic
mfx compute, predict(pmarg1)
mfx compute, predict(pmarg2)
gen rage1=rage/10
biprobit (WTJA=lnbidA impagclimate adapt1 hhinc hhsize caste female edu lrage) (WTJB=lnbidB
impagclimate adapt1 hhinc hhsize caste female edu lrage), cluster(wardno)
estat ic
*mfx compute, predict(pmarg1)
*mfx compute, predict(pmarg2)
*matrix med_inc=(8,0,1,5,0,1,0,39.5,1)
wtpcikr lnbidA impagclimate adapt1 hhinc hhsize caste female edu lrage, reps(50000) eq(WTJA) expo
wtpcikr lnbidB impagclimate adapt1 hhinc hhsize caste female edu lrage, reps(50000) eq(WTJB) expo
gen pclimate1=pclimate*10
biprobit (WTJA=lnbidA pclimate1 adapt1 hhinc hhsize caste female edu) (WTJB=lnbidB pclimate1
adapt1 hhinc hhsize caste female edu), cluster(wardno)
estat ic
*mfx compute, predict(pmarg1)
*mfx compute, predict(pmarg2)
*matrix med_inc=(8,0,1,5,0,1,0,39.5,1)
wtpcikr lnbidA pclimate1 adapt1 hhinc hhsize caste female edu, reps(50000) eq(WTJA) expo
wtpcikr lnbidB pclimate1 adapt1 hhinc hhsize caste female edu, reps(50000) eq(WTJB) expo

//wald test for mean of WTP
biprobit (WTJA=lnbidA pclimate1 adapt1 hhinc hhsize caste female edu lrage) (WTJB=lnbidB pclimate1
adapt1 hhinc hhsize caste female edu lrage), cluster(wardno)
test
([WTJA]_cons=[WTJB]_cons)([WTJA]lnbidA=[WTJB]lnbidB)([WTJA]pclimate1=[WTJB]pclimate1)([
WTJA]adapt1=[WTJB]adapt1)([WTJA]hhinc=[WTJB]hhinc)([WTJA]hhsize=[WTJB]hhsize)([WTJA]ca
ste=[WTJB]caste)([WTJA]caste=[WTJB]caste)([WTJA]female=[WTJB]female)([WTJA]edu=[WTJB]ed
u)
biprobit (WTJA=lnbidA impagclimate adapt1 hhinc hhsize caste female edu lrage) (WTJB=lnbidB
impagclimate adapt1 hhinc hhsize caste female edu lrage), cluster(wardno)
test
([WTJA]_cons=[WTJB]_cons)([WTJA]lnbidA=[WTJB]lnbidB)([WTJA]impagclimate=[WTJB]impagcli
mate)([WTJA]adapt1=[WTJB]adapt1)([WTJA]hhinc=[WTJB]hhinc)([WTJA]hhsize=[WTJB]hhsize)([W
TJA]caste=[WTJB]caste)([WTJA]caste=[WTJB]caste)([WTJA]female=[WTJB]female)([WTJA]edu=[W
TJB]edu)
margins, predict(p11) at(impagclimate=(7.93 10)) atmeans  //gender and perception
estat ic
tab adapt1, gen(adapters)
label var adapters1 "
```

```
graph pie adapt1 climateadoption2, plabel(_all  sum, color(white))  title("adopters vs non_adopters")
```

```
*************************************R code**************************************
***********************Chapter 2************************
########################Bootstrapping methods###############
detach(mydata)
rm(list=ls(all=T))

#read data in R
library(foreign)
mydata<-read.dta(file='C:/wenmei/wenmei/wenmei/firstchapterdata/remittance/nlss201023.dta')
mydata<-data.frame(mydata)
attach(mydata)
x<-hhcal
#x1<-log(hhcal+1)
y<-diversity
#design a matrix for the gamma model
n<-2971

library(bootstrap)
library(boot)
library(copula)
library(sandwich)
library(VineCopula)
library(CopulaRegression)

data <- cbind(x, y, rep(1, n), temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat2, credit,
nutrichi2, land1, female, hage, read, hcast11,hcast12,hcast13,equip2)
#names(data)
ncol(data)
# design a matrix for the gamma model
# design a matrix for the gamma model
R<-cbind(rep(1,n),temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat3, credit, nutrichi2,
land1, female, hage, read, hcast11,hcast12,hcast13,equip2)

#design a matrix for the poisson model
S<-cbind(rep(1,n),temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat3, credit, nutrichi2,
land1, female, hage, read, hcast11,hcast12,hcast13,equip2)
exposure <- rep(1, n)
family = 3

#getting initial values
mar <- mle_marginal(x, y, R, S, family, exposure = exposure,
        sd.error = T, zt = F)
alpha0 <- mar$alpha
beta0 <- mar$beta
delta0 <- mar$delta
theta0 <- mar$theta
tau0 <- mar$tau
sd.alpha0 <- mar$sd.alpha
sd.beta0 <- mar$sd.beta
```

```
family0 <- mar$family

# optimize the loglikelihood function of copula
para0 <- c(alpha0, beta0, theta2z(theta0, family), log(delta0))

# creating the optimizing object function
foo <- function(para, x, y, R, S, family, exposure, zt){
  p <- ncol(R)
  q <- ncol(S)
  alpha <- para[1:p]
  beta <- para[(p + 1):(p + q)]
  theta <- z2theta(para[p + q + 1], family)
  # theta <- para[p + q + 1]
  delta <- exp(para[p + q + 2])
   mu<-as.vector(exp(R%*%alpha))
      lambda<-as.vector(exp(S%*%beta))
 ll0<-sum(log(dgamma(x,shape=1/delta,rate=1/(delta*mu)))+(-theta-
1)*log(pgamma(x,shape=1/delta,rate=1/(delta*mu)))+log(((pgamma(x,shape=1/delta,rate=1/(delta*mu))^
(-theta)+(ppois(y,lambda))^(-theta)-1)^(-1/theta-1)- ((pgamma(x,shape=1/delta,rate=1/(delta*mu))^(-
theta)+(ppois(y-1,lambda))^(-theta)-1)^(-1/theta-1)))))
  return(-ll0)

}

# bootstrapping to get results
statistics <- function(data, indices, d){
data <- data[indices, ]
dummy <- optim(para0, foo, x = data[, 1], y = data[, 2],
  R = data[, c(3:13)], S = data[, c(3:13)],
  family = family, exposure = exposure, zt = F,
  method = "BFGS")
return(dummy$par[d])
}
Dummy <- boot(data, statistics, R = 500)
Dummy
dummy<-optim(para0,foo,x=x,y=y,R=R,S=S,family=family,exposure=exposure,zt=F,method="BFGS")

#calculate AIC
#calculate theta
out<-dummy$par
 p <- ncol(R)
  q <- ncol(S)
k<-p+q+2
  alpha <- out[1:p]
  beta <- out[(p + 1):(p + q)]
    delta <- exp(out[p + q + 2])
   mu<-as.vector(exp(R%*%alpha))
      lambda<-as.vector(exp(S%*%beta))
```

```
#calculate theta
theta_initial<-BiCopEst(rank(x-mu)/(length(x)+1),rank(y-lambda)/(length(y)+1),family=family)$par
delta<-exp(par1[p+q+2])
u<-pgam(x,mu,delta)
v<-ppois(y,lambda)
vv<-ppois(y-1,lambda)

foo<-function(para){
        theta0<-z2theta(para,family)
        out<-(-sum(log(D_u(u,v,theta0,family)- D_u(u,vv,theta0,family))))
        return(out)
    }

para_initial<-theta2z(theta_initial,family)
para.ifm<-optim(para_initial,foo,method="BFGS")$par
theta<-z2theta(para.ifm,family)
theta

ll<-sum(log(dgamma(x,shape=1/delta,rate=1/(delta*mu)))+(-theta-
1)*log(pgamma(x,shape=1/delta,rate=1/(delta*mu)))+log(((pgamma(x,shape=1/delta,rate=1/(delta*mu))^
(-theta)+(ppois(y,lambda))^(-theta)-1)^(-1/theta-1)- ((pgamma(x,shape=1/delta,rate=1/(delta*mu))^(-
theta)+(ppois(y-1,lambda))^(-theta)-1)^(-1/theta-1)))))
ll
AIC<-2*(k-ll)
AIC


####################frank copula##########################
detach(mydata)
rm(list=ls(all=T))
#read data in R
library(foreign)
mydata<-read.dta(file='C:/wenmei/wenmei/wenmei/firstchapterdata/remittance/nlss201023.dta')
mydata<-data.frame(mydata)
attach(mydata)
x<-hhcal
#x1<-log(hhcal+1)
y<-diversity
#design a matrix for the gamma model
n<-2971

library(bootstrap)
library(boot)
library(copula)
library(sandwich)
library(VineCopula)
library(CopulaRegression)
```

```
data <- cbind(x, y, rep(1, n), temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat3, credit,
nutrichi2, land1, female, hage, read, hcast11,hcast12,hcast13,equip2)
#names(data)
ncol(data)
# design a matrix for the gamma model
R<-cbind(rep(1,n),temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat3, credit, nutrichi2,
land1, female, hage, read, hcast11,hcast12,hcast13,equip2)

#design a matrix for the poisson model
S<-cbind(rep(1,n),temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat3, credit, nutrichi2,
land1, female, hage, read, hcast11,hcast12,hcast13,equip2)
exposure <- rep(1, n)
family = 5

#getting initial values
mar <- mle_marginal(x, y, R, S, family, exposure = exposure,
        sd.error = T, zt = F)
alpha0 <- mar$alpha
beta0 <- mar$beta
delta0 <- mar$delta
#theta0 <- mar$theta
theta0<-0.12
tau0 <- mar$tau
sd.alpha0 <- mar$sd.alpha
sd.beta0 <- mar$sd.beta
family0 <- mar$family

# optimize the loglikelihood function of copula
para0 <- c(alpha0, beta0, theta2z(theta0, family), log(delta0))

# creating the optimizing object function
foo1 <- function(para, x, y, R, S, family, exposure, zt){
  p <- ncol(R)
  q <- ncol(S)
  alpha <- para[1:p]
  beta <- para[(p + 1):(p + q)]
  theta <- z2theta(para[p + q + 1], family)
  # theta <- para[p + q + 1]
  delta <- exp(para[p + q + 2])
   mu<-as.vector(exp(R%*%alpha))
      lambda<-as.vector(exp(S%*%beta))
# u1<-dgamma(x,shape=1/delta,rate=1/(delta*mu))
#u2<-pgamma(x,shape=1/delta,rate=1/(delta*mu))
#u3<-ppois(y,lambda)
ll4<-sum(log(((dgamma(x,shape=1/delta,rate=1/(delta*mu)))*exp(-
theta*(pgamma(x,shape=1/delta,rate=1/(delta*mu))))*(exp(-theta*(ppois(y,lambda)))-1)/(exp(-
theta)+exp(-theta*((pgamma(x,shape=1/delta,rate=1/(delta*mu)))+(ppois(y,lambda))))-exp(-
theta*(pgamma(x,shape=1/delta,rate=1/(delta*mu))))-exp(-theta*(ppois(y,lambda)))))-
((dgamma(x,shape=1/delta,rate=1/(delta*mu)))*exp(-
```

```
theta*(pgamma(x,shape=1/delta,rate=1/(delta*mu))))*(exp(-theta*(ppois(y-1,lambda)))-1)/(exp(-
theta)+exp(-theta*((pgamma(x,shape=1/delta,rate=1/(delta*mu)))+(ppois(y-1,lambda))))-exp(-
theta*(pgamma(x,shape=1/delta,rate=1/(delta*mu))))-exp(-theta*(ppois(y-1,lambda)))))))

return(-ll4)

}

# bootstrapping to get results
statistics <- function(data, indices, d){
data <- data[indices, ]
dummy <- optim(para0, foo, x = data[, 1], y = data[, 2],
  R = data[, c(3:20)], S = data[, c(3:20)],
  family = family, exposure = exposure, zt = F,
  method = "BFGS")
return(dummy$par[d])
}
Dummyfrank <- boot(data, statistics, R = 500)
Dummyfrank

dummyfrank<-
optim(para0,foo1,x=x,y=y,R=R,S=S,family=family,exposure=exposure,zt=F,method="BFGS")

#calculate AIC
#calculate theta
out<-dummy1$par
p<-ncol(R)
q<-ncol(S)
k<-p+q+2
alpha <- out[1:p]
beta <- out[(p + 1):(p + q)]
delta <- exp(out[p + q + 2])
mu<-as.vector(exp(R%*%alpha))
lambda<-as.vector(exp(S%*%beta))

#calculate theta
theta_initial<-BiCopEst(rank(x-mu)/(length(x)+1),rank(y-lambda)/(length(y)+1),family=family)$par
u<-pgam(x,mu,delta)
v<-ppois(y,lambda)
vv<-ppois(y-1,lambda)

foo<-function(para){
                        theta0<-z2theta(para,family)
                        out<-(-sum(log(D_u(u,v,theta0,family)- D_u(u,vv,theta0,family))))
                        return(out)
            }
para_initial<-theta2z(theta_initial,family)
para.ifm<-optim(para_initial,foo,method="BFGS")$par
theta<-z2theta(para.ifm,family)
```

```
theta
ll4<-sum(log(((dgamma(x,shape=1/delta,rate=1/(delta*mu)))*exp(-
theta*(pgamma(x,shape=1/delta,rate=1/(delta*mu))))*(exp(-theta*(ppois(y,lambda)))-1)/(exp(-
theta)+exp(-theta*((pgamma(x,shape=1/delta,rate=1/(delta*mu)))+(ppois(y,lambda))))-exp(-
theta*(pgamma(x,shape=1/delta,rate=1/(delta*mu))))-exp(-theta*(ppois(y,lambda)))))-
((dgamma(x,shape=1/delta,rate=1/(delta*mu)))*exp(-
theta*(pgamma(x,shape=1/delta,rate=1/(delta*mu))))*(exp(-theta*(ppois(y-1,lambda)))-1)/(exp(-
theta)+exp(-theta*((pgamma(x,shape=1/delta,rate=1/(delta*mu)))+(ppois(y-1,lambda))))-exp(-
theta*(pgamma(x,shape=1/delta,rate=1/(delta*mu))))-exp(-theta*(ppois(y-1,lambda)))))))
ll4
AIC<-2*(k-ll4)
AIC
vuongtest(Dummy,Dummyfrank)

###########product Copula#########
detach(mydata)
rm(list=ls(all=T))
#read data in R
library(foreign)
mydata<-read.dta(file='C:/wenmei/wenmei/wenmei/firstchapterdata/remittance/nlss201023.dta')
mydata<-data.frame(mydata)
attach(mydata)
x<-hhcal
#x1<-log(hhcal+1)
y<-diversity
#design a matrix for the gamma model
n<-2971
library(bootstrap)
library(boot)
library(copula)
library(sandwich)
library(VineCopula)
library(CopulaRegression)

data <- cbind(x, y, rep(1, n), temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat3, credit,
nutrichi2, land1, female, hage, read, hcast11,hcast12,hcast13,equip2)
#names(data)
ncol(data)
# design a matrix for the gamma model
R<-cbind(rep(1,n),temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat3, credit, nutrichi2,
land1, female, hage, read, hcast11,hcast12,hcast13,equip2)

#design a matrix for the poisson model
S<-cbind(rep(1,n),temprain, mountain, hill, dscfarm, dscforest,  road1, newremithat3, credit, nutrichi2,
land1, female, hage, read, hcast11,hcast12,hcast13,equip2)
exposure <- rep(1, n)

#getting initial values
my.gamma<-glm(x~-1 +R,family=Gamma(link="log"))
```

```
alpha0<-my.gamma$coefficients
    delta0<-summary(my.gamma)$dispersion

pois.model=glm(y~S-1,offset=log(exposure),family=poisson(link="log"))
        beta0<-coef(pois.model)

# optimize the loglikelihood function of copula
para0 <- c(alpha0, beta0, log(delta0))

# creating the optimizing object function
foo2 <- function(para, x, y, R, S, exposure, zt){
  p <- ncol(R)
  q <- ncol(S)
  alpha <- para[1:p]
  beta <- para[(p + 1):(p + q)]
    delta <- exp(para[p + q + 1])
   mu<-as.vector(exp(R%*%alpha))
      lambda<-as.vector(exp(S%*%beta))
ll4<-sum(log(dgamma(x,shape=1/delta,rate=1/(delta*mu)))+log(ppois(y,lambda)-ppois(y-1,lambda)))

return(-ll4)

}

# bootstrapping to get results
statistics <- function(data, indices, d){
data <- data[indices, ]
dummy <- optim(para0, foo, x = data[, 1], y = data[, 2],
  R = data[, c(3:20)], S = data[, c(3:20)],
   exposure = exposure, zt = F,
  method = "BFGS")
return(dummy$par[d])
}

Dummyprod <- boot(data, statistics, R = 500)
Dummyprod


dummyproduct<-optim(para0,foo2,x=x,y=y,R=R,S=S,exposure=exposure,zt=F,method="BFGS")
#calculate AIC
#calculate theta
out<-dummyproduct$par
p<-ncol(R)
q<-ncol(S)
k<-p+q+1

alpha <- out[1:p]
beta <- out[(p + 1):(p + q)]
delta <- exp(out[p + q + 1])
```

```
mu<-as.vector(exp(R%*%alpha))
lambda<-as.vector(exp(S%*%beta))

ll0<-sum(log(dgamma(x,shape=1/delta,rate=1/(delta*mu)))+log(ppois(y,lambda)-ppois(y-1,lambda)))
ll0
AIC<-2*(k-ll0)
AIC
```

**********************************Chapter 3************************************

```
#Household characteristics
#renaming variables
library(reshape)
agedata2010<-rename(agedata2010, c(v01_02="hgender", v01_03="hage", v01_08="hcaste"))
attach(agedata2010)
#export data
write.dta(agedata2010,"C:/wenmei/wenmei/chapter2data/panel/2010/hhchara2010.dta")
#create a unique id for household
WWW<-ifelse(xhnum<10, xhpsu*10, xhpsu)
WWWHH<-paste(as.character(WWW),as.character(xhnum),sep="")
WWWHH<-as.numeric(WWWHH)
dacenter20101<-cbind(dacenter,WWWHH)
dacenter20101<-data.frame(dacenter20101)
write.dta(dacenter20101,"C:/wenmei/wenmei/chapter2data/panel/2010/dacenter2010.dta")

#agriculture extension(if the household got any advice from the government agriculture extension service)
agriextdata<-read.dta("C://wenmei//wenmei//chapter2data//paneldata//PANEL2010//xh00_s00.dta")
attach(agriextdata)
agriextdata1<-agriextdata[c("xhpsu","xhnum","v13_74","v13_82","v13_83")]
agriextdata1<-data.frame(agriextdata1)
agriextdata20101<-cbind(WWWHH,v13_74,v13_82,v13_83)
agriextdata20102<-data.frame(agriextdata20101)
agriextdata20103<-
rename(agriextdata20102,c(v13_74="equip",v13_82="agriextent",v13_83="reanotagri"))
attach(agriextdata20103)
agriextdata20103<-cbind(WWWHH,equip,agriextent,reanotagri)
agriextdata20104<-data.frame(agriextdata20103)
write.dta(agriextdata20104,"C:/wenmei/wenmei/chapter2data/panel/2010/agriext2010.dta")

#household head education, part 1
heducp2010<-read.dta("C://wenmei//wenmei//chapter2data//paneldata//PANEL2010//xh10_s07.dta")
attach(heducp2010)
heducp20101<-heducp2010[which(v07_idc==1),]
heducp20102<-heducp20101[c("v07_02", "v07_03", "xhpsu", "xhnum", "v07_11")]
attach(heducp20102)
#create a unique id for households
WWW<-ifelse(xhnum<10,xhpsu*10,xhpsu)
WWWHH<-paste(as.character(WWW),as.character(xhnum),sep="")
WWWHH<-as.numeric(WWWHH)
heducp20103<-rename(heducp20103,c(v07_02="read",v07_03="write",v07_11="hedu"))
heducp20103<-data.frame(heducp20103)
heducp20103<-cbind(WWWHH,read,write,hedu)
attach(heducp20103)
write.dta(heducp20103,"C:/wenmei/wenmei/chapter2data/panel/2010/heducp2010.dta")
panel20100<-merge(x1,x2,by="WWWHH",all=T)
panel20101<-merge(x3,panel20100,by="WWWHH",all=T)
panel20102<-merge(x4,panel20101,by="WWWHH",all=T)
panel20103<-merge(x5,panel20102,by="WWWHH",all=T)
```

```
panel20104<-merge(x6,panel20103,by="WWWHH",all=T)
panel20105<-merge(x7,panel20104,by="WWWHH",all=T)
panel20106<-merge(x8,panel20105,by="WWWHH",all=T)
attach(panel20106)
time<-rep(2010,1032)
time<-as.vector(time)
panel20107<-
cbind(WWWHH,hedu,read,write,hgender,hage,hcaste,equip,agriextent,reanotagri,waterpump,plough,tract
or,time)
panel20107<-data.frame(panel20107)
write.dta(panel20107,"C:/wenmei/wenmei/chapter2data/panel/2010/panel2010newdata.dta")

********************get the portion of land irrigated*********************
pirrigdata<-read.dta("C://wenmei//wenmei//chapter2data//paneldata//PANEL2010//xh20_s13a1.dta")
pirrigdata<-data.frame(pirrigdata)
attach(pirrigdata)
pirrigdata1<-pirrigdata[which(v13_16a==2 |v13_16b==2 |v13_16c==2 |v13_16d==2),]
attach(pirrigdata1)
pirrigdata2<-pirrigdata1[which(v13_07==1),]
WWW<-ifelse(xhnum<10,xhpsu*10,xhpsu)
WWWHH<-paste(as.character(WWW),as.character(xhnum),sep="")
WWWHH<-as.numeric(WWWHH)

#panel 2003
agedap2003<-read.dta("C://wenmei//wenmei//chapter2data//paneldata//PANEL2003//Z01A.dta")
attach(agedap2003)
#keep the observations for household head
agedap20030<-agedap2003[which(IDC==1),]
attach(agedap20030)
agedap20031<-agedap20030[c("WWWHH", "V01A_02", "V01A_05", "V01A_01A")]
attach(agedap20031)
#rename the variables
library(reshape)
agedap20032<-rename(agedap20031,c(V01A_02="hgender", V01A_05="hage", V01A_01A="hcaste"))
attach(agedap20032)
summary(agedap20032)
write.dta(agedap20032,"C:/wenmei/wenmei/chapter2data/panel/2003/hagep2003.dta")

#householdhead education,part 1
heducp2003<-read.dta("C://wenmei//wenmei//chapter2data//paneldata//PANEL2003//Z07A.dta")
attach(heducp2003)
heducp20031<-heducp2003[which(IDC==1),]
attach(heducp20031)
heducp20032<-heducp20031[c("WWWHH", "V07A_02", "V07A_03")]
heducp20033<-rename(heducp20032,c(V07A_02="read",V07A_03="write"))
attach(heducp20033)
write.dta(heducp20033,"C:/wenmei/wenmei/chapter2data/panel/2003/heducp2003.dta")

#part 2
```

```
heducp12003<-read.dta("C://wenmei//wenmei//chapter2data//paneldata//PANEL2003//Z07B.dta")
attach(heducp12003)
heducp120031<-heducp12003[which(IDC==1),]
attach(heducp120031)
heducp120032<-heducp120031[c("WWWHH", "V07B_02")
heducp120033<-rename(heducp120032,c(V07B_02="hedu"))
attach(heducp120033)
write.dta(heducp120033,"C:/wenmei/wenmei/chapter2data/panel/2003/heducp12003.dta")

#agriculture extension(if the household got any advice from the government agriculture extension service)
detach(heducp120033)
agriextdata<-read.dta("C://wenmei//wenmei//chapter2data//paneldata//PANEL2003//Z11F3.dta")
attach(agriextdata)
agriextdata1<-agriextdata[c("WWWHH", "V11F3_09","V11F3_10")]
agriextdata1<-data.frame(agriextdata1)
attach(agriextdata1)
agriextdata20033<-rename(agriextdata1,c(V11F3_09="agriextent",V11F3_10="reanotagri"))
attach(agriextdata20033)
agriextdata20034<-data.frame(agriextdata20033)
write.dta(agriextdata20034,"C:/wenmei/wenmei/chapter2data/panel/2003/agriext2003.dta")

#if the household has modern agricultural techniques
#equipment
detach(agriextdata20034)
equipdata<-read.dta("C://wenmei//wenmei//chapter2data//paneldata//PANEL2003//Z11F1.dta")
attach(equipdata)
equipdata1<-equipdata[c("WWWHH","V11F1_01")]
equipdata1<-data.frame(equipdata1)
attach(equipdata1)
equipdata20033<-rename(equipdata1,c(V11F1_01="equip"))
attach(equipdata20033)
equipdata20034<-data.frame(equipdata20033)
write.dta(equipdata20034,"C:/wenmei/wenmei/chapter2data/panel/2003/equip2003.dta")

#cross section 2003
agedap2003<-read.dta("C://wenmei//wenmei//wenmei//firstchapterdata//NLSS
Data//NLSS_II//HH//Z01A.dta")
attach(agedap2003)
#keep the observations for household head
agedap20030<-agedap2003[which(V01A_IDC==1),]
attach(agedap20030)
agedap20031<-agedap20030[c("WWWHH", "V01A_02", "V01A_05", "V01A_01A")]
attach(agedap20031)

#rename the variables
library(reshape)
agedap20032<-rename(agedap20031,c(V01A_02="hgender", V01A_05="hage", V01A_01A="hcaste"))
attach(agedap20032)
summary(agedap20032)
```

```
write.dta(agedap20032,"C:/wenmei/wenmei/chapter2data/panel/2003/hagepcross2003.dta")

#householdhead education,part 1
heducp2003<-read.dta("C://wenmei//wenmei//wenmei//firstchapterdata//NLSS
Data//NLSS_II//HH//Z07A.dta")
attach(heducp2003)
heducp20031<-heducp2003[which(V07A_IDC==1),]
attach(heducp20031)
heducp20032<-heducp20031[c("WWWHH", "V07A_02", "V07A_03")]
heducp20033<-rename(heducp20032,c(V07A_02="read",V07A_03="write"))
attach(heducp20033)
write.dta(heducp20033,"C:/wenmei/wenmei/chapter2data/panel/2003/heducpcross2003.dta")
#part 2
heducp12003<-read.dta("C://wenmei//wenmei//wenmei//firstchapterdata//NLSS
Data//NLSS_II//HH//Z07B.dta")
attach(heducp12003)
heducp120031<-heducp12003[which(V07B_IDC==1),]
attach(heducp120031)
heducp120032<-heducp120031[c("WWWHH", "V07B_02")]
heducp120033<-rename(heducp120032,c(V07B_02="hedu"))
attach(heducp120033)
write.dta(heducp120033,"C:/wenmei/wenmei/chapter2data/panel/2003/heducp1cross2003.dta")

#agriculture extension(if the household got any advice from the government agriculture extension service)
detach(heducp120033)
agriextdata<-read.dta("C://wenmei//wenmei//wenmei//firstchapterdata//NLSS
Data//NLSS_II//HH//Z11F3.dta")
attach(agriextdata)
agriextdata1<-agriextdata[c("WWWHH", "V11F3_09","V11F3_10")]
agriextdata1<-data.frame(agriextdata1)
attach(agriextdata1)
agriextdata20033<-rename(agriextdata1,c(V11F3_09="agriextent",V11F3_10="reanotagri"))
attach(agriextdata20033)
agriextdata20034<-data.frame(agriextdata20033)
write.dta(agriextdata20034,"C:/wenmei/wenmei/chapter2data/panel/2003/agriextcross2003.dta")
#if the household has modern agricultural techniques

#equipment
detach(agriextdata20034)
equipdata<-read.dta("C://wenmei//wenmei//wenmei//firstchapterdata//NLSS
Data//NLSS_II//HH//Z11F1.dta")
attach(equipdata)
equipdata1<-equipdata[c("WWWHH","V11F1_01")]
equipdata1<-data.frame(equipdata1)
attach(equipdata1)
equipdata20033<-rename(equipdata1,c(V11F1_01="equip"))
attach(equipdata20033)
equipdata20034<-data.frame(equipdata20033)
write.dta(equipdata20034,"C:/wenmei/wenmei/chapter2data/panel/2003/equipcross2003.dta")
```

```
detach(euipdata20034)
modertech0<-read.dta("C://wenmei//wenmei//wenmei//firstchapterdata//NLSS
Data//NLSS_II//HH//Z11F2.dta")
attach(modertech0)
modertech0<-data.frame(modertech0)


#water pump
waterpump1<-modertech0[which(V11F2_EQIP=="water pump"),]
waterpump2<-waterpump1[c("WWWHH","V11F2_02")]
attach(waterpump2)
#rename variables
library(reshape)
waterpump2003<-rename(waterpump2,c(V11F2_02="waterpump"))
attach(waterpump2003)
write.dta(waterpump2003,"C:/wenmei/wenmei/chapter2data/panel/2003/waterpumpcross2003.dta")
modertech0<-read.dta("C://wenmei//wenmei//wenmei//firstchapterdata//NLSS
Data//NLSS_II//HH//Z11F2.dta")
attach(modertech0)
modertech0<-data.frame(modertech0)
#tractor
tractor1<-modertech0[which(V11F2_EQIP=="tractor"),]
tractor2<-tractor1[c("WWWHH","V11F2_02")]
attach(tractor2)

#rename variables
library(reshape)
tractor2003<-rename(tractor2,c(V11F2_02="tractor"))
attach(tractor2003)
write.dta(tractor2003,"C:/wenmei/wenmei/chapter2data/panel/2003/tractorcross2003.dta")
modertech0<-read.dta("C://wenmei//wenmei//wenmei//firstchapterdata//NLSS
Data//NLSS_II//HH//Z11F2.dta")
attach(modertech0)
modertech0<-data.frame(modertech0)

#plough
plough1<-modertech0[which(V11F2_EQIP=="plough"),]
plough2<-plough1[c("WWWHH","V11F2_02")]
attach(plough2)
#rename variables
library(reshape)
plough2003<-rename(plough2,c(V11F2_02="plough"))
attach(plough2003)
write.dta(plough2003,"C:/wenmei/wenmei/chapter2data/panel/2003/ploughcross2003.dta")
###merge datasets
panel20030<-merge(x1,x2,by="WWWHH",all=T)
panel20031<-merge(x3,panel20030,by="WWWHH",all=T)
panel20032<-merge(x4,panel20031,by="WWWHH",all=T)
panel20033<-merge(x5,panel20032,by="WWWHH",all=T)
```

```
panel20034<-merge(x6,panel20033,by="WWWHH",all=T)
panel20035<-merge(x7,panel20034,by="WWWHH",all=T)
panel20036<-merge(x8,panel20035,by="WWWHH",all=T)
attach(panel20036)
time<-rep(2003,3912)
time<-as.vector(time)
panel20037<-
cbind(WWWHH,hedu,read,write,hgender,hage,hcaste,equip,agriextent,reanotagri,waterpump,plough,tract
or,time)
panel20037<-data.frame(panel20037)
write.dta(panel20037,"C:/wenmei/wenmei/chapter2data/panel/2003/panel2003newcrossdata.dta")
#merge 2010 panel with 2003 panel
x11<-read.dta("C://wenmei//wenmei//chapter2data//panel//2010//panel2010newdata.dta")
x11<-data.frame(x11)
x12<-read.dta("C://wenmei//wenmei//chapter2data//panel//2003//panel2003newdata.dta")
x12<-data.frame(x12)
x13<-read.dta("C://wenmei//wenmei//chapter2data//panel//2003//panel2003newcrossdata.dta")
x13<-data.frame(x13)
panel201003new <- merge(x11,x12,by="WWWHH")

#Climate indices generation. Create coefficient variation for rainfall and temperature in R, using station
#104 as an example
library(foreign)
#rainfall
rain1<-read.dta(file="C:/wenmei/wenmei/chapter2data/rainfall/seasonraifall/r104.dta")
rain<-data.frame(rain1)
attach(rain)
#keep observation up to 2002 for the past 30 years
rain2<-rain[which(year>1980 & quarter!=4),]
attach(rain2)
#recoding missing value to NA
rainfall[rainfall==T]<-NA
rain1<-na.omit(rainfall)
sdrain<-sd(rain1,na.rm=T)
sdrain3<-3*sdrain
sdrain3<-sum(rain1>sdrain3)
ob1<-!is.na(rain1)
ob<-sum(ob1)
mrain<-mean(rain1,na.rm=T)
cvrain<-sdrain/mrain
amrain1<-sum(rain1>mrain)
amrain<-amrain1/ob

******************************Spatial filtering eigenvectors*****************************
#create the distanc-based neighborhood objects
# opens the ESRI shapefile and prepares the data
library(spdep) #this opens the spatial dependency package
library(maptools)
library(RColorBrewer)
```

```
library(maptools)
col.poly <- readShapePoly('C:/wenmei/wenmei/chapter2data/Stata9/chapter2/DISTRICT')

#subset the observation I need
buffer<-subset(col.poly, DISTRICT_I ==1 | DISTRICT_I ==2 | DISTRICT_I ==4 | DISTRICT_I ==5
| DISTRICT_I ==6 | DISTRICT_I ==7 | DISTRICT_I ==8 | DISTRICT_I ==11 | DISTRICT_I
==12 | DISTRICT_I ==13 | DISTRICT_I ==15 | DISTRICT_I ==16 | DISTRICT_I ==17 |
DISTRICT_I ==18 | DISTRICT_I ==19 | DISTRICT_I ==20 | DISTRICT_I ==23 | DISTRICT_I
==24 | DISTRICT_I ==27 | DISTRICT_I ==30 | DISTRICT_I ==31 | DISTRICT_I ==32 |
DISTRICT_I ==33 | DISTRICT_I ==34 | DISTRICT_I ==35 | DISTRICT_I ==37 | DISTRICT_I
==39 | DISTRICT_I ==41 | DISTRICT_I ==43 | DISTRICT_I ==45 | DISTRICT_I ==46 |
DISTRICT_I ==48 | DISTRICT_I ==49 | DISTRICT_I ==50 | DISTRICT_I ==51 | DISTRICT_I
==52 | DISTRICT_I ==53 | DISTRICT_I ==55 | DISTRICT_I ==57 | DISTRICT_I ==59 |
DISTRICT_I ==60 | DISTRICT_I ==65 | DISTRICT_I ==67 | DISTRICT_I ==71 | DISTRICT_I
==73 | DISTRICT_I ==74 | DISTRICT_I ==75)

#create the neighborhood and neighborhood weight matrix
#cnb=poly2nb(buffer) #neighborhood structure could not be created based on continguity characteristics
in my datasets
#sets spatial coordinates to create spatial data, or retrieves spatial coordinates
#coords is the average coordinator of each dimension
coords<-coordinates(buffer)
IDs<-row.names(as(buffer,"data.frame"))
#only use distance_based nieghbors because the objects in the dataset is not contingiuty
dis_nb<-knn2nb(knearneigh(coords,k=1),row.names=IDs)
#looking for the minimum distance to ensure all objects has one neighbor using "nbdists"
dsts<-unlist(nbdists(dis_nb,coords))
max_dist<-max(dsts)

#produce neighbor objects based on distance
sy11_nb<-dnearneigh(coords, d1=0,d2=max_dist,row.names=IDs)
#convert neighborhood structure to neighbor list for use in creating a matrix
#nb2listw supplements a neighbours list with spatial weights for the chosen coding scheme
nlist=nb2listw(dis_nb, style='B')  #creating a binary matrix

#convert neighborhood list into matrix, now I have obtained a spatial weight matrix (Meat)
cmat=listw2mat(nlist)

#now creating the bread, B
n<-length(buffer)
B<-diag(n)-matrix(1,n,n)/n

#Now create the weighted matrix for generating eigenvectors
BMB<-B%*%cmat%*%B

#the function eigen() generates eigenvalues and eigenvectors.
eig<-eigen(BMB,symmetric=T)

#eig$vetors generate n by n eigenvectors
```

```
EV<-as.data.frame(eig$vectors[,eig$values/eig$values[1]>0.25])

#keep the first 3 eigenvectors
#EV1<-as.data.frame(,c[1:3])

#writing into CSV file
library(foreign)
EV2<-write.csv(EV1,'C:/wenmei/wenmei/chapter2data/Stata9/chapter2/sfiltering.csv')
EV3<-write.csv(EV,'C:/wenmei/wenmei/chapter2data/Stata9/chapter2/sfiltering1.csv')
#subset the district variable
col.poly <- readShapePoly('C:/wenmei/wenmei/chapter2data/Stata9/chapter2/DISTRICT')
#subset the observation I need
buffer<-subset(col.poly, DISTRICT_I ==1 | DISTRICT_I ==2 | DISTRICT_I ==4 | DISTRICT_I ==5
| DISTRICT_I ==6 | DISTRICT_I ==7 | DISTRICT_I ==8 | DISTRICT_I ==11 | DISTRICT_I
==12 | DISTRICT_I ==13 | DISTRICT_I ==15 | DISTRICT_I ==16 | DISTRICT_I ==17 |
DISTRICT_I ==18 | DISTRICT_I ==19 | DISTRICT_I ==20 | DISTRICT_I ==23 | DISTRICT_I
==24 | DISTRICT_I ==27 | DISTRICT_I ==30 | DISTRICT_I ==31 | DISTRICT_I ==32 |
DISTRICT_I ==33 | DISTRICT_I ==34 | DISTRICT_I ==35 | DISTRICT_I ==37 | DISTRICT_I
==39 | DISTRICT_I ==41 | DISTRICT_I ==43 | DISTRICT_I ==45 | DISTRICT_I ==46 |
DISTRICT_I ==48 | DISTRICT_I ==49 | DISTRICT_I ==50 | DISTRICT_I ==51 | DISTRICT_I
==52 | DISTRICT_I ==53 | DISTRICT_I ==55 | DISTRICT_I ==57 | DISTRICT_I ==59 |
DISTRICT_I ==60 | DISTRICT_I ==65 | DISTRICT_I ==67 | DISTRICT_I ==71 | DISTRICT_I
==73 | DISTRICT_I ==74 | DISTRICT_I ==75)
district<-buffer[buffer$DISTRICT_I]
vdistrict<-write.csv(district,'C:/wenmei/wenmei/chapter2data/Stata9/chapter2/district.csv')

#merge the eigenvector dataset with the panel frontier data. Read the eigenvector dataset into R
spfil<-read.csv("C:/wenmei/wenmei/chapter2data/Stata9/chapter2/sfiltering.csv",header=T,sep=',')
#rename district name
library(reshape)
spfil<-rename(spfil,c(DISTRICT_I="v00_dist"))
spfil<-data.frame(spfil)
attach(spfil)

#read the frontier panel data into R
fdata<-read.dta(file="C://wenmei//wenmei//chapter2data//panel//2010new//panel200310fron1.dta")
fdata<-data.frame(fdata)
attach(fdata)
fpdata1<-merge(spfil,fdata,by="v00_dist",all.x=T,all.y=T)

*****************Frontier analysis in R********************
#frontier analysis
detach(frontierpanel)
rm(list=ls(all=T))
detach(fdata1)
rm(list=ls(all=T))
library(foreign)

#fdata<-read.dta(file="C://wenmei//wenmei//chapter2data//panel//2003//panel201003newpanelfinal2.dta")
```

```
#fdata<-read.dta(file="C://wenmei//wenmei//chapter2data//panel//2010new//panel200310fron4.dta")
fdata<-read.dta(file="F://dissertation//chapter2data//panel//2010new//panel200310fron4.dta")
#install.packages("plm")
library(plm)
frontierpanel<-plm.data(fdata,c("WWWHH","time"))
frontierpanel<-data.frame(fdata)
attach(frontierpanel)
fdata1<-frontierpanel[which(mpaddy>10 & mpaddy<15000),]
attach(fdata1)
hist(mpaddy)
hgender<-as.numeric(hgender)
hgender<-ifelse(hgender==2, 0, 1)    #0 is female, 1 is male head
read<-as.numeric(read)
hread<-ifelse(read==2,0,1)           #0: could not read, 1: could read
ariextent<-as.numeric(agriextent)
agriext<-ifelse(agriextent==2,0,1)
mrain<-log(mrainfall+1)
elev1=elevation/10000
elev2=log(elevation+1)/100
road2=log(road)/100
road22=road2^2
river2=log(river)/100
mpaddy1<-log(mpaddy+1)
labor1<-log(labor+1)
fert1<-log(fertilizer+1)
seed1<-log(seed+1)
cap1<-log(capital+1)
parea1<-log(paddyarea+1)

#model analysis
#extreme climate model
install.packages("frontier")
library(frontier)
mfrontier1.1<-sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+factor(time),data=fdata1,
timeEffect=T)
summary(mfrontier1.1)
AIC(mfrontier1.1)
mfrontier1.2<-
sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+psd32+rpe3+v3+factor(time) ,data=fdata1,
timeEffect=T)
summary(mfrontier1.2)
AIC(mfrontier1.2)
mfrontier1.3<-sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+psd32+rpe3+v3+factor(time) |
river2+road2+factor(time),data=fdata1, timeEffect=T)
summary(mfrontier1.3)
AIC(mfrontier1.3)
mfrontier1.4<-sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+psd32+rpe3+v3+factor(time) |
river2+road2+dscfarm+agriext+factor(time),data=fdata1, timeEffect=T)
summary(mfrontier1.4)
```

```
AIC(mfrontier1.4)
mfrontier1.5<-sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+psd32+rpe3+v3+factor(time) |
river2+road2+dscfarm+agriext+hgender+hread+factor(time),data=fdata1, timeEffect=T)
summary(mfrontier1.5)
AIC(mfrontier1.5)

#average climate model
spmrain2<-spmrain^2
spmtemp2<-spmtemp^2
sumrain2<-sumrain^2
fmrain2<-fmrain^2
sumtemp2<-sumtemp^2
fmtemp2<-fmtemp^2
mfrontier2.1<-sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+factor(time), data=fdata1,
timeEffect=T)
summary(mfrontier2.1)
AIC(mfrontier2.1)
mfrontier2.2<-
sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+sumrain+sumrain2+sumtemp+sumtemp2+v3+f
actor(time),data=fdata1, timeEffect=T)
summary(mfrontier2.2)
AIC(mfrontier2.2)
mfrontier2.3<-
sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+sumrain+sumrain2+sumtemp+sumtemp2+v3+f
actor(time) | river2+road2+factor(time), data=fdata1, timeEffect=T)
summary(mfrontier2.3)
AIC(mfrontier2.3)
mfrontier2.4<-
sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+sumrain+sumrain2+sumtemp+sumtemp2+v3+f
actor(time) | river2+road2+dscfarm+agriext+factor(time),data=fdata1, timeEffect=T)
summary(mfrontier2.4)
AIC(mfrontier2.4)
mfrontier2.5<-
sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+sumrain+sumrain2+sumtemp+sumtemp2+v3+f
actor(time) | river2+road2+dscfarm+agriext+hgender+hread+factor(time),data=fdata1, timeEffect=T)
summary(mfrontier2.5)
AIC(mfrontier2.5)

#average climate during cropping season
mfrontier3<-
sfa(mpaddy1~labor1+fert1+seed1+cap1+irriport+parea1+spmrain+spmrain2+spmtemp+spmtemp2+sumr
ain+sumrain2+sumtemp+sumtemp2+fmrain+fmrain2+fmtemp+fmtemp2+v3+factor(time) |
river2+road2+dscfarm+agriext+hgender+hread+factor(time),data=fdata1, timeEffect=T)
summary(mfrontier3)
AIC(mfrontier3)

##############Likelihood ratio test
install.packages("lmtest")
require(lmtest)
```

```
lrtest(mfrontier1.5)
lrtest(mfrontier2.5)

##############Efficiency score
efficiencies(mfrontier1.5)
```

Appendix C: Survey

Microfinance and Capabilities to Mitigate Adverse Impact of Climate Change in Rural Nepal (Version A)

Collaborative Project between the Nepal Study Center, University of New Mexico and Dhulikhel Hospital, Kathmandu University

August, 2014

Research team:

NSC UNM: Wenmei Guo, Dr. Alok K. Bohara (Nepal Study Center, University of New Mexico)

KU: Dr. Biraj Karmacharya and Ms. Samita Giri (Department of Community Programs at Dhulikhel Hospital-Kathmandu University)

Namaskar, I am [Enumerator's name: ....] from the Nepal Study Center at the University of New Mexico, USA and Kathmandu University. We are conducting a survey with residents of Bahunepati, like you, about the effect of microfinance on the capability to cope with climate change. The survey will take approximately 90 minutes.

You have been randomly selected to participate in this survey, and your household was chosen using a random selection process from a list of households in this VDC. You will be asked a series of questions, most of which have Yes/No answers, designed to understand behaviors regarding the strategies you adopted to cope with climate change. Some questions in this survey may cause you to feel slightly uncomfortable; however, you may refuse to answer any individual question. Although this study will not benefit you personally, we hope that our results will add to the knowledge about how to enhance the ability to protect your household against climate change.

All of your responses will be *anonymous.* Only the researchers involved in this study and those responsible for research oversight will have access to the information you provide. Your responses will be handwritten and stored securely at the research facility at Nepal Study Center in the University of New Mexico. Your responses will be numbered and coded, and your name will not be on any documents. The coding will be used on all your documents, but will not connect to your name. So while we know from the record of your verbal consent that you participated in this research study, no data will be linked to you. The primary surveys will be stored in a locked safe until coding.

Participation in this study is completely voluntary. You are free to decline to participate, to end participation at any time for any reason, or, again, to refuse to answer any individual question. Refusing to participate will involve no penalty or loss of benefits to which you are otherwise entitled, (such as your health care outside the study, the payment for your health care, and your health care benefits).

i.	Are you 18 years or older? (Ask this question only if the respondent looks teenage)	Yes .... 1 No 2	□ Go to ii. □Ask for another member of the house who is 18 years or older
ii.	Do you want to participate in this survey?	Yes .... 1 No 2	□ Complete the survey □ Thank for the time and collect some basic information in the following box only.

iii.	Are you involved in any micro finance program?	Yes……………………………………..1 Micro Finance name ______________ Micro Finance number……. [ ][ ] No……………………………………….2	

Fill in the following table even if the respondent does not want to participate in the survey so that we can keep record of non-response rate.

Date of Interview: ___________ (dd/mm/yy)

Study # ....

Location # ....

Supervisor's Name: .... Enumerator's Name: ....

<u>About Respondents:</u>

Full Name: Mr./Mrs./Miss.. Time ....

Address:

Name of village: ....

Ward number in VDC (1-9): .... Name of the community: ....

Household Number: ....

Relationship of the respondent to the household head[1]: ....

1 Relation of respondent to the household head. Head=1; Husband/wife=2; son/daughter=3; grandchild=4; father/mother=5; brother/sister=6; nephew/niece=7; son/daughter-in-law=8; brother/sister-in-law=9; father/mother-in-law=10; other family relative=11

Section A: Demographic

In this section, we would like to ask some questions about your household demographic. We would also ask you some questions about your income and wealth.			
A1.	What is your household size (people living under the same roof)?	No. of household members...…………….. ☐☐	
A2.	What is your gender?	Male…………………………………………...1 Female…………………………………………2	
A3.	What is your current age?	Years .... ☐☐	
A4.	What is the head of household's age?	Years .... ☐☐	
A5.	What is your current marital status?	Never Married .... 1 Currently Married .... 2 Divorced .... 3 Separated .... 4 Widowed 5	
A6.	What type of family do you live?	Joint family …………………………………1 Nuclear family……………………………….....2	
A7.	What is the highest level of education that you have completed?	No formal schooling .... 1 Grades (1-5) .... 2 Grades(6-8) .... 3 Grades (9-12) .... 4 Bachelors .... 5 Masters or other professional degrees 6	
A8.	What is the highest level of education that the head of household has completed?	No formal schooling .... 1 Grades (1-5) .... 2 Grades(6-8) .... 3 Grades (9-12) .... 4 Bachelors .... 5 Masters or other professional degrees 6	

<table>
<tr><td>A9.</td><td colspan="1">What is the head of household’s primary occupation?</td><td colspan="3">Unemployed 1
In school 2
Agriculture 3
Shop keeper/ Self Employed 4
Health Sector 5
Administrative Job (ex.
Government, NGO) 6
Labor 7
Not working outside the house 8
Other .... 96</td><td></td></tr>
<tr><td>A10.</td><td>What is the family’s primary religion?</td><td colspan="3">Hindu 1
Buddhist 2
Muslim 3
Kirate 4
Christian 5
Other .... 96</td><td></td></tr>
<tr><td>A11.</td><td>What is the family’s primary caste/ethnicity?</td><td colspan="3">Brahmin 1
Chherti 2
Newar 3
Janajati 4
Madhesi, Thaurs, Musalman 5
Pahadi Dalit 6
Madhesi Dalit 7
Other .... 96</td><td></td></tr>
<tr><td rowspan="9">A12.</td><td rowspan="9">Does any member of your household own:</td><td></td><td>Yes</td><td>No</td><td rowspan="9"></td></tr>
<tr><td>Bicycle</td><td>1</td><td>2</td></tr>
<tr><td>Cell Phone</td><td>1</td><td>2</td></tr>
<tr><td>Motorcycle</td><td>1</td><td>2</td></tr>
<tr><td>Car/Truck</td><td>1</td><td>2</td></tr>
<tr><td>Water pump</td><td>1</td><td>2</td></tr>
<tr><td>Tractor</td><td>1</td><td>2</td></tr>
<tr><td>Telephone</td><td>1</td><td>2</td></tr>
<tr><td>TV</td><td>1</td><td>2</td></tr>
</table>

		Radio	1	2	
		Refrigerator	1	2	
		Internet	1	2	
A13.	Is there anyone in your household working abroad?	Yes .... 1 No 2			
A14.	Did your household receive remittances in the past 12 months?	Yes .... 1 No 2			If no, go to A16.
A15.	How much remittance did your household receive in the past 12 months?	Rupees…………………….. ☐☐☐☐			
A16.	What is your total household income per month last year?	Less than 5000 .... 1 5001-10000 .... 2 10001-20000 ..../... 3 20001-30000 .... 4 30001-40000 .... 5 40001-50000 .... 6 50001-70000 .... 7 70001-100000 .... 8 Greater than 100000 .... 9 Do not know .... 99 Refused 111			

Section B: Social Network

In this section we would like to ask you about your relationships with friends and family. We will be asking about how often you visit your friend's or relatives' house. Additionally, we would like to know the type of community group you or someone in your family participates in.			
B1.	How many close friends and relatives do you have whom you can freely share private matters, call on help, or borrow money?	No. of friends and relatives…………..……… ☐☐	
B2.	How frequently do you visit your friends and relatives?	More than 5 times per month…………..……………...1 3– 5 times per month……………………….……....2 1-2 times per month……………………...……3 Less than 1-2 times per month…………………..……4	
B3.	How frequently do your friends and relatives visit you?	More than 5 times per month…………………….....1 3– 5 times per month………………………..….. 2 1-2 times per month…………………………..…3 Less than 1-2 times per month……………………..…4	
B4_a.	Do you or anyone in your household participate in an organization or cooperative in your community? For instance, a water committee, women's group, forestry group, NGO, etc.	Yes……………………………………………….1 No……..……………….…………………………...2	If no, go to B5
B4_b.	If yes, please check out those all applied.	☐ Microfinance program……………………………1 ☐ Agriculture group……………………………....2 ☐ Forest group……………………………………3 ☐ Water group(irrigation group)……………….....4 ☐ Women group………………………………….5 ☐ Credit group……………………………………6	

		☐ Others, please specify: ____________________ 96	
For the following questions, I would give you a statement about the degree that you trust the people in your ward. With 5 being strongly agree, while 1 being strongly disagree, please circle the one based on your feeling.			
B5.	Most people are trustable in this village.	Strongly disagree……………………………………1 Disagree……………..…………………………………...2 Neutral………..…………………..……………………...3 Agree….………………………………………………...4 Strongly Agree..……………………………………...5	

Section C: Food Security

The following questions are to know about your household's food security situation. Could you please tell me how many days in the past 7daysyour household has eaten the following foods and what the source was (input 0 for items that were not eaten over the last 7 days).				
	Food Item	a. No of days eaten the item in the last 7 days	b. Food source (write those all applied (code 1))	**Code 1: Food Source Codes:**
C1.	Maize	( )	☐ , ☐ , ☐	1=Own production (crops, animal) 2=hunting, fishing 3=gathering 4=borrowed 5=purchase with wages 6=exchange labor for food 7=exchange items for food 8=gift (food) from family relatives 9=food aid (NGOs etc.) 96=Other (specify: ______________)
C2.	Rice/Paddy	( )	☐ , ☐ , ☐	
C3.	Millets	( )	☐ , ☐ , ☐	
C4.	Roots and tubers (potatoes, yam)	( )	☐ , ☐ , ☐	
C5.	Wheat/Barley	( )	☐ , ☐ , ☐	
C6.	Fish	( )	☐ , ☐ , ☐	
C7.	White meat- poultry	( )	☐ , ☐ , ☐	
C8.	Pork	( )	☐ , ☐ , ☐	
C9.	Red meat-goat, sheep	( )	☐ , ☐ , ☐	
C10.	Red meat-Buffalo	( )	☐ , ☐ , ☐	
C11.	Eggs	( )	☐ , ☐ , ☐	
C12.	Pulses/Lentils	( )	☐ , ☐ , ☐	
C13.	Vegetables	( )	☐ , ☐ , ☐	
C14.	Oil/Ghee/Butter	( )	☐ , ☐ , ☐	
C15.	Fresh fruits	( )	☐ , ☐ , ☐	
C16.	Sugar/Salt	( )	☐ , ☐ , ☐	
C17.	Milk/Curd	( )	☐ , ☐ , ☐	
For the following questions, we would like to ask you how you cope with food shortage in the last 7 days.				
C18.	In the past 12 months, how frequently did you worry that your household would not have enough food?	Never……………………………………………………1 Rarely (once)………………………………………………2 From time to time (2 to 3 times)…………………………3		

		Often （5 or more times）………………………………4	
C19.	In the past 12 months, how often were you or any household member not able to eat the kinds of food you/he preferred because of a lack of resource?	Never……………………………………………………1 Rarely……………………………………………………2 From time to time…………………………..…………3 Often……………………………………………….…4	
C20.	In the past 12 months, how often did you or any household member have to eat a limited variety of foods due to a lack of resources?	Never……………………………………………………1 Rarely……………………………………………………2 From time to time…………………………..…………3 Often……………………………………………….…4	
C21.	In the past 12 months, how often did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	Never……………………………………………………1 Rarely……………………………………………………2 From time to time…………………………..…………3 Often……………………………………………….…4	
C22.	In the past 12 months, how often did you or any household member eat fewer meals in a day because of resources to get food?	Never……………………………………………………1 Rarely……………………………………………………2 From time to time…………………………..…………3 Often……………………………………………….…4	
C23.	In the past 12 months, how often was there with no food to eat of any kind in your household because of lack of resources to get food?	Never……………………………………………………1 Rarely……………………………………………………2 From time to time…………………………..…………3 Often……………………………………………….…4	
C24.	In the past 12 months, how often did you or any household member go to sleep at night hungry because there was not enough food?	Yes………………………………………………………1 No……………………………………………………..2	
C25.	Has any member of your household received food aid in the last 6 months?	Yes………………………………………………………1 No……………………………………………………..2	

Section D Farming and livestock

In this section, we are going to ask you some questions about the farming and livestock of your household. We will ask you the information of the quality of the land, the crops grown by your household, and the live stocks fed by your household.			
D1.	What is the gender of farmer head in your household?	Male……………………………………………1 Female..……………………………………..2	
D2.	How long has the farmer head been engaging in farming?	No. of years………………………...... [ ][ ]	
D3.	Does any member of your household own any agriculture land?	Yes .... 1 No 2	If no, go to D7
D4.	How many ropani/bigha of agriculture land in total does your household own?	Unit Code: Ropani ....1 Bigha 2	
		D4_a Unit | Area: D4_b. R/B | D4_c. A/K | D4_d. P/D	
		| | |	
D5.	What is the fertility level of your agriculture land?	Highly fertile…………………………………..1 Fertile…………………………………………2 Low fertile……………………………………..3 Infertile...………………………………...4	
D6.	What is the erosion level of your agriculture land?	Severe erosion………………………………1 Moderate erosion……………………………2 Slight erosion…………………………………3 No erosion……………………………………..4	

For the following questions, we will ask you some questions about your crop harvest in the last harvesting year. We want to know what kind of crop you grew, the quantity you harvested, your agriculture income and cost, etc.

In the past AGRICULTURE YEAR, what crops did you grow? LIST ALL CROPS GROWN BY HOUSEHOLD FIRST BEFORE ASKING Q.			D9. Did you use an improved variety of seed of ..[CROP]. .?	D10. Which season was the crop harvested?	Land area for planting the …[crop]… in total? <u>Unit Code:</u> Ropani ....1 Bigha 2				Please provide the following information related to quantity of ..[CROP].. produced by your household.		Please report the total revenue if all the ..[crop]… were sold.	
	D7. Crop Descri -ption	D8. Crop Code (code 2)	Yes……..1 No………2	Wet season...1 Dry season...2	D11_a Unit	D11_b. Area			A	B	C	D
						D11_b1 R/B	D11_b2 A/K	D11_b3 P/D	D12_a Unit (code 3)	D12_b Total quantity harvested	D12_c. Price per unit	D12_d. Total revenue (if all the …[crop] … were sold)
											Rupees/uni t	Rupees
01												
02												
03												
04												
05												
06												
07												
08												
09												
10												

Code 2(Agriculture Code):

Cereal: 1=paddy, 2=wheat, 3= maize, 4=millet, 5=barley, 6=buckwheat, 7=other cereals

Pulses and Legumes: 8=soybeans, 9=gram, 10=red gram, 11=green gram, 12=coarse gram, 13=lentil, 14=grass pea, 15=pea, 16=cow pea, 17=other legumes

Tuber and Bulb Crops: 18= potato, 19=sweet potato, 20=colocasia, 21=other tubes

Oilseed Crops: 22=Mustard, 23=ground nut, 24=linseed, 25=sesame, 26=other oilseed

Cash Crops: 27=sugarcane, 28=jute, 29=tobacco, 30=other cash crops

Spices: 31=chilies, 32=onions, 33=garlic, 34=ginger, 35=turmeric, 36=cardamom, 37=coriander seed, 38=other spices

Vegetables: 39=tomato, 40=cauliflower, 41=cabbage, 42=other vegetables

Citrus Fruits: 43=orange, 44=lemon, 45=lime, 46=sweet lime, 47=other citrus

Non-Citrus Fruits: 48=mango, 49=banana, 50=guava, 51=jack fruit, 52=pineapple, 53=lichee, 54=pear, 55=apple, 56=plum, 57=papaya, 58=pomegranate, 59=other fruit

Other: 60=tea, 61=thatch, 62=fodder trees, 63=banboo, 64=other trees

Code 3(Unit Code):1=kilogram, 2=gram, 3=maund, 4=liter, 5=muri, 6=pathi, 7=manna, 8=kuruwa, 9=number/pieces, 10=dozen, 11=quintal

For the following questions, we will ask you the expenditure on farming in the last agriculture year. Please provide the expenditure on each crop you harvested (If you don't use the item, please write ZERO).									
D13. Copy the crop code from D6	D14. Total expenditure on seeds and plants	D15. Total expenditure on fertilizer	D16. Total expenditure on hired labor	D17. Irrigation charges/maintenance of watercourses, etc	D18. Improvements on land or buildings	D19. Repair or maintenance of equipment	Expenditure on renting in:		
							D20_a. Tractor	D20_b. Thresher	D20_c. Other machinery

For the following questions, we would like to ask you some information about the livestock.			
D21.	Does your household own any livestock, herds, other farm animals or poultry?	Yes .... 1 No 2	If no, go to section E
D22.	How many of the following animals does your household own? (input 0 for items that are not raised)	Goat .... ☐☐ Cow/bull .... ☐☐ Sheep .... ☐☐ Buffalo .... ☐☐ Chickens .... ☐☐ Ducks .... ☐☐ Pigs.. ☐☐ Others.. ☐☐	

Section F: Climate Change

In this section we are going to ask you about your knowledge about climate change, perception about climate change, your adaptation strategies for the climate change/climate risk, and willingness to pay for crop insurance. Climate change refers to change in rainfall pattern, change in temperature pattern, etc. Extreme climate event refers to drought, flood, heavy rainfall, etc.

Cause of Climate Change

For the following questions, I would propose some statements about the cause of climate change, and ask the degree of your agreement on the statement. Please circle the one that best describes your feeling.

F1_a. Deforestation is one of the causes for climate change.

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

F1_b. Pollution from burning fossil fuel is one of the causes for climate change

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

F1_c. Applying pesticide and chemical fertilizer in agriculture is one of the causes for climate change.

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

F1_d. Forest fire is one of the causes for cliamte change

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

F1_e. Using modern electronic tools is one of the causes for climate change

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

F1_f. What other activities do you think cause climate change? ______________________________

Ex-post Impact of Climate Change

For the following questions, I would propose some statements about the impact of climate change on your household in the past 5 years, and ask the degree of your agreement on the statement. Please circle the one that best describes your feeling.

F2_a. Climate change caused more pets, weeds, etc on my field.

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

F2_b. Climate change caused the increase of the rate of illnesses in my household.

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

F2_c. Climate change affected education in my household, for example, kids could not to to school because of hot weather in summer.

☐ Strongly disagree ☐ Disagree ☐ Neutral ☐ Agree ☐ Strongly agree

F2_d. Climate change caused shortage of water supplies in irrigation in my household.				
☐ Strongly disagree	☐ Disagree	☐ Neutral	☐ Agree	☐ Strongly agree
F2_e. Climate change caused other income loss other than agriculture and livestock in my household.				
☐ Strongly disagree	☐ Disagree	☐ Neutral	☐ Agree	☐ Strongly agree
F2_ f. Climate change caused more usage of fertilizers and pecticide in my field.				
☐ Strongly disagree	☐ Disagree	☐ Neutral	☐ Agree	☐ Strongly agree
F2_g. What other aspects of your household have been affected by climate change? ______________________________				
Climate Information Access				
Type of information	F3. Did you receive any information? 1=yes 2=no If no, go to next row	F4. From whom or how did you receive the information? (see code 4)	F5. Did it include advice on how to use the information in your farming? 1=yes 2=no	F6. Did you use the advice in your farming? 1=yes 2=no
_a. Farming practices				
_b. Forecast of drought, flood, heavy rainfall, icy snow, tidal surge or other extreme event				
_c. Forecast of pest or disease outbreak				
_d. Forecast of weather for today, the next 24 hours and/or next 2-3 days				
_e. Forecast of weather for the following 2 to 3months				
Code 4: 1=Farmer to farmer extension; 2=Governmet agricultural extension or veterianry officers; 3= Radio; 4= Television; 5= NGO project officers; 6= Friends, relatives, or neighbours; 7=Meteorological offices; 8=Newspaper; 9=Traditional forecaster/Indigenous knowledge; 10= Local group/gathering/meetings; 11=religious faith; 96=others				

Perception about climate change (ex-post percetption)			
F7.	What change do you think in the rainfall trend in the past 20 years?	Incerase……………………………………………1 No change…………………………………………2 Decrese……………………………………………3 Altered change…………………………………….4 Don't know……………………………………….99	
F8.	What change do you think in the temperature trend in the past 20 years?	Incerase……………………………………………1 No change…………………………………………2 Decrese……………………………………………3	

		Altered change……………………………………..4 Don't know……………………………………..99	
Perception about climate change (ex-ante percetption)			
Due to large amount of "greenhouse gases" emissions, such as carbon dioxide from burning straw, the earth's temperature has been increasing in recent decades. Scientists say that the temperature will continue to increase in the future. They warned that by 2050, the global temperature will increase by 3 °C on average and by 5.5 °C by 2100. If the temperature continues to increase, human being's well being would be affected. Expected effects on human being, especially people in developing countries would be agriculture and livestocks, such as increase in pests and deseases, decrease in production, etc.			
F9.	We would like to know your perception of how likely climate change would continue in the next 10 years if nothing is done to prevent it. Please tell us the range that best describes your perception.	Highly likely……………………………………4 Likely…………………………………………...3 Somewhat likely…………………………………...2 Not likely at all……………………………………1 I Don't know…………………………………99	
F10.	We would like to know your perception of the degree of the impact of climate change in the next 10 years on your loss of asset and income (e.g., the loss of agriculture, livestock, house, etc.). With 0 standing for no impact, 1 for low impact, 2 for medium impact and 3 for high impact, please write a number that best describes your perception.	Degree of impact……………………… ☐☐	
Mitigation Strategies to adapt to climate change			
F11.	Did you adopt any mitigation strategies to adapt to climate change?	Yes……………………………………………1 No……………………………………………..2	If no, go to F13
F12.	What kind of mitigation strategies did/does your household adopt to prevent the adverse impact of climate change on your life? (Check all those applied)	Soil conservation……………….……..………..…1 Planting trees……………........…………….........…2 Use/Modification/Repairs of Irrigation system………...3 Increase water conservation………………..………..4 Different crop varieties……..……………………....….5 Planting a higher production variety……………..……6 Planting shorter cycle variety………………..........…...7 Planting longer cycle variety……………………..……8 Planting drought tolerant variety………………………9 Planting flood tolerant variety………………………...10 Early and late planting……………………………...…11 Improved seeds, fertilizers, etc…………..…………….12 Changing from rain-fed to irrigated agriculture……….13	

		Livestock diversification…………………………….....14 Migration to other places…………………………..…..15 Engagement in insurance………………..………..…16 Income diversification………………....………..…...17 Seeking assistance from NGO……………………..…...18 Shift from farming activities to non-farm activities ……19 Others, specify: ______________________________96	
F13.	Why don't you adpat mitigation strategies? (Check all those applied)	Not having enough money……………………………1 Not having enough time…………………...……..…2 Not knowing what to do…………………...………..3 Not necessary………………………………………4 No reason……………………………….……...…5 Other reason, specify:________________________ 96	
Perception about extreme climate event (ex-ante perception)			
F14.	We would like to know your perception of how likely each extreme climate event would happen in in the next 10 years. With 0 standing for not likely at all, 1 for somewhat likely, 2 for likely and 3 for highly likely, please tell us a number that best describes your perception.	Drought……………………………..	
		Flood………………………………	
		Heavy rainfall…………………………	
		Storm……….………………………	
		Ice rain/snow…………………………	
F15.	We would like to know your perception of how many each extreme climate events would happen in in the next 10 years in total (please write a number that best describes your perception).	Drought……………………………..	
		Flood………………………………	
		Heavy rainfall…………………………	
		Storm……….………………………	
		Ice rain/snow……………………….	

F16.	We would like to know your perception of the severity of each future extreme climate event in terms of its impact on your income and asset. With 0 standing for no impact, 1 for low impact, 2 for medium impact and 3 for high impact, please write a number that best describes your perception.	Drought…………………………….. Flood………………………………. Heavy rainfall………………………… Storm……….…………………………… Ice rain/snow………………………..	
Mitigation Strategies to cope with extreme climate event			
F17.	Did you adopt any mitigation strategies to cope with extreme climate event?	Yes…………………………………………..1 No………………………………………...2	If no, go to F19
F18.	What kind of mitigation strategies did/does your household adopt to prevent the adverse impact of climate change on your life? (Check all those applied)	Collective action for infrastructure[20]……………………..1 Common property resource management [21]……………..2 Asking food or money from relative /neighbor /friends…3 Seeking assistant from government / NGO /religious organizations…………………………………………….….4 Spending less money on food items……………………..…5 Spending less money on school fees……………….…….6 Spending less money on health care……………………..…7 Spending less money on house maintenance……...……..8 Investment in physical and human capital……………....9 Crop, plot, livestock diversification…….……………...10 Income source diversification…………………………..….11 Switch to more secure income sources………………...12 Engagement in contract insurance……………………..13 Migration to other places…………………..……………14 Others, specify: ________________________________96	
F19.	Why don't you adpat mitigation strategies? (Check	Not having enough money…………………1	

[20] Collective action in infrastructure is talking about some infrastructure construction, such as building river dikes to prevent flood water, building irrigation canals to maintain water supply during drought time, etc.
[21] Common property resource management is referring to "jointly management of common property resources by households, such as forests and lakes to ensure a sustainable extraction of natural resources".

	all those applied)	Not having enough time……………………2 Not knowing what to do……………………3 Not necessary………………………………4 No reason……………………………...…5 Other reason, specify: _______________ 96	
F20.	On a scale of 1 to 10, how confident do you think you are prepared for the climate shocks, including the shocks from climate change and extreme climate event? With 1 being not confident and 10 being very confident.	Degree of confidence………………………… [ ][ ]	

Willingness to Pay for Weather-indexed Micro Insurance

We would like to propose two hypothetical scenarios, in which we want to know your willingness to pay for a weather-index based micro insurance. We are going to introduce two insurance products: the first one only coving paddy while the second one covering several types of livestock in additional to paddy. In what follows you will be asked how much you would be willing to pay for each insurance in this order: first, insurance for paddy; second, insurance for both paddy and livestock, in which you would be asked twice about your WTP for each product.

Suppose your community is considering the introduction of a weather-index micro insurance program for farmers in your area. This insurance product is designed to protect farmers against deficient/excess cumulative rainfall during a cropping season. Your community is interested in knowing: 1) how many farmers are interested in joining this program; and 2) how much premium they are willing to pay for certain types of policies. A description of the policy is provided below.

- **Coverage**: This policy protects farmers against deficient/excess cumulative rainfall during a cropping season. If there is continuous heavy rainfall for 10 days or continuous no rainfall/little rainfall for 30 days, during the crop vegetative phase (months *March* to *June* and *July* to *November* after sowing), a payout would be made to the farmers.(In order to make the amount of rainfall more objective and easier to measure, the rainfall data is based on the record of the closest weather station to your village instead of the rain fell on your field. The standard is "if the rainfall for any 10 consecutive days is cumulatively above 120 millimeters or any 30 consecutive days is cumulatively below 10 millimeters")

➢ **Insurance A:**
  - **Description:** Insurance A only covers paddy. As long as the weather meets the requirement described in the coverage. A payout would be made to farmers.
  - **Pay Out**: NPR 10000 per ropani per year insured

➢ **Insurance B**
  - **Description:** Insurance B extents the coverage of the insurance. In additional to paddy, the insurance also covers livestock. In total, it covers paddy, buffaloes, cows, goats, chicken and ducks.
  - **Payout:** 10000 NPR per ropani insured, 8100 NPR per cow insured, 26000 per buffaloes insured, 3800 per goat insured, and 380 per poultry (including ducks and chicken) insured.

- Payment would be made to farmers for paddy as long as the weather meets the requirement described in the coverage. As to livestock, payment would be made after evaluation of damage by experts from agriculture office. It's according to the number of dead livestock due to the bad weather.

Now I would like to summarize the two policies and ask your willingness to pay for them, respectively.

Insurance A:

F21.	**Would you be willing to pay [fill in randomly chosen bid amount: ___________ Rupee] for insurance A** per year that covers paddy cultivated and grown between March and November ?	Yes .... 1 No 2

Instructions to enumerator for Question F21: This is a follow up question to F21 and should be asked casually. If the respondent answered yes to their given bid value, they should be asked if they would pay the next higher bid amount. Or if the respondent answered no to their given bid value, they should be asked to pay the next lower bid amount. Here are the bid amounts:

NPR 100, 200, 350, 500, 700 and 1200

For example: 1) The respondent was asked if they would pay 200 Nrs for the insurance, they said **yes**. You would ask if they would pay 350 Nrs for the insurance (the next higher amount).

2) The respondent was asked if they would pay 200 Nrs for the insurance, they said **no**. You would ask if they would pay 100 Nrs for the insuance (the next lower amount).

F22.	What if you were instead asked to pay _______ Nrs for the insurance. Would you buy the weather-indexed insurance?	Yes .... 1 No 2
F23.	On a scale of 1 to 10, how certain are you of your answer to the previous question? With 1 being not certain and 10 being very certain.	Degree of certain.. ☐☐

Insurance B:

F24.	**Would you be willing to pay [fill in randomly chosen bid amount: ___________ Rupee] for insurance B** per year that covers the followings: 1. Paddy 2. Buffalo 3. Cows 4. Goats 5. Chicken 6. Ducks	Yes .... 1 No 2

Instructions to enumerator for Question F24: This is a follow up question to F24 and should be asked casually. If the respondent answered yes to their given bid value, they should be asked if they would pay the next higher bid amount. Or if the respondent answered no to their given bid value, they should be asked to pay the next lower bid amount. Here are the bid amounts:

NPR 100, 200, 350, 500, 700 and 1200

For example: 1) The respondent was asked if they would pay 200 Nrs for the insurance, they said **yes**. You would ask if they would pay 350 Nrs for the insurance (the next higher amount).

2) The respondent was asked if they would pay 200 Nrs for the insurance, they said **no**. You would ask if they would pay 100 Nrs for the insuance (the next lower amount).

<table>
<tr><td>F25.</td><td>What if you were instead asked to pay _______ Nrs for the insurance. Would you buy the weather-index insurance?</td><td colspan="6">Yes 1
No .... 2</td></tr>
<tr><td>F26.</td><td>On a scale of 1 to 10, how certain are you of your answer to the previous question? With 1 being not certain and 10 being very certain.</td><td colspan="6">Degree of certain…………………………… [ ][ ]</td></tr>
<tr><td rowspan="2">F27.</td><td rowspan="2">Please rank the items that covered by the insurance, with 1 being the most important, while 6 being the least important.</td><td>paddy</td><td>buffalo</td><td>cows</td><td>goats</td><td>chicken</td><td>ducks</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>F28.</td><td>Do you think this rainfall-indexed micro insurance program presented above is the best way to deal with the climate impact?</td><td colspan="6">Yes……………………………………..1
Somewhat…………………………………..2
No……………………………………3
Don’t know……………………………………99</td></tr>
</table>

Section G: Health

In this section we want to ask about your health. We also want to know your perceived health status.			
G1.	Has a doctor ever diagnosed you with or confirmed that you had any chronic illness?	Yes……………………………………………………1 No……………………..…………………………………2	
G2.	Did you have any health problem during the past 6 months (including chronic illness)?	Yes……………………………………………………1 No……………………..…………………………………2	
G3.	How long does it take for a round-trip to the clinic where you usually go when you are sick?	Minutes…………………………………. ☐☐	
G4.	How often did you go to doctor for the illnesses in the past 6 months?	Never…………………………………………………1 Rarely…………………………………………………2 Sometimes……………………………………………3 Frequently……………………………………………4 Constantly……………………………………………5	
G5.	What is your approximate expenditure in the past 6 months (rupees)?	Yes……………………………………………………1 No……………………..……………………………...2	
G6.	What is the reason that you went to the doctor in the past 6 month? (Code 5)	Reason…………………___, ___, ___, ___, ___, ___	
G7.	Overall, how do you rate your health during the past 12 month/past month/present health status?	Excellent………………………………………………5 Very good……………………………………………..4 Good…………………………………………………..3 Fair……………………………………………………2 Poor…………………………………………………...1	
The following questions are about the weight and height of the oldest child under 5 years old in the household.			
G8.	What is the weight of the child?	In Kg………………………………… ☐☐ Don't know……………………………………..…99	
G9.	What is the height of the child?	In CM……………………………….. ☐☐ Don't know………………………………….…99	

G10.	What is the age of the child?	Months………………………………… ☐☐	
G11.	What is the gender of the child?	Male……………………………………………1 Female…………………………………………2	

Code 5: Nature of chronic illness (multiple answers possible)

1=Heart conditions; 2=Respiratory; 3=Asthma; 4=Epilepsy; 5=Cancer; 6=Diabetes; 7=Kidney/liver Disease; 8=Rheumatism related; 9=Gynecological Problems; 10= Occupational Illnesses; 11=High/Low Blood Pressures; 12=Gastrointestinal Disease; 13=Diarrhea; 14=Dysentery; 15=Respiratory Problems; 16=Malaria; 17=Cold/Fever/Flu; 18=Other Fever; 19=Skin Disease; 20= Measles; 21=Jaundice; 22=Parasites; 23=Injury; 24=Dental Problems; 25=Prenatal care; 26=Delivery care; 27=Postnatal care; 96=Others, please specify:_________________________

Section H: Intimate Partner Violence (This section is only for female respondents, if male, please skip this section)

In this section, we are going to ask if you have ever experienced sexual abuse and violence from your intimate partner. If yes, we would want to know the reason.			
H1.	Have you ever experienced the following types of violence against women? (Multiple answer, check all those applied)	Scold……………………………...………..1 Physical assault…………………………………….2 Sexual abuse……………………………………….3 Polygamy…………………………………………..4 Prostitution ....5 Caste discrimination………………………………6 Girls trafficking…………………………………….7 Others, please specify______________________96	
H2.	If experienced, what are the reasons? (Multiple answer, check all those applied)	Cooked bad food…………………………………1 Went outside without husband permission………..2 Children…………………………………………...3 Refused for sex……………………………………4 No dowery………………………………………...5 Caste……………………………………………….6 Others, please specify______________________96	
H3.	Do you ever refused your husband when you don't want sex?	Yes…………………...……………………….1 No…………………………………………………2 Refused to answer………………………………3	If no, go to section H
H4.	How often did it occur?	Rarely……………………………………………….1 Sometimes……………………………………………..2 Frequently……………………………………………..3 Constantly……………………………………………..4	

Section I: Savings

In this section, we are going to ask you some questions about the loans and savings in the household and your financial literacy.			
I1.	Do you access to any loan last year, such as bank?	Yes…………………………………………..1 No……………………………………………2	If no go to I3
I2.	How much in total did your household borrow over the past year?	Rupees……………………………. ☐☐☐☐	
I3.	How much in total did your household save over the past year?	Rupees……………………………. ☐☐☐☐	
I4.	Do you have a personal bank account?	Yes…………………………………………..1 No……………………………………………2	
The following question is to test your financial literacy. Please provide the answer based on your calculation. If you don't know that, please say don't know.			
I5.	Suppose you need to borrow NRS1000. Two people offer you a loan One loan required you to pay back NRS 1200 in one month. The second loan requires you to pay back NRS 1000 plus 15% interest. Which loan represents a better deal for you?	Loan A……………………………………………1 Loan B……………………………………………2 The same…………………………………………3 Don't Know………………………………………99	

Section J: Risk Tolerance

Please refer to the separate sheet about "Introduction for interviewer about risk tolerance lottery game" about this section. Mark down the results of the game in the followings.			
J1.	Which choice does the respondent make?	Choice 1…………………………………………1 Choice 2…………………………………………2 Choice 3…………………………………………3	
J2.	How much does the respondent get?	Rupees……………………………. ☐☐☐	

Appendix D: Derivation of Payout

There are four key elements we take into account. The first one is the amount of payout. Following Ramasubramanian (2012) and Chantarat et al. (2013), we decided a 100% insured product. The amount of payout is calculated based on the revenue of paddy and the price of livestock. The information is obtained using multiple steps, taking rice as an example. First, we extracted the price of rice for the Sindhupalchock district from the community survey of NLSS 2010 (55 ruppees/kg). Second, the amount of paddy production per hectare in Sindhupalchock in 2009 (2643 kgs) and the production trend (110%) are obtained from a Nepalese report developed by the World Bank. Finally, the revenue of rice in 2014 was calculated by multiplying the unit price, production quantity, trend, and inflation rate.

The second element is the bids, which is created based on premium rate. As discussed by previous literature, the reasonable range varies from 1% to 12% (e.g.,). We finally decided premium rates of 1%, 2%, 3.5%, 5%, 7%, and 12%. The third element which should be taken into account is the cropping season. This piece of information was based on the information provided by the agricultural experts in Nepal.

The final element is cumulative rainfall levels, the criterion of making the payout. For the crop insurance available in Nepal, there is no criterion of drought or excessive rainfall to

The evaluation of failure is investigated by the local agriculture expertise on the basis of natural disasters, and done by communicating with farmers, which leads to a subject and inconvincible evaluation result. In order to overcome this drawback, we proposed a cumulative rainfall levels.

We proposed two types of description to the respondents. Considering the education background of the respondents, we started with a subjective description of heavy rainfall or no rainfall. Most papers design the policy based on the aggregate rainfall amount over two, three, or four consecutive days (the world bank, 2009). However, 4 consecutive days with heavy rainfall is common in Nepal. After discuss with the experts, we finally decide "heavy rainfall for 10 days or continuous no rainfall/little rainfall for 30 days". We also proposed an objective measure of the rainfall amount to the respondents, which is determined based on the optimal weather condition for paddy of about 120 mm of precipitation a month.

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