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Household Structure, Climate Change, and Livelihoods in southern Africa

by

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Dedicated to My Beloved Parents

Abstract

This thesis investigates three areas under the theme of household structure, climate change and livelihoods in southern Africa. The use of female-headship to identify vulnerable subgroups and to direct poverty-alleviation policies is a contentious issue in the literature. In the first paper of this thesis, we demonstrate the importance of heterogeneity in household structures for establishing clear links between female-headship and household income. Using data from Zimbabwe and South Africa we find that female-headed households, as a whole, do not have lower incomes than male-headed households. Income differentials across female-headed households are significantly related to the amount of male presence and its complementarity with children living in the households. After accounting for these sources of observed heterogeneity, we find significant unexplained heterogeneity across female-headed households.

Current empirical approaches that investigate the adoption of innovations in response to future climate change suffer several limitations due to their reliance on cross sectional data. In the second paper of this thesis, we overcome these limitations by using the contingent behavior method. Using a unique set of data collected in rural Eastern Cape in 2011, we examine how households would adopt different livelihood activities (i.e. gardening, livestock, natural resource harvesting, casual labor, small business and formal employment) in response to future climate change. Our results show that households increase the adoption of natural resource harvesting, casual labor, and small business in response to

increases in dry-spells, and gardening and livestock in response to increases in wet-spells.

In southern Africa, potential differences between men and women with respect to access to productive resources, division of labor and preferences in allocating household resources are likely to create gender differences in adoption of innovations. In the third paper of this thesis, we investigate the differences in the adoption of innovations in response to future climate change between men and women who live in different household headships. This study also uses the contingent behavior method and the data from rural Eastern Cape collected in 2011. We find that men and women who live in different household headship types are likely to adopt different innovations in response to future climate change.

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Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background and introduction to the three studies

This thesis contains three studies regarding livelihoods of rural households in southern Africa. My first study examines heterogeneity within households and its implications for policies that use female headship as a poverty indicator. Rural households in southern Africa live amidst economic and social conditions that affect both household income and the intra-household distribution of economic status between men and women. For instance, social norms influence the plight of women both within the household and outside in the community where the household is situated. Within the household, women are often bound by customs and face barriers to participation in income generating activities such as livestock production and formal and informal labor markets (Pant 2000; Agarwal 1989). Outside of the households, women have been documented to have less access to productive assets such as land and capital, and markets due to patriarchal systems of property rights and access regulations (Kevane and Gray, 2010; Lele, 1986).

These effects, such “internal” and “external” constraints, can be complex for female-headed households. For example a female-headed household may have more control over household resources without a male head but may face barriers in access to community resources without male head present. Welfare of the household, consequently, becomes dependent on household structure (the composition of the household in terms of its members and their age and gender profile) and how it interacts with the internal and external constraints that the household faces. Thus, the use of female-headship without accounting for household structure, as an indicator for targeting poverty programs can be misleading.

In this study, I examine the interacted effects of headship and household structure on household income. First, based on amount of adult male presence in a household, I disaggregate broad categories of headship into more specific sub-types. Second, I allow for potentially different effects of children on income to vary across different ages, gender and sub-types of household headships. Third, using random parameter models, I econometrically account for unobserved heterogeneity across households. My analysis is based on unique household survey data sets from Zimbabwe and South Africa.

My second study examines the economic responses used by households' to deal with climate change. In southern Africa, increased temperatures and uncertain precipitation patterns in many areas are reducing yields of primary crops and exposing farmers to new sources of risk and uncertainty (Lobell et al. 2008, Watts and Goodman 1997). These changes have large implications for households' food security, health, and the aggregate natural resource base of communities (Luseno 2003). According to the Intergovernmental Panel on Climate Change (IPCC), these climatic changes are likely to continue in the future. Temperature increases in southern Africa are expected to be greater than the global average, and rainfall will decline in certain areas (IPCC, 2007). Households that rely on rain-fed agriculture, pastoralism, and natural resources for their livelihoods are highly vulnerable to these future scenarios (Cooper et al. 2008).

Studies have documented that households can mitigate at least part of the adverse impacts of climate change through innovations to secure their food and to smooth income in the face of climatic shocks (e.g. Kandlinkar and Risbey 2000; Falco et al. 2011). The innovations that households adopt range from adjusting livelihood activities (e.g. doing less gardens and more livestock) to adoption of a variety of strategies within the choice of multiple livelihood activities (e.g. changing crops and/or livestock breeds).

Current empirical approaches that investigate adoption of innovations in response to climate change (e.g. using structural Ricardian models) generally use variability in weather across climate zones in cross sectional data as a proxy for the effects of climate change on households' economic behavior. Accordingly, these approaches are unable to capture the adoption responses to changes in specific climate variables that may not be reflected by varying weather across geographic spaces, but that vary over time. Further, the current approaches require data to be collected across large geographical areas and cannot account for the adoption of innovations that people may use in the long-run, but may not use currently.

In order to overcome these limitations, in my second study, I use a different approach based on the contingent behavior method. Using a unique set of data collected in rural Eastern Cape in 2011, South Africa, I examine how households would adopt different livelihood activities (e.g. gardening, livestock and small business) in response to future climate change. My interests in this study include finding the effects of capital stocks, innovative strategies, household demographics, and unobserved heterogeneity in adoption of future livelihood activates.

The third study, also using the contingent behavior method, tests the hypothesis that the adoption of innovations is gender specific. In this study, I consider innovation defined in more detail over households' contingent choices, encompassing technological changes (e.g. adoption of new crop varieties), adjustments in existing technologies (e.g. change in planting and harvesting dates), adjustments in household labor supply (e.g. increase in supplying labor in off-farm labor markets) and changes in household expenditure patterns (e.g. reducing personal consumption). Previous studies have attempted to incorporate gender dimensions into adoption models, by including the gender of the household head in empirical models (e.g. Hassan and Nhemachena 2008; Deressa et al. 2009) or the gender of the individual adopting as an explanatory variable (e.g. Swai et al. 2012). However, no study investigates the differences in the adoption of innovation between men and women who live in different headships. Using the household survey data collected in rural Eastern Cape in 2011, my third study aims to fill this gap.

The next three chapters of this thesis, respectively, present the three studies described above. The final chapter provides an overall conclusions and policy implications.

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Chapter 2: Heterogeneity of Household Structures and Income: Evidence from Zimbabwe and South Africa

2.1 Introduction

Female-headed households are frequently regarded by policy makers and donors as being more vulnerable to poverty than male-headed households. Moreover, if female heads cannot adequately invest in human capital, their impoverishment can be transmitted, inter-generationally, to their children (Chant 1997; Cheng 1999; Mehra et al. 2000). Because of their vulnerability, female-headed households are often the focus of poverty alleviation programmes (e.g. Buvinic and Gupta 1997; Japan Social Development Fund 2011). But the empirical link between female headship and poverty remains a contentious issue (Fuwa 2000; Chant 2003; Shaffer 1998). Some scholars have found evidence supporting the hypothesis that female-headed households are poorer than male-headed households (e.g. Buvinic and Gupta 1997) while others have not found a significant link (e.g. Appleton 1996; Quisumbing et al. 2001).

The ambiguity in the relationship between household headship and poverty has been attributed to the fact that headship is only one aspect of household structure (Handa 1994; Fuwa 2000). Within female and male-headed households, there is frequently considerable heterogeneity in terms of the gender and ages of other family members, which can potentially influence the productive capacity of a household. For example, a female head may be a widow, or may have a male spouse that migrated to an urban centre. Whether a male spouse is living, and the composition of men and women (and boys and girls) that remain resident in the household, can potentially influence the economic status of households.

In this paper we examine household structures and their implications for the earnings of households. Surprisingly, few studies have focused on income generation and heterogeneity in household structure. Studies typically account for heterogeneity by relying on broad categories of headship types (e.g. male vs. female-headed).[1] Our overall goal is to contribute to the poverty debate by considering three key sources of heterogeneity among household structures.

First, we account for heterogeneity among household headship types. These differences may imply distinctly different constraints, both outside and inside the household, for the use of productive resources. For example, female-headed households may face *external gendered constraints*, which originate from outside the household. Examples of such constraints include limited property rights that restrict a household's access to resources such as land and irrigation water (e.g. Kevane and Gray 1999; Lele 1986; Meinzen-Dick et al. 1997; Deininger et al. 2006) and limited employment opportunities in the formal wage sector (e.g. Fortin 2005; Brown and Haddad 1995; Fafchamps and Quisumbing 1999). These limitations may be alleviated by the presence of a male spouse, or other adult males in the household. Inside the household, there may be *internal gendered constraints.* For example, male spouses, or other adult males may

[1] See, for example, Shaffer (1998) and Horrell and Krishnan (2007). Notable exceptions that consider more nuanced considerations of household headship are Fuwa (2000) and Appleton (1996).

reinforce social norms by imposing restrictions that limit the participation of women in some income generating activities, including their engagement in local activities such as livestock production, and in formal and informal labor markets (Pant 2000; Agarwal 1989). Conversely, in the absence of a male spouse, female heads may be less constrained in seeking off-farm work (Institute of Development Studies 2001). In order to address this type of heterogeneity, we create a scale for differentiating household headship types. We rank the households in our sample on the basis of the degree to which there is adult male presence. We assume that this classification is correlated with the differing internal and external gender constraints that households face with varying headship types, but these constraints are unobserved in our data.

Second, we consider heterogeneity in the productive roles played by children in households with differing headship types. The role of children in income generation is well documented and the child labor literature has identified linkages between adult and child labor. For example, in some economies, children and women are found to be substitute sources of labor, while children and men are found to be complements in production (Grant and Hamermesh 1981). But such investigations have not explored whether and how the productive role of children may vary among household headship types. By extending the child labor literature, we account for differences in income among households with varying headship types, as influenced by the gender and age of resident children.

Third, in addition to the observed sources of heterogeneity mentioned above, we also account for unobservable attributes of household headship types.

Unobserved household heterogeneity may arise from sources such as household social networks, risk aversion and credit constraints (Deb and Rosati 2004). While it is clear that these factors are widely prevalent in rural economies and important determinants of household income, previous studies of household headship have not explicitly accounted for such unobservables. If female-headed household unobservables are correlated with observed factors that determine household income, not accounting for the heterogeneity may partially lead to the conflicting results regarding the link between female headship and income observed in the previous literature.

We build an empirical model that allows us to econometrically test whether household income is significantly different along the heterogeneous scale of headship types. We also employ our model to investigate whether children (of different genders and ages) substitute or complement adult labor regarding income generation in households with varying headship types. Our econometric model also allows us to explicitly introduce unobserved heterogeneity through the use of random parameters.

We analyze data collected in two developing economies in Africa: Zimbabwe, and South Africa. Having two data sets allows us to compare our empirical results across two different types of economies. Particularly, the existence of social grants (i.e. pensions and child grants) in South Africa, which are absent in Zimbabwe, could cause relationships between variables to differ between these two countries. Both data sets have three distinguishing characteristics. First, our data sets allow us to disaggregate households into a number of household headship categories among which internal and external gendered constraints may vary. Second, the data sets contain measures of household level income on a quarterly basis, which allows us to control for seasonal variation in income. Finally, both data sets contain information that allows us to impute values, not only for cash income (e.g. from wages, social grants, and items that households sell), but also for subsistence income that is made up of items that households use for their own consumption. Subsistence income, in these types of economies, has been shown to make up important components of household livelihoods (e.g. Campbell et al. 2002).

The remainder of the paper is organized as follows. In section 2.2, we present our conceptual framework, where we develop an index of gendered constraints that categorizes household headships into different sub-types. Sections 2.3 and 2.4, respectively, describe our empirical approach and the data used in our analysis. In section 2.5, we present our empirical findings, and we conclude in section 2.6.

2.2 Conceptual Approach

To differentiate household headship types, we start with the assumption that an increasing amount of adult male presence in households decreases external gendered constraints and increases internal gendered constraints. We define the amount of adult male presence along two dimensions: 1) how often male adults are present (i.e. present, temporarily present, or not present); and 2) the type of male present (i.e. male spouse vs. other male adults). For the first dimension, we assume that adult male presence increases ordinally between the categories of none, temporary, and present. For the second dimension, we assume that a male spouse is associated with a greater amount of adult male presence than other male adults.

Figure 2.1 shows the six different types of household headships that are categorized according to the amount of adult male presence. The first category (a), with the highest adult male presence, is male-headed and has the male spouse and other male adults present. We assume that this type of household faces the lowest level of external gendered constraints and the highest level of internal gendered constraints. The sixth category (f), with no adult male presence, is female-headed without a male spouse and no other male adults are present. We assume that this type of household faces the highest level of external gendered constraints and the lowest level of internal gendered constraints. Between these two extremes of male presence are categories (b) through (e).

We use these headship categories to investigate relationships with household income. However, as shown in Figure 2.1, the external and internal gendered constraints are hypothesized to move in opposite directions among the ranked households. It could be possible to estimate the impact of external constraints if we were able to control for internal constraints by using a measure of female autonomy, such as the ones used in the bargaining literature (e.g. Agarwala and Lynch 2006; Hazarika2000; Chakraborty and De 2011). However, we do not have measures of female autonomy in our data set. Therefore, the net effect of headship type on income may be difficult to identify *a priori*, and is an empirical question to investigate using our data from South Africa and Zimbabwe.

The ambiguity associated with external and internal gender constraints, working in opposite directions, is potentially a key source underlying the conflicting empirical results in the literature on household headship type and poverty or income.

2.3 Empirical Approach

Our baseline econometric model is:

$$Y_{it} = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6t} + \beta_7 X_{7i} + \varepsilon_i, i = 1,\ldots,n, t = 1,\ldots,T \leq 4, \quad (2.1)$$

where Y_{it} denotes the household income of household *i* in time period *t*. Explanatory variables (*X*) denote our two groups of household structure variables (i.e. type of headship, X_{1i} and profile of children in the household, X_{2i}), and a number of different types of control variables that are commonly used in the literature: capital stocks, X_{3i} (e.g. Appleton 1996); environmental factors, X_{4i} (e.g. Rupasingha and Goetz 2007); ethnic characteristics, X_{5i} (e.g. Andersson et al. 2005); seasonality, X_{6t} (e.g. Khandker 2012); and household characteristics, X_{7i} (e.g. Canagarajah et al. 2001). We also explore interaction effects between headship types and child profiles. The β's denote a vector of the parameters to be estimated and ε is a vector of error terms of the model.

Despite the specific types of household headships (X_{1i}) used in our baseline specification (equation 2.1), households within each headship type could still be heterogeneous due to unobservable household-specific factors. For example, consider households that are female-headed with a male spouse who is temporarily present. The households within this category can be heterogeneous according to the frequency with which the male spouse visits the household, which may affect underlying gendered constraints, and thereby household income. Since we do not have information about the factors that could cause such heterogeneity, we econometrically account for their potential presence. To capture this additional type of heterogeneity we specify random coefficients on each headship variable. Unlike their fixed coefficient counterparts, random coefficient models allow the parameter of interest to vary across households.

The random parameters model is defined in terms of the density of the observed random parameters and the non-random or fixed parameters, of the model. Following Greene (2004), the random parameters model can be written as:

$$f\left(y_{it} \middle| x_{it}, v_i, \beta_i, \theta\right) = g\left(y_{it}, \beta_i' x_{it}, \theta\right), i = 1, \ldots, n, t = 1, \ldots, T \geq 1, \tag{2.2}$$

$$\beta_i = \beta + \Gamma v_i \tag{2.3}$$

Using simulated maximum likelihood methods, equation (2.2) was estimated separately for the Zimbabwe and South Africa data. The vector x_{it} contains the explanatory variables defined in equation (2.1), and y_{it} is household income. The random vector *v* introduces the distribution of the random parameters. The parameters can include a set of non-random parameters, θ. According to equation (2.3), β, and Γ define the random parameters. β is the vector of means of the random parameters, Γ is a diagonal matrix that contains the variances of the random parameters.

Other than the headship specific heterogeneity mentioned above, households can also be heterogeneous with respect to other unobservable attributes such as ability, motivation or collective efforts. These un-observables can make some households more likely than others to have a low (or high) income. In order to account for this type of unobserved heterogeneity, we allow household specific intercepts to have random parameters which effectively account for household level heterogeneity not associated with headship type.[2] Further, we expect that the effects of child profiles on income can vary with headship types due to unobserved heterogeneity related to children. In order to account for such effects, we specify random parameters on the child profile variables and their interactions with headship types.

An important econometric issue concerns the potential endogeneity of headship types with respect to household income. In the context of the two economies that we investigate, the endogeneity of headship types may result from the presence of migration and, in South Africa, social grants. Migration could cause a household to be female-headed, since the husband leaves and the wife takes the role of head. Similarly, social grants in South Africa may affect household structure (Klasen and Woolard 2005). For example, a young woman may decide to bear a child, and head a new household in order to be eligible for child care grants. Under both situations, headship may be endogenous.

We do not econometrically address the possible endogeneity of the headship types, because, as shown by Card (2001) solutions to endogeneity

[2] Fixed-effects panel data models are often used to control for unobserved heterogeneity. However, since some of our explanatory variables are time-invariant variables and fixed-effects models do not allow the estimation of time-invariant variables (e.g. Dougherty 2007), we are not able to use fixed effect models in our analysis. Instead, we adopt the random parameters model that allows household specific random intercepts, as explained above.

problems, such as instrumental variable estimation, cannot be used when the effects of the covariates are heterogeneous. Under such circumstances, the conceptual foundation of a random parameter model and an instrumental variable model are at odds with each other. This result occurs, when the effects of covariates are heterogeneous, the instruments are likely to be correlated with unobserved individual effects. Therefore, even if the instruments satisfy the conditions for the validity (i.e. instruments are correlated with the endogenous variables and uncorrelated with the unobservables in the outcome equation), they fail to identify causal effects.

However, the different time frames involved with earning income vs. migrating and forming households may alleviate the concerns about endogeneity. Migration and household formation are phenomena that occur infrequently and can therefore only be observed over long periods. Our study collects income data that spans a year. Therefore, over the period that we collect income data, we assume that migration and household formation are constant. In other words, migration and household formation decisions, and household production decisions are likely to be inter-temporally separate (Horrell and Krishnan 2007). Accordingly, we assume that migration and household formation are exogenous to household income. Nonetheless, potentially confounding effects of migration may arise from the inclusion of remittance income. In our measures of household income we exclude the income gained from remittances.[3]

[3] We also estimated models that include remittances in the dependent variable. The signs and significance of key variables of interest remained unchanged, so we do not present the results of those models in this paper. Further, in South Africa,

2.4 Data Collection

The Zimbabwean data that we use in this paper were collected in a comprehensive household income and expenditure survey undertaken by the Center for International Forestry Research (Campbell et al. 2002). The survey was carried out in two communal areas, Romwe and Mutangi, over a 15 month period during 1999-2000. These areas are situated in Chivi District of Masvingo Province in south-eastern Zimbabwe. Mutangi is considered to have a greater level of land degradation, lower rainfall, and less infrastructure than Romwe (Campbell et al 2002). Both areas are indicative of the biophysical and socio-economic conditions of large portions of the communal areas running from the north-west, down the central and eastern areas to the south of the Zimbabwe. Because of seasonal variability, data were collected quarterly. The Romwe area contained 417 households in 10 villages and the Mutangi area contained 453 households in 18 villages. A complete household list was compiled for the villages and a stratified random sample was taken with households selected from each of the villages in proportion to the total household number in a village. The target sample size was 125 households each from Romwe and Mutangi. Contact was made with 245 households in total, but because of enumerator problems in the third quarter in Mutangi, a number of cases had to be deleted from the final data compilation. Therefore, the sample used in this paper consists of 124

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there were a considerable number of households who had zero incomes after grant incomes were excluded from the total income. Since having zero income could limit the data available for our empirical models, we did not exclude the grant income from the total income.

households in Romwe and 75 households in Mutangi, with four quarters of panel data.

The South African data were collected in a similar household income and expenditure survey that we undertook during 2010 and 2011. The survey was carried out in two research areas of Eastern Cape Province; Lessyton and Willowvale. These two areas are situated in the former ‘homeland’ areas of the Transkei and Ciskei, where access to basic services remains far lower than the rest of the province. Both areas show high dependency on natural resources alongside multiple livelihood strategies. However, these sites also differ in a number of important respects. Lessyton is somewhat peri-urban, being located close to Queenstown, a town located in the middle of the Eastern Cape Province. Willowvale, on the other hand, is more rural and isolated from nearby towns due to poor condition of roads and infrequent public transportation. Each area is comprised of a number of villages. The households were randomly selected within the villages, stratified by the population size of each village. In this paper, we use two quarters of panel data, collected from 164 households in Lessyton and 150 households in Willowvale in the first quarter, and 159 households in Lessyton and 145 households in Willowvale in the second quarter.

The data collected were used to construct the variables needed to populate equation (2.1) for separate Zimbabwe and South Africa models. Table 2.1 defines the dependent and explanatory variables, and reports their expected signs. Measures of income (Y_{it}) are calculated from quantity and price data collected on a quarterly basis. In the Zimbabwean survey, respondent recall over a three month period was used to gather values for large items, including remittances, wages, dry-land crop production, and natural resource harvesting, while weekly recall was used on other smaller items, that are not easily remembered over such a long period, including garden production, and livestock production (e.g. milk, draft). In the South African survey, recall over three months was used on all items.

Income earned consists of subsistence and cash income. The cash income for a given item (e.g. maize) was calculated by valuing the quantity sold, at the average local price of the respective item.[4] Our data sets also have quarterly data on income received from wages and remittances, and in the case of South Africa, social grants, that were included in total cash income. Subsistence income was similarly valued. For each item (e.g. maize) consumed domestically, a value was imputed by multiplying the amount consumed times the average local price of the item. Total household income (Y_{it}) was calculated by aggregating cash and subsistence incomes over all sectors. However, the consumption needs of households that are in different headship types may vary due to differences in the size and composition of households (Buvinic and Gupta 1997). In general, female-headed households are considered to be smaller than male-headed households (Chant 2003; Appleton 1996). Further, consumption needs of households may also be affected by potential presence of scale economies (Dreze and Srinivasan 1997). Therefore, using a formula that is commonly used for poverty and welfare analysis in Africa, we adjust total household income for

[4] We used 5% trimmed means for prices that were collected base on local sales. A trimmed mean is the arithmetic mean calculated after the highest 5% and lowest 5% of cases have been eliminated.

varying household size and composition (adult equivalence) and the potential presence of economies of scale (e.g. May, Carter, and Posel 1995; Woolard and Klasen 2005).[5]

Our key interest in this paper is on relationships with household headship types (X_{1i}) and income. We use Zimbabwean data to create six dummy variables that represent all six types of household headships given in Figure 2.1. However, the South African data does not contain information to distinguish between households in which there are no male spouses and households in which male spouses are temporarily absent. Accordingly, we create only four dummy variables that correspond with categories (a), (c) and (d), and (f) in Figure 2.1. For both countries, the headship type with the no adult male presence in the household (i.e. Category "f" in Figure 2.1), is considered as the base category. In both surveys, data on household headship variables were collected only in the first quarter. Therefore we assume that these structures remain the same in the following quarters.

As mentioned earlier, external and internal gendered constraints are hypothesized to move in opposite directions among the ranked households. Therefore, the net effect of household type on income may be difficult to identify. Accordingly, although we expect that the income of household headships given

[5] The formula is as follows. Adult equivalent income = Household Income / (Adults + 0.5 Children)$^{0.9}$. In the results that follow, we conducted sensitivity analyses using alternative equivalent scales, and parameter values of economies of scales. The results were not sensitive to the choice of alternative scales.

above have different income levels relative to the base category, *a priori*, we do not have expected signs for the coefficients of the headship variables.

For children in the household (X_{2i}), we hypothesize that they may be substitutes or complements in productive work, or they may not actively participate as a part of the household labor force, depending on their gender, age and type of headship in their households. Further, we expect that substitution and complementary relationships of children of different ages and gender may also depend on the number of adults (either male or female) in a household. For example, the role of teen males in a household with two teen males and three adults may be different from the role of teen males of a household with two teen males and only one adult. In order to account for such complexities related to role the of children, we include four types of child dependency ratios (i.e. the ratio of the number of children to the number of adults): a teen male dependency ratio (aged 10-16 years); a young male dependency ratio (aged 5-9 years); a teen female dependency ratio (aged 10-16 years); and a young female dependency ratio (aged 5-9 years). Such child dependency ratios have been identified in previous studies as varying across headship types (e.g. Handa 1994; Meenakshi and Ray 2002). However, the previous studies do not investigate the impacts of child dependency ratios across headship types on livelihood measures such as income. In this paper, we interact all child dependency ratios with each headship type dummy (i.e. $X_{1i} * X_{2i}$) in order to identify how child dependency ratios may contribute differently to income, depending on the type of headship. We do not have expected signs for the coefficients of the child dependency ratios. Rather, based on empirical findings on child dependency ratios, we seek to develop profiles of relationships between the attributes of children and income across the different types of household headships. Our empirical approach allows us to estimate the reduced form relationship between child attributes and income, the nature of which will be dictated by underlying substitution and complementary relations of children with adults in household production.

There are a number of different types of capital stocks (X_{3i}) that could influence the generation of household income, including human, natural, physical and social capital.[6] For human capital, we use measures of both household aggregate and individual levels of education and skills, which were collected in the first quarter at both study sites. For aggregate levels, we use the number of the household members with primary and secondary education in Zimbabwe, and the number of skills present in households in South Africa. We expect these variables to have positive impacts on income as education and skills may increase choices available to households for income generation. With respect to individual measures of human capital, in Zimbabwe, we include dummy variables that indicate household heads with primary and secondary education, while household heads with no education is taken as the base category. For South Africa, we include years of education of household head as a continuous variable. We also investigate non-linear effects of education on income with a squared term. For

[6] Measures of financial capital (i.e. savings and debt) were small in the study areas, so were not included in our models. Though livestock is sometimes included in this category, we include these values as part of natural capital in our analysis.

measures that apply to specific members of the household, we do not have expected signs.

Regarding natural capital, for Zimbabwe we have data on areas of irrigated and non-irrigated farm-land, and three classes of farm animals (cattle, goats/sheep, and donkeys). For South Africa, we have areas of irrigated lands, and two classes of farm animals (cattle and goats/sheep).[7] Data on farm-lands were collected in each quarter at the Zimbabwean site and only in the first quarter at the South African site. Data on farm-animals were collected in each quarter at both study sites. We include farm-animals as stock variables and not as flow variables. Since the total income contains the cash and in-kind income from livestock, inclusion of farm animals that were sold and slaughtered may lead to an identity relationship between income and farm-animals. To avoid this issue, we use only the number of farm-animals that were available at the end of each quarter of data collection. Households with larger endowments of land may generally engage more in agricultural activities, producing food which they can sell or consume. Farm animals may be used for land preparation and draft purposes. Further, animal manure may increase soil fertility, thereby increasing agriculture production and productivity. Based on such possibilities, we expect households that are endowed with more natural capital to have higher income.

For physical capital we use data on the number of farm implements owned per household in Zimbabwe, and for South Africa we use a physical capital index generated by applying principal component analysis (appendix A). For social

[7] There is almost no dry-land farming done at the South Africa site.

capital in Zimbabwe, we generate a dummy variable that indicates whether the household has a membership in a social organization, holds a position in a social group, or both. From the South Africa data set, we use a social capital index, again generated by using principal component analysis (appendix A). Data that were used to construct physical and social capital variables were collected only in the first quarter at both study sites. Physical and social capitals are expected to facilitate the pursuing of income generating activities amongst household members and hence, we expect lager physical and social capital stocks to be associated with higher levels of income.

In both data sets, we control for environmental factors (X_{4i}) by using a dummy variable that indicate location of the data collection (i.e. Romwe vs. Mutangi in Zimbabwe and Lessyton vs. Willowvale in South Africa). In addition, in the Zimbabwean data set, we generate a dummy variable that indicates whether a given household belongs to the Shona or Ndebele ethnic group (X_{5i}). In the case of South African data, all households belong to the Xhosa tribe. Given that data was collected over time, we control for the season of data collection (X_{6t}). We also have a number of household characteristics (X_{7i}) in both data sets, including age of household head, number of children below 5 years of age, number of adults above 65 years of age, ratio of adult males to total adults and household size. We also include age of household head squared to capture the potential non-linear effect of age on income. We expect that, age of the household head will positively affect income initially, since older ages may represent households with greater experience and productivity, but that such effects may dwindle at further older ages. Since the dependents are unlikely to participate in productive activities, we expect households with more dependents to have lower incomes. We do not have an expectation on the effect of ratio of adult males to total adults on income. Based on the empirical literature (for example, Fuwa 2000; and Appleton 1996), we expect larger households to have lower income per adult equivalence. The South African data also has information on whether a chronically ill person resides in the household, which we expect will lower income. Furthermore, in the South African data set, we generate dummy variables to indicate whether a household contains one of three types of individuals that makes it potentially eligible to receive social grants: 1) a male 65 years or older; 2) a female 60 years or older; or 3) a child 15 years or younger. We do not have expected signs for grant eligibility variables.

2.5 Results

The models are based on 792 and 617 observations, respectively, for Zimbabwe and South Africa. The results are given in Table 2.2 and 2.5 for Zimbabwe and South Africa respectively. Overall, the models performed quite well. Likelihood ratios tests confirmed that the overall models are statistically significant. Most of the regression coefficients were statistically significant and have signs that are intuitively appealing. The random parameters on headship variables indicate that effects of household headship on income can vary even within the households of a specific headship type. The mean effects of headship variables appear in the top panel in both Tables. Following the discussion on the relationship between headship and income, we use these household types as reference points to measure how household income changes with the addition of children. We first discuss the results of the random parameter model applied to the Zimbabwean data, and then turn to South African results.

2.5.1 Zimbabwe

The estimated coefficient on each headship variable (Table 2.2, Rows 1-6) refers to the income differential between a headship type and the base category, all else held constant. The base category represents households that have no adult males in the household. Since we include four child category variables and their interactions with headship types in our models, the estimated coefficients on each headship variable, including the base category, apply only to households that have no adult children. The statistically significant and positive headship coefficients (in four of the five headship types) suggest that household income is increasing with household adult male presence, holding household size and other factors constant.

We use the estimated coefficients in Table 2.2 to further examine the nature of the relationship between household income and adult male presence, with particular attention to whether or not the relationship is nonlinear. That is, do constraints on access to resources bear down upon women in a way that having more adult male presence causes a monotonic increase in income? Are there productivity differences among genders in the tasks they perform which reinforce or offset the aforementioned effect? Our objective is not to separate out these two effects, rather we seek to identify the reduced form pattern of the relationship. We expect the pattern to be dictated by both the effects of productivity differences among men and women, and by discrimination against women when they try to appropriate returns to different tasks without the help of men.

To this end we graph the coefficients (i.e. income differentials) reported in Table 2.2 against different levels of adult male presence (i.e. headship types). Figure 2.2 reveals that a marginal increase in the amount of adult male presence, relative to no adult male presence, yields no significant effect on income until the amount of adult male presence reaches a critical threshold in the third category. As adult male presence increases beyond the third category, the external gendered constraints seem to be relaxed by the presence of other male adults, and the positive effects of having lower internal constraints appear to result in a dramatic rise in income (by approximately 130 % relative to the income of our reference households). At this threshold point, it appears as though male presence is overcoming the external gendered constraints. However, with further increases in adult male presence, internal constraints seem to increase, thereby deteriorating the positive effects of having lower external constraints, as reflected by diminishing returns to income at higher levels of adult male presence.[8] The distinct and significant relationship in Figure 2.2 demonstrates that returns to income generating activities are conditioned on the amount of adult male presence in a household. This result, in turn, suggests that the economic constraints, or alternatively productivity differences, facing women in Zimbabwe are likely causing large gender gaps in equality of opportunity.

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[8] We empirically tested the null hypothesis that all four statistically significant coefficients of headship variables are simultaneously no different from each other, and rejected the null hypothesis at 5 percent level of significance.

We now turn to the relationship between child dependency ratios and household income in each type of household. As mentioned in section 2.4, we consider four types of child dependency ratios: teen male, teen female, young male and young female. Note that in Table 2.2, the estimated coefficient on a particular child dependency ratio, say for example teen male, represents the income differential that our reference households would face if the teen male dependency ratio increases from zero to one. Similarly, the estimated coefficient on the teen male ratio when interacted with a specific headship type represents the income differential that the headship type would experience when the teen male dependency ratio increases from zero to one.

In Table 2.2, three of the four child dependency ratios (i.e. except the teen female dependency ratio) are statistically significant, indicating that these ratios play a significant role in income determination of poor households with no adult male presence (Table 2.2, Rows 7-10). Although significant, not all of these three contributions are positive. While the teen male and young female dependency ratios have positive effects on income, the young male dependency ratio has a negative effect. Interestingly, these effects vary by headship type, as indicated by the coefficients on the interaction terms between the child dependency ratios and headship types (Rows11-30). Taken together, these results suggest that heterogeneous types of child dependency ratios within homogeneously defined headship types can create significant differences in household income, a finding that reinforces our hypotheses regarding the heterogeneity of female-headed households.

Recall that, as mentioned above, the coefficient of any child dependency ratio variable represents a change in income with respect to one unit of change in the particular child dependency ratio. However, these coefficients can be difficult to interpret. Therefore, in order to have a unit free measure of child dependency ratios, we calculate the elasticity for each child dependency ratio at the mean of the respective child dependency ratio (Table 2.3). Elasticities allow us to quantify the percentage change in income with respect to one percent change in a particular dependency ratio. Using these elasticities, we seek to establish how the economic role of children evolves as household adult male presence changes.

In Figure 2.3, we plot the elasticity of the teen male dependency ratio corresponding to each headship type. Figure 2.3 shows that, in response to a 1% increase of the teen male dependency ratio, income of our reference households increases by 1.25% (Figure 2.3, Category 1). From this evidence it seems that male teenagers substitute for missing male adults and offset some of the productivity and/or discrimination based disadvantages faced by female-headed households. However, with an increase in adult male presence, the teen male dependency ratio has a negative effect on income (Figure 2.3, Category 2). With further increases in adult male presence, the teen male dependency ratio continues to have negative effects, although the magnitudes of the effects become smaller at the higher levels of adult male presence. The negative effects of the teen male dependency ratio on income seems to indicate that, in households with male adults, the effort of teen male children may not complement the income generating efforts of adults.

The effects of the dependency ratios related to young male and female children (Figure 2.4) are different from the effects of the teen male dependency ratio discussed above. In our reference households (i.e. households that have no adult males in the household), the young male dependency ratio has a negative effect on income (Figure 2.4, Category 1). Increasing the young male dependency ratio by one percent in the reference households decreases income by about 0.43%. This finding suggests that, in contrast to teen males (i.e. in Figure 2.3), young males may not substitute for missing male adults. With a small increase in adult male presence, however, an increase in the young male dependency ratio causes a large positive effect on income (Figure 2.4, Category 2). This large gain deteriorates starting with the third category, similar to results in Figure 2.2. In contrast to the young male dependency ratio, the young female dependency ratio has a positive effect on income in households that have no adult males in the household, suggesting that efforts of young females could be complementary to adult females in income generating (Figure 2.4, Category 2). But with increasing adult male presence, the positive effect of the young female dependency ratio disappears, and becomes slightly negative for the third, fourth and sixth headship categories.

In addition to headship types and child dependency ratios, most of our control variables were also statistically significant and have expected signs (Table 2.2, Rows 31-53). Human capital, measured by the level of education of the household head, has a positive impact on income. Specifically, income of households where the household head has primary education is approximately

15% higher than for households where the head has no formal education. However, secondary or higher levels of education have no significant effects. Likewise, neither the number of household members with primary education per capita, nor the number of household members with secondary education per capita has significant effects on income. This finding implies that Zimbabwe lacked opportunities for higher educated people in these rural areas.

Our results show that the effect of land on income depends on the type of land. Amounts of garden land (that are highly productive because of water) have a strong positive effect on income, while the extent of dry land in Zimbabwe has no significant effect on income. With respect to the effects of farm animals, we found that the number of cattle and donkeys owned by the household have positive effects on income, while numbers of goats has no significance. Moreover, physical capital endowments have a positive effect on income. Ethnicity of the household does not have a significant impact on income, but we do find that income differs significantly by season and location. Considering other demographic variables, dependency ratios relating to the children aged below 5 years and the adults aged above 65 years have negative and significant effects on income. Further, age of the household head shows a non-linear effect on income.

The standard deviation of random parameters of a specific headship type shows the deviation of the income differential between the particular headship type and the base category, from the mean income differential (Table 2.4). The standard deviations are statistically significant for most headship types, meaning that, due to unobserved heterogeneity, the effect of headship on income may vary significantly across the households within these headship types. Further, statistical significance of the random parameters on the intercept may indicate the presence of unobserved heterogeneity that is specific to our reference households; and/or heterogeneity due to other unobservable attributes that are not specific to any particular headship type such as ability, motivation or collective efforts. Similarly, the statistically significant standard deviations of the random parameters of some child dependency ratios confirm that effects of those dependency ratios on income can vary even within the households of a specific headship type.

2.5.2 South Africa

As in the case of Zimbabwe, the estimated coefficient on each headship variable (Table 2.5, Rows 1-4) refers to the income differential between a headship type and the base category (households that have no adult males in the household), all else held constant. Like the Zimbabwean case, coefficients of each headship type, including the base category, apply to the households that do not have adult children. The estimated coefficients of household headship types are statistically significant and positive for two of the three household headship types included in the model, meaning that that income is increasing with household adult male presence, holding household size and other factors constant. In Figure 2.5, we graph the coefficients of income differentials reported in Table 2.5 against different levels of adult male presence (headship types). Figure 2.5 show a similar pattern to the corresponding figure for Zimbabwe. Specifically, a marginal increase of adult male presence, relative to no adult male presence, does not have a significant effect on income, until the level of adult male presence reaches a threshold in the third category. Beyond this threshold, an increase of adult male presence is associated with diminishing returns, again, perhaps because internal gendered constraints are increasing.

With respect to the effects between child dependency ratios and income, as shown in Table 2.5, only the teen male and young female dependency ratios are statistically significant. Further, the effect of the teen male dependency ratio and income varies by headship type, as indicated by the signs and the significance of the coefficients on the interaction terms between the teen male dependency ratio and headship types (Rows 9-11). Again, in order to interpret these effects, we calculate the elasticity of teen male dependency ratio corresponding to each headship type (Table 2.3), and plot the values in Figure 2.6. In the figure, a one percent increase in the teen male dependency ratio is associated with 0.1% increase in income of the households that have no adult males in the household (Figure 2.6, Category 1). This finding supports the evidence we obtained for Zimbabwe; that male teenagers may substitute for missing male adults and offset some of the productivity and/or discrimination based disadvantages faced by female-headed households. With an increase in adult male presence, the teen male dependency ratio is associated with a drop in income (Figure 2.6, Category 2). However, with further increases in adult male presence, the teen male dependency ratio shows no relationship with income. The young female dependency ratio has a positive effect on income in female-headed households that have adult males, suggesting that efforts of young females could be complementary to adult males or females in income generating (Figure 2.6, Category 2).

Our South African results also highlight some important effects between income and the other control variables such as capital stocks. Human capital shows non-linear effects on income (Table 2.5, Rows 21-22). When all other factors that affect income are held constant, income decreases with increasing years of education of households head up to a certain level, but eventually increases. In addition to effects of education, we also find that the endowment of skills has a positive effect on income. Regarding natural capital, our result shows that endowments of cattle and goats/sheep have positive effects on income while land endowments are not significant. Social capital has a positive effect on income. Regarding, the proxy variables that we included to capture social grant eligibility, presence of a female aged 60 years or above has a positive effect on income, but the presence of a male aged 65 years or above, and the presence of child aged 15 years or below, are not significant. In addition, we found a negative effect of household size on income. We do not find evidence for seasonal and location differences in household income. Statistical significant standard deviations of random parameters of headship variables (including the intercept) and some child dependency ratios confirmed the presence of unobserved heterogeneity in the respective variables (Table 2.4). Therefore the relationships between income and headship type, and income and child dependency ratios on income could vary even within households of a specific headship type.

2.5.3 Comparisons between Zimbabwe and South Africa

Our results show some similarities and differences between the two economies that we studied. In both economies, household income increases with increasing adult male presence, although there is some evidence of diminishing returns to additional adult male presence. Further, the households that are without adult male presence have less income than the ones with permanently present male spouses. However, these income differentials are much lower in South Africa. For example, households that are without adult male presence have 51% and 107% less income than the households with a permanently present male spouse and without other adult males in South Africa and Zimbabwe, respectively. A possible reason is that the existence of social grants in South Africa may decrease income inequality among different household headship types.

Our results also show that, in both economies, the teen male dependency ratio affects positively on household income in the households without adult male presence. Moreover, in Zimbabwe, the young female dependency ratio in the households without adult male presence, and the young male dependency ratio in several headship types have positive effects on income. Again, differences between these two economies could explain these differential results. The rural Zimbabwean economy is characterized by income generated by labor intensive activities, where agriculture natural resource activities dominate household income portfolios comprising about 60% of average household income (Campbell et al. 2002). Under such circumstances, child labor clearly emerges as either a substitute or a complement to income generating effort of adults. On the other hand, income in the rural South African economy is dominated by social grants that constitute about 57% of household income portfolios. In contrast, agriculture only comprises 8%. Therefore, the relationship between labor and income is less pronounced in such situations.

We also find that, in both economies, income could vary even with the households of a specific headship type (Table 2.4). Income varies within the households that are without a male spouse and with other adult males, and the households that are with a male spouse and without other adult males. However, only in Zimbabwe does the income vary within households that are in the base category (households that are without adult male presence). Further, in both economies, we do not find statistical evidence for varying household income within the households that have male spouses and other adult males.

2.6 Conclusions

In this study we use two distinct data sets to empirically investigate the relationship between household headship and income. Unlike existing studies, which generally only distinguish between male and female-headed households, we disaggregate household headship into more subtle headship types based on our index of male presence and associated gendered constraints. Using dummy variables for different categories of children and their interactions with headship types, we control for the heterogeneity in the roles that children may undertake in these different headship types. Further, using random parameters models, we econometrically account for unobserved heterogeneity in the average impacts of different household headship categories on income.

Our econometric models yield strong empirical evidence regarding the nature of the relationship between household headship and income. Specifically, a marginal increase in the amount of adult male presence, relative to no adult male presence, does not have significant effects on income until the amount of adult male presence reaches a critical threshold, where an adult male resides in the household. Beyond this threshold, household income increases, although there is some evidence of diminishing returns at higher levels. Such findings were robust between the two economies we studied. However, we do find significant differences in the role of children between the two study sites, with Zimbabwean children playing more significant complementary and substitute roles in income generation than in South Africa, where social grants dominate income portfolios.

Based on the empirical results, our study has four primary contributions. First, our findings shed light on the debate regarding income levels of female-headed vs. male-headed households. Based on the empirical evidence from Zimbabwe, we find that female-headed households, as a whole, do not have lower incomes than male-headed households. Instead, only some subgroups of female-headed households, which have low amounts of adult male presence, have lower income levels. Specifically, our results show that female-headed households without a male spouse and without male adults (the base category) have lower income than most other household types, once household size and other characteristics are controlled for. However, female-headed households without a male spouse, but with other male adults possessed the highest incomes. Moreover, income levels of households where the male spouse is away and where there are no other male adults, had income levels that were no different from households in the base category. Based on these results, we argue that the use of male versus female household headship as a vulnerability indicator could mask important gender dimensions in the empirical relationships between household structures and income. In other words, our results suggest that finer divisions of headship types are needed to identify vulnerable households. Moreover, the above results suggest that the use of female headship to represent vulnerable groups may cause misallocations of aid resources.

Our second contribution expands the first one. That is, our empirical findings at both study sites about the relationship between household headship and income explain the possible impacts of gendered constraints and household income. As mentioned earlier, our results show a positive effect of a resident adult male on income. An increase in adult male presence implies a decrease in external gendered constraints and an increase in internal gendered constraints. As these two types of constraints move in opposite directions, the persistent positive effect of adult male presence on income suggests that positive effects of low levels of external gendered constraints are greater than the negative effects of increasing levels of internal gendered constraints. Although the positive income effects of low levels of external gendered constraints is gradually deteriorated with increasing male presence and the accompanying increase in internal gendered constraints, the net effect remains positive, and statistically significant.

The third contribution of the paper is related to the second specific objective of the study. Our findings on the relationships between child dependency ratios and household income convey important information for policy makers working on subsistence economies. Our results suggest that the role of children on household productive activities depends on the age of the child, its gender and the type of headship. One of the most striking findings is the differential role of children in the households that have no adult males in the household. In such households, teen male children are likely to substitute the missing male adults and can therefore be treated as livelihood assets that help poor households to confront gendered constraints and/or productivity differences. As opposed to their male counterparts, teen female children do not appear to contribute in the income generating effort of adults in households that have no adult males in the household. This finding was common to the both economies we studied. Further, the empirical evidence from Zimbabwe suggests that the efforts of young male children may be complementary to the effort of adult males, while young females could be complementary to adult females in the households that have no adult males in the household.

Our final contribution is related to our third specific objective. Unlike previous studies, in this paper we econometrically control for household-level unobserved heterogeneity. Therefore, we are able to quantify, not only the average effects of household headship on income, but also the deviations of the effects across households. Statistically significant deviations of the random parameters of most household headship suggest that, due to unobserved heterogeneity, the effect of headship on income may vary significantly even within the households of a specific headship type. Therefore, neglecting unobserved heterogeneity may have to ambiguous empirical results in the literature with respect to the effects of headship type on income.

Table 2.1: Variable definitions and expected signs

Variable	Definition (Zimbabwe)	Definition (South Africa)	Predicted Signs
Dependent Variable, Income (Y)	Gross subsistence and cash income per adult equivalent	Same as for Zimbabwe	NA
Headship types (X_1)			
No male spouse - no male adults	1= No male spouse, no male adults, 0 = otherwise (base category)	Same as for Zimbabwe	+ [a]
Male spouse away - no male adults	1= Male spouse away, no male adults, 0 = otherwise	NA	+/-
No male spouse - male adults present	1= No male Spouse, male adults present, 0 = otherwise	Same as for Zimbabwe	+/-
Male spouse present - no male adults	1= Male spouse present, no male adults, 0 = otherwise	Same as for Zimbabwe	+/-
Male spouse away - male adults present	1= Male spouse away, male adults present, 0 = otherwise	NA	+/-
Male spouse and male adults present	1= Male spouse and male adults present, 0 = otherwise	Same as for Zimbabwe	+/-
Child variables (X_2)			
Teen males dependency ratio	Number of male children aged 10 -16 years per adults	Same as for Zimbabwe	+/-
Teen females dependency ratio	Number of female children aged 10-16 years per adults	Same as for Zimbabwe	+/-
Young males dependency ratio	Number of male children aged 5 - 9 years per adults	Same as for Zimbabwe	+/-
Young females dependency ratio	Number of female children aged 5 - 9 years per adults	Same as for Zimbabwe	+/-
Capital stocks (X_3)			
Human capital			
Household head with no education	1= household head has no formal education, 0 = otherwise (base category)	NA	NA
Household head with primary education	1 = household head has primary education, 0 = otherwise	NA	+/-
Household head with Secondary education	1 = household head has secondary education, 0 = otherwise	NA	+/-
Household members with primary education	Number of household members with primary education per capita	NA	+

Table 2.1 (continued)

Variable	Definition (Zimbabwe)	Definition (South Africa)	Predicted Signs
Household members with secondary education	Number of household members with secondary education per capita	NA	+
Household head years of education	NA	Years of education of household head	+/-
Household head years of education squared	NA	Years of education of household head squared	+/-
Number of Skills	NA	Number of skills available to the household	+
Natural capital			
Number of cattle	Number of cattle per capita	Same as for Zimbabwe	+
Number of goats and sheep	Number of goats and sheep per capita	Same as for Zimbabwe	+
Number of Donkeys	Number of donkeys per capita	NA	NA
Area of non-irrigated farm-land planted	Dry-land area planted (acres) per capita	NA	NA
Area of irrigated farm-land	Garden area planted (acres) per capita	Size of the garden plot(acres) per capita	+
Physical capital			
Physical capital index[b]	Number of farm implements per capita	PCA indicator for physical capital	+
Social capital			
Social capital index[c]	1 = has a membership or a position in a social organization, 0 = otherwise	PCA indicator for social capital	+
Environmental factors (X_4)			
Location	1 = Romwe, 0 = Mutangi	1 = Lessyton, 0 = Willowvale	+/-
Ethnic characteristics (X_5)			
Shona	1= Shona, 0 = otherwise(base category)	NA	NA
Ndebele	1= Ndebele, 0 = otherwise	NA	+/-
Missing data	1 = missing data for ethnic group, 0 = otherwise	NA	+/-

Table 2.1 (continued)

Variable	Definition (Zimbabwe)	Definition (South Africa)	Predicted Signs
Seasonality (*X_6*)			
Season 1	1 = March - May, 1999, 0 = otherwise	1= January - February, 2011, 0 = otherwise(base category)	+/-, NA
Season 2	1 = June - August, 1999, 0 = otherwise	1= June - July 2011, 0 = otherwise	+/-
Season 3	1 = September - November, 1999, 0 = otherwise	NA	+/-
Season 4	1 = December, 1999 - February, 2000, 0 = otherwise (base category)	NA	NA
Household characteristics (*X_7*)			
Age of household head	Age of household head	Same as for Zimbabwe	+
Age of household head squared	Age of household head squared	Same as for Zimbabwe	-
Children below 5	Number of children aged below 5 years per adults	Same as for Zimbabwe	-
Adults above 65	Number of adults aged above 65 per adults	Same as for Zimbabwe	-
Ratio of adult males	Number of adult males per total adults	Same as for Zimbabwe	+/-
Size of household	Number of household members	Same as for Zimbabwe	-
Chronically ill	NA	1= if a chronically ill person is present, 0 = otherwise	-
Child grant	NA	1= if a child aged 15 years or below is present, 0 = otherwise	+/-
Male above 65	NA	1= if a male 65 aged years or above is present, 0 = otherwise	+/-
Female above 65	NA	1= if a female aged 60 years or above is present, 0 = otherwise	+/-

Table 2.2: Random parameters model estimation for Zimbabwe: Dependent variable is income per adult equivalence expressed in logs

Row Number	Variable	Coefficient
Headship Types (X_1)		
1	No male spouse - no male adults (base category)	5.734*** (0.450)
2	Male spouse away - no male adults	1.449 (1.327)
3	No male spouse - male adults present	1.317*** (0.348)
4	Male spouse present - no male adults	1.173*** (0.325)
5	Male spouse away - male adults present	0.849** (0.348)
6	Male spouse and male adults present	1.074*** (0.343)
Child Variables (X_2)		
7	Teen males dependency ratio	1.771*** (0.366)
8	Teen females dependency ratio	0.107 (0.147)
9	Young males dependency ratio	-3.585*** (0.979)
10	Young females dependency ratio	1.222** (0.602)
Child Variable Interactions with Headship Types ($X_2 * X_1$)		
11	Teen males dependency ratio* row 2	-2.504*** (0.949)
12	Teen males dependency ratio* row 3	-2.883*** (0.461)
13	Teen males dependency ratio* row 4	-1.321*** (0.372)
14	Teen males dependency ratio* row 5	-1.554*** (0.396)
15	Teen males dependency ratio* row 6	-1.538*** (0.390)
16	Teen females dependency ratio* row 2	-0.253 (0.305)
17	Teen females dependency ratio* row 3	-0.331 (0.318)
18	Teen females dependency ratio* row 4	0.112 (0.165)
19	Teen females dependency ratio* row 5	-0.010 (0.219)

Table 2.2 (continued)

Row Number	Variable	Coefficient
20	Teen females dependency ratio* row 6	0.273 (0.210)
21	Young males dependency ratio* row 2	3.921*** (1.069)
22	Young males dependency ratio* row 3	3.385*** (1.089)
23	Young males dependency ratio* row 4	3.343*** (0.986)
24	Young males dependency ratio* row 5	3.549*** (1.008)
25	Young males dependency ratio* row 6	3.535*** (1.014)
26	Young females dependency ratio* row 2	-1.087 (1.200)
27	Young females dependency ratio* row 3	-1.113* (0.668)
28	Young females dependency ratio* row 4	-1.353** (0.610)
29	Young females dependency ratio* row 5	-0.975 (0.685)
30	Young females dependency ratio*row 6	-1.387** (0.637)
Capital stocks (*X_3*)		
	Human capital	
31	Household head with primary education	0.143*** (0.055)
32	Household head with Secondary education	0.010 (0.085)
33	Household members with primary education	-0.145 (0.137)
34	Household members with secondary education	-0.121 (0.096)
Natural capital		
35	Number of cattle	0.344*** (0.033)
36	Number of goats and sheep	-0.001 (0.027)
37	Number of Donkeys	0.242*** (0.067)
38	Area of non-irrigated farm-land planted	0.078 (0.056)
39	Area of irrigated farm-land	1.700*** (0.458)

Table 2.2 (continued)

Row Number	Variable	Coefficient
Physical capital		
40	Physical capital index	0.306*** (0.033)
	Social capital	
41	Social capital index	0.018 (0.043)
Environmental factors (X_4)		
42	Location	0.113** (0.049)
Ethnic characteristics (X_5)		
43	Ndebele	-0.011 (0.095)
44	Missing data	-0.087 (0.140)
Seasonality (X_6)		
45	Season 1	0.754*** (0.055)
46	Season 2	-0.289*** (0.053)
47	Season 3	-0.700*** (0.048)
Household characteristics (X_7)		
48	Age of household head	-0.028*** (0.010)
49	Age of household head squared	0.000** (0.000)
50	Children below 5	-0.402*** (0.067)
51	Adults above 65	-0.231* (0.140)
52	Ratio of adult males	0.057 (0.176)
53	Size of household	0.002 (0.012)
54	Sample Size:	792
55	R-Square:	0.43

Note. 1) Single asterisk (*) indicates significance at the 10% level, double asterisk (**) indicates significance at the 5% level and triple asterisk (***) indicates significance at the 1% level; 2) Standard errors are reported in parentheses; 3) Since random parameters model do not report R-square values, we report R-square values of the models estimated by OLS.

Table 2.3: The elasticities of child dependency ratios across different headship types

		Zimbabwe			South Africa	
Row Number	**Headship Type (X_1)**	**Teen Males**	**Young Males**	**Young Females**	**Teen Males**	**Young Females**
1	No male spouse - no male adults (base category)	1.26	-0.43	0.35	0.10	NA
2	Male spouse away - no male adults	-1.75	2.35	NA	NA	NA
3	No male spouse - male adults present	-0.52	0.41	-0.18	0.12	0.43
4	Male spouse present - no male adults	-0.48	0.67	-0.19	NA	NA
5	Male spouse away - male adults present	-0.62	0.57	0.00	NA	NA
6	Male spouse and male adults present	-0.38	0.32	-0.14	NA	NA

Note. Elasticities are calculated for the statistically significant effects of child dependency ratios only.

Table 2.4: Standard deviations of the random parameters

Row Number	Variable	Zimbabwe	South Africa
Headship Types (X_1)			
1	No male spouse - no male adults (base category)	0.538*** (0.017)	0.035 (0.028)
2	Male spouse away - no male adults	0.020 (0.118)	NA
3	No male spouse - male adults present	0.201*** (0.059)	0.274*** (0.042)
4	Male spouse present - no male adults	0.343*** (0.025)	0.370*** (0.054)
5	Male spouse away - male adults present	0.380*** (0.049)	NA
6	Male spouse and male adults present	0.014 (0.035)	0.001 (0.061)
Child Variables (X_2)			
7	Teen males dependency ratio	0.113*** (0.035)	0.040 (0.096)
8	Teen females dependency ratio	0.001 (0.032)	0.025 (0.133)
9	Young males dependency ratio	0.063 (0.054)	0.063 (0.148)
10	Young females dependency ratio	0.061 (0.069)	0.494*** (0.093)
Child Variable Interactions with Headship Types ($X_{2*}X_1$)			
11	Teen males dependency ratio* row 2	0.114 (0.145)	NA
12	Teen males dependency ratio* row 3	0.753*** (0.161)	1.135*** (0.163)
13	Teen males dependency ratio* row 4	0.048 (0.050)	0.012 (0.273)
14	Teen males dependency ratio* row 5	0.041 (0.094)	NA
15	Teen males dependency ratio* row 6	0.056 (0.094)	0.004 (0.296)
16	Teen females dependency ratio* row 2	0.120* (0.069)	NA
17	Teen females dependency ratio* row 3	0.335** (0.166)	0.001 (0.272)
18	Teen females dependency ratio* row 4	0.142*** (0.052)	0.466** (0.180)
19	Teen females dependency ratio* row 5	0.102 (0.092)	NA

Table 2.4 (continued)

Row Number	Variable	Zimbabwe	South Africa
20	Teen females dependency ratio* row 6	0.025 (0.091)	0.031 (0.486)
21	Young males dependency ratio* row 2	0.393** (0.173)	NA
22	Young males dependency ratio* row 3	0.810*** (0.278)	0.011 (0.246)
23	Young males dependency ratio* row 4	0.159** (0.069)	0.012 (0.276)
24	Young males dependency ratio* row 5	0.153 (0.163)	NA
25	Young males dependency ratio* row 6	0.010 (0.210)	0.047 (0.565)
26	Young females dependency ratio* row 2	0.276 (0.390)	NA
27	Young females dependency ratio* row 3	0.166 (0.218)	0.213 (0.327)
28	Young females dependency ratio* row 4	0.651*** (0.097)	0.042 (0.203)
29	Young females dependency ratio* row 5	0.044 (0.238)	NA
30	Young females dependency ratio*row 6	0.289* (0.168)	0.255 (0.364)

Note. 1) Single asterisk (*) indicates significance at the 10% level, double asterisk (**) indicates significance at the 5% level and triple asterisk (***) indicates significance at the 1% level; 2) Standard errors are reported in parentheses.

Table 2.5: Random parameters model estimation for South Africa: dependent variable is income per adult equivalence expressed in logs

Row Number	Variable	Coefficient
Headship Types (*X_1*)		
1	No male spouse- No male adults (base category)	7.074 (0.432)
2	No spouse-male adults present	0.218 (0.170)
3	Male spouse present- no male adults	0.515*** (0.178)
4	Male spouse and male adults present	0.370* (0.209)
Child Variables (*X_2*)		
5	Teen males dependency ratio	0.343** (0.166)
6	Teen females dependency ratio	0.179 (0.320)
7	Young males dependency ratio	0.252 (0.349)
8	Young females dependency ratio	-0.233 (0.223)
Child Variable Interactions with Headship Types (*X_2*X_1*)		
9	Teen males dependency ratio*row 2	-0.738** (0.286)
10	Teen males dependency ratio* row 3	0.114 (0.347)
11	Teen males dependency ratio* row 4	0.228 (0.429)
12	Teen females dependency ratio* row 2	0.525 (0.464)
13	Teen females dependency ratio* row 3	-0.090 (0.418)
14	Teen females dependency ratio* row 4	0.320 (0.649)
15	Young males dependency ratio* row 2	0.249 (0.444)
16	Young males dependency ratio* row 3	-0.127 (0.458)
17	Young males dependency ratio* row 4	0.268 (0.758)

Table 2.5 (continued)

Row Number	Variable	Coefficient
18	Young females dependency ratio* row 2	0.759 (0.444)
19	Young females dependency ratio* row 3	0.368* (0.327)
20	Young females dependency ratio* row 4	0.542 (0.525)
Capital stocks (X_3)		
Human capital		
21	Household head years of education	-0.037* (0.022)
22	Household head years of education squared	0.003** (0.002)
23	Number of Skills	0.073** (0.033)
Natural capital		
24	Number of cattle	0.106*** (0.034)
25	Number of goats and sheep	0.061** (0.028)
26	Area of irrigated farm-land	0.072 (0.164)
Physical capital		
27	Physical capital index	0.073 (0.056)
Social capital		
28	Social capital index	0.066* (0.034)
Environmental factors (X_4)		
29	Location	-0.040 (0.120)
Seasonality (X_6)		
30	Season 2	0.058 (0.063)
Household characteristics (X_7)		
31	Age of household head	-0.004 (0.014)
32	Age of household head squared	0.000 (0.000)
33	Children below 5	0.143 (0.127)
34	Adults above 65	0.145 (0.253)
35	Ratio of adult males	-0.228 (0.211)

Table 2.5 (continued)

Row Number	Variable	Coefficient
36	Size of household	-0.087*** (0.015)
37	Chronically ill	-0.067 (0.070)
38	Child grant	-0.151 (0.094)
39	Male above 65	-0.072 (0.124)
40	Female above 65	0.271** (0.106)
	Sample Size:	617
	R-Square :	0.25

Note. 1) Single asterisk (*) indicates significance at the 10% level, double asterisk (**) indicates significance at the 5% level and triple asterisk (***) indicates significance at the 1% level; 2) Standard errors are reported in parentheses; 3) Since random parameters model do not report R-square values, we report R-square values of the models estimated by OLS.

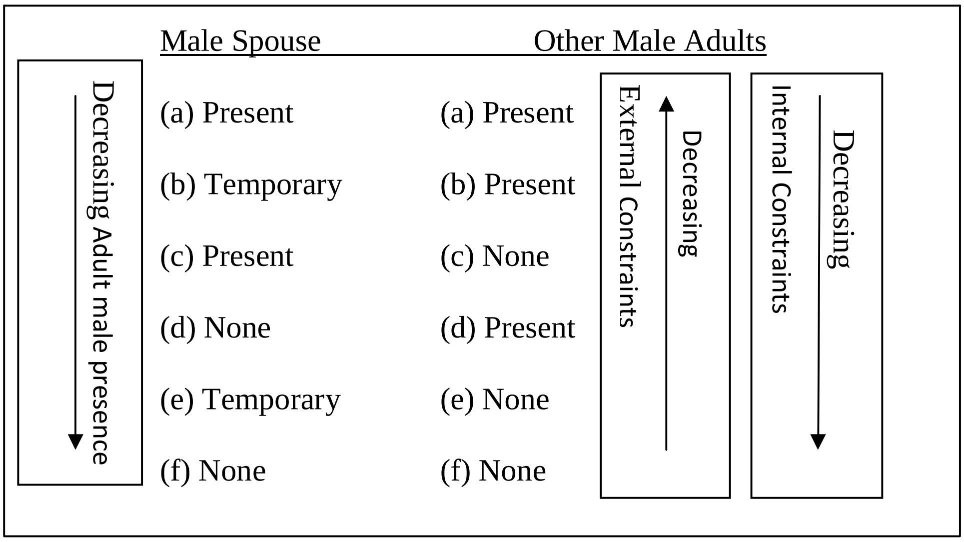

Figure 2.1: Ranking of households according to the amount of adult male presence

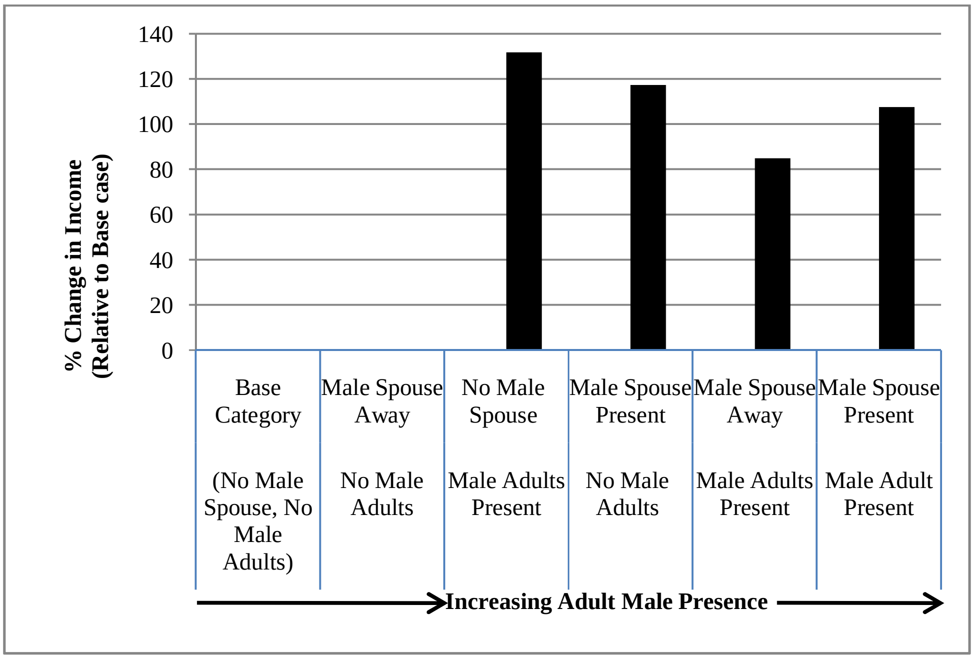

Figure 2.1: Effects of headship on income in Zimbabwe

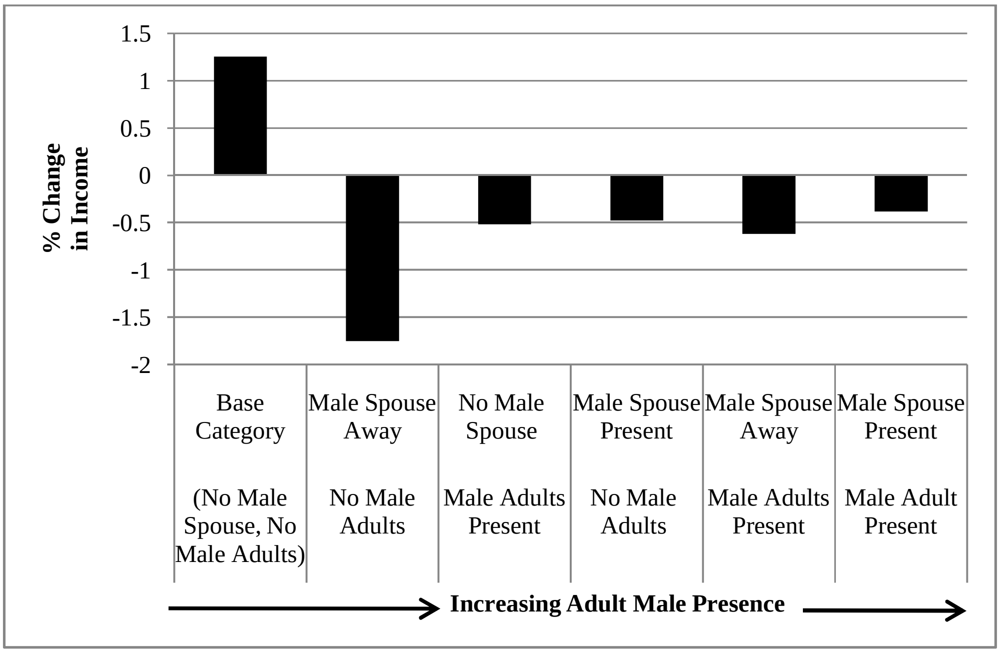

Figure 2.2: Effects of teen male dependency ratio on income in Zimbabwe

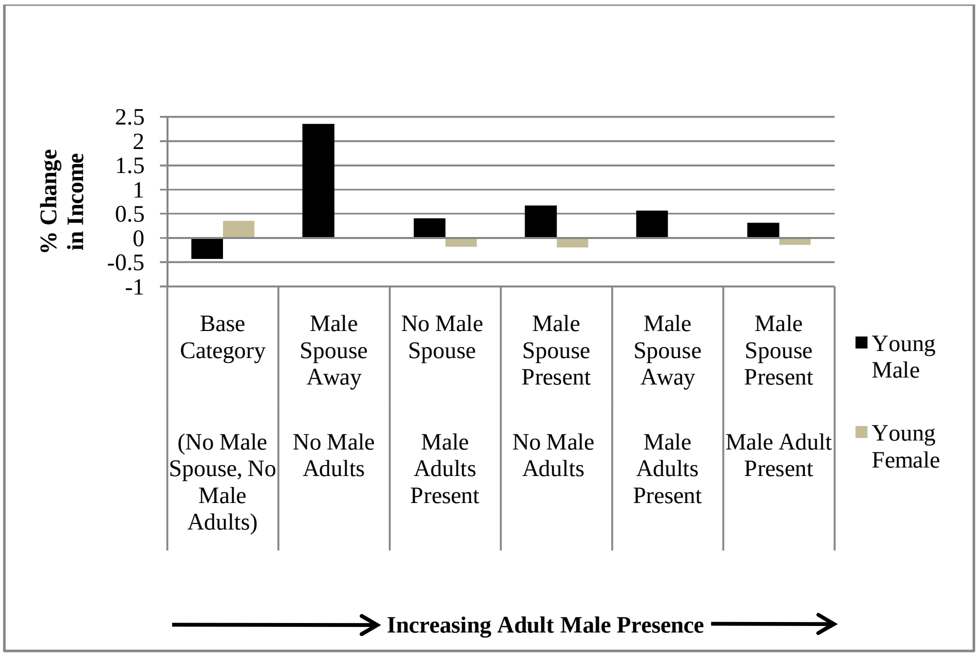

Figure 2.3: Effects of young child dependency ratio on income in Zimbabwe

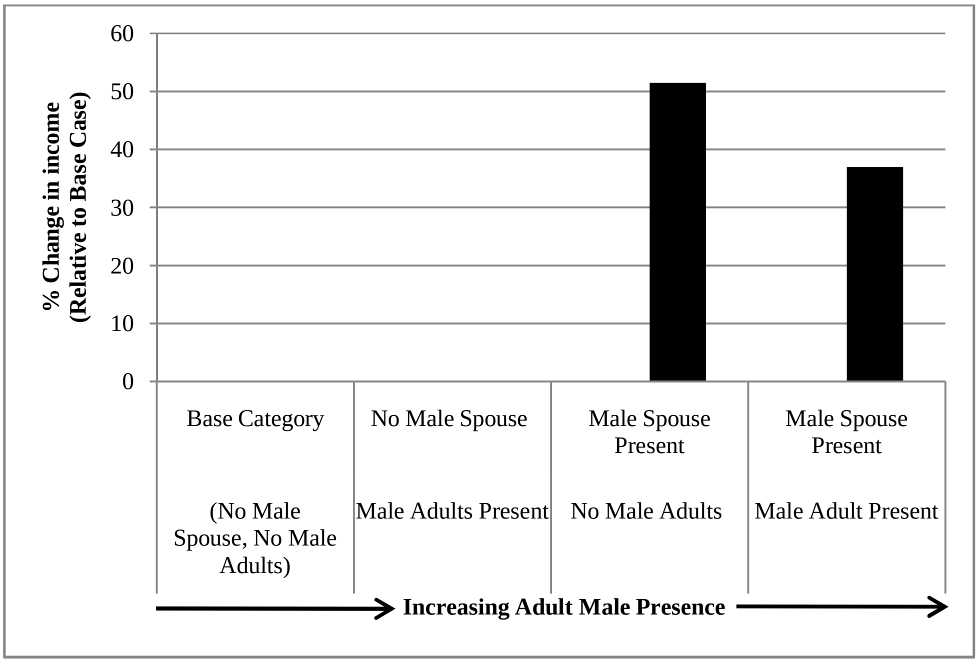

Figure 2.4: Effects of headship on income in South Africa

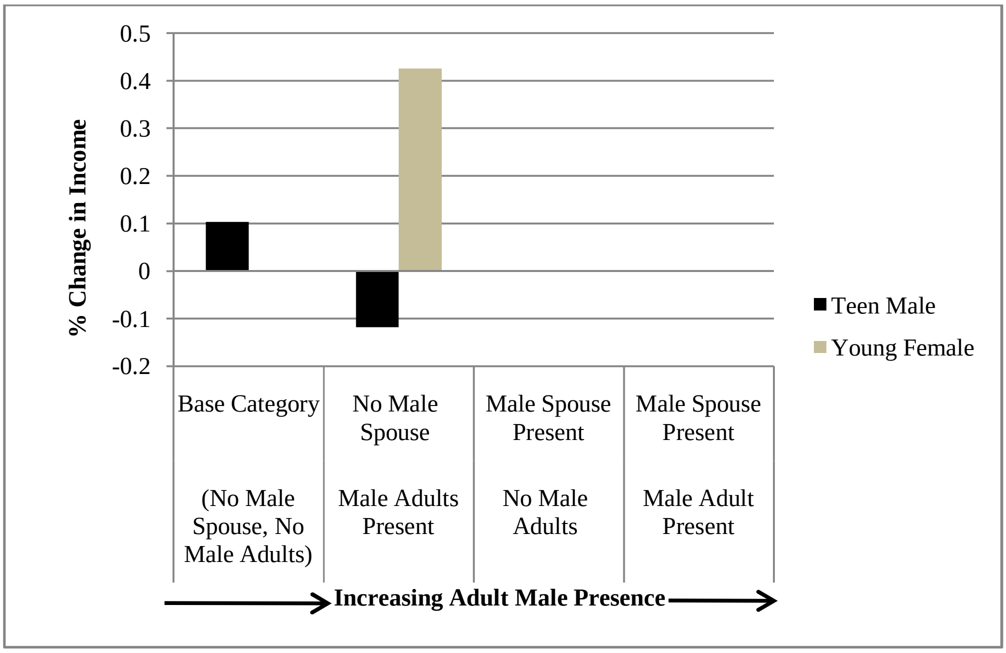

Figure 2.5: Effects of child dependency ratios on income in South Africa

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Chapter 3: Household Innovations in Response to Climate Change: A Contingent Behavior Study of South African Households

3.1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) defines adaptation to climate change as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2001). Empirical evidence reveals that households adopt a wide variety of such adjustments to secure their food and to smooth income in the face of climate change (e.g. Kandlinkar and Risbey 2000; Falco et al. 2011). For instance, households adopt different livelihood activities, farming systems, soil and water conservation strategies, and changing crop and livestock species (e.g., Below et al. 2010). Henceforth, we refer to these household level adjustments as innovations.[9]

A fairly large literature has been devoted to quantifying how households' respond to climate change. The literature can be partitioned into three distinct categories. The first focuses on directly examining household innovations and factors that drive them (e.g. Deressa et al. 2009; Bryan et al. 2009). These studies demonstrate that innovations are driven by household and community factors such

[9] The adjustments that households may adopt in response to future climate change may not be totally new to them. For example, households may increase adoption of off-farm income generating activities in response to future reduction of rainfall. However, households may have already done the same adjustment during past droughts. Accordingly, our definition of innovations may be narrower than the standard definitions of innovations used in the economic literature (e.g. Feder and Umali 1993).

as households' access to productive resources (e.g. land), markets (e.g. credit), extension services and socio-demographic variables. The second uses the Ricardian model to indirectly quantify the impact of climate change. Similar to a standard hedonic model, the Ricardian approach assumes that a farmer maximizes net farm profits by choosing inputs subject to climate and technological constraints. Land values or net revenue of farm lands embody the marginal contributions of innovations adopted by households to deal with adverse climatic impacts. Climate impacts under this approach are, therefore, estimated as coefficients of climate variables in a regression model specifying land or net farm revenues as a function of its covariates (e.g. Mendelsohn et al. 1994, 1996; Seo et al. 2005). Finally, the third type of studies, referred to as structural Ricardian studies, combines elements from the first and second (e.g. Kurukulasuriya and Mendelsohn, 2008; Seo and Mendelsohn 2008). Structural Ricardian studies assume that an agent chooses from multiple innovation alternatives in the first stage, and maximizes net revenues in the second stage, conditional on the first stage adoption choices.

Ideally, understanding household level adaptation to climate change requires time series data on households' behavioral responses to identifiable shifts, variability, and extreme events in the climate (Chambwera and Stage 2010; Smit and Wandel 2006). However, such data is usually not available, particularly in developing country contexts. Most of the literature on this issue, therefore, relies on variability in weather across climate zones in cross sectional data as a proxy for the time effects of climate change on households' economic behavior.

This approach is limited in several ways. First, it fails to consider adoption responses to changes in cross-section specific time-varying climate scenarios. Second, in order to get sufficient variability in weather variables that vary across space the empirical models used in studies require data to be collected across large geographical areas which may be costly and/or infeasible. Third, with a reliance on cross sectional data, innovations identified by the studies are limited to current activities of households. That is, cross-sectional data precludes the adoption of innovations that people may use in the long-run, but may not use currently.

In this paper, we use an alternative approach; the contingent behavior method. The contingent behavior method is used to identify individual's behavioral responses to a given change in environmental conditions (Morton et al. 1995). Using a carefully designed hypothetical scenario that explains the status quo and a change from the status quo, the contingent behavior method directly elicits the information about the behavior of individuals under the new state (Whitehead et al. 2010). The approach is similar to the other stated preference methods, such as contingent valuation and choice experiments, in that individuals do not make actual behavioral changes, but individuals state their hypothetical behavioral responses to proposed environmental changes.

The contingent behavior method offers two advantages in evaluating the efficacy of household innovations in response to climate change. First, the method can exploit variability in climatic conditions incorporated into the study design as future scenarios and, therefore, is not reliant on cross sectional climate variability.

Thus, the method does not require sampling over a large geographical area and can also include time varying climate variables that do not change across space. Second, the contingent behavior method can yield information about long-run behavioral responses to climate change. Due to its flexibility, the contingent behavior method has been used widely in developed economies in order to assess changes in recreation demand in response to changes in environmental conditions, (e.g. Richardson and Loomis 2004; Chase et al. 1998; Christie et al. 2007; Cameron et al. 1996). However, to our knowledge, the contingent behavior method has never been applied in climate change studies in a developing country context.

The contingent behavior method may have some limitations. A major concern is whether model estimates subject to hypothetical bias. However, Hanley et al. (2002) in assessing changes in trip frequency by beach users in relation to environmental quality conclude that contingent behavior models do not suffer from hypothetical market bias. Further, Richardson and Loomis (2004) compare stated preference and revealed preference analyses in visitation behavior in response to changes in climate, and find that the two approaches produce statistically identical estimates of future visitation. Another issue is whether preferences regarding unfamiliar or complex goods or attributes are well-formed and consistent (Groom et al. 2007). However, this limitation could be minimized by proper designing of contingent behaviour questions.

The overall goal of this study is to introduce the contingent behavior approach as a method for studying households' responses to future climate change in developing economies. The objective of this paper is to investigate the innovations that are likely to be adopted by households in rural South Africa in response to anticipated climate change. To meet our objective we designed and deployed a contingent behavior survey in the Eastern Cape Province of South Africa in 2011. The Eastern Cape, with a population of approximately seven million, is the poorest province in South Africa, The region is predicted to be highly vulnerable to climate change, with the western sections getting hotter and drier, while the coastal zone in the east experiencing an increase in later summer rainfall, floods, greater variability in climate and rising sea levels (Pyle 2007). The Eastern Cape also has high HIV prevalence, with rates that were predicted to peak at just over 20% for the adult population by 2012 and at over 30% for adult woman (UNAIDS 2007).

Our survey yields a total of 326 observations that we use to build our empirical analysis. The innovations that we model are household choices concerning future livelihood activities across a grid of climate scenarios. We define livelihood activities as income generating activities (e.g. gardening, casual labor or small business) that households undertake in order to maximize their welfare. An appealing feature of our data is that it encompasses both cash earnings and in-kind earning of households.

In identifying an innovation profile for households that is specific to climate change, it is important to account for other factors that drive innovation. We therefore pay special attention to accounting for both observed and latent household level heterogeneity in households' innovation choices. We are particularly interested in the role of three sets of household attributes: First, we control for the influence of household specific factors (i.e. capital stocks, health status, risk aversion, and demographics) that have been shown in the literature to affect households' innovation choices. Second, we examine whether households' innovative choices of livelihood activities are affected by other innovations (henceforth referred to as innovative strategies) that households may adopt in response to future climate change (e.g. increase of the use of rain water harvesting methods). Third, we explore whether unobserved household attributes (such as its entrepreneurial ability) affect households' innovation adoption decisions.

The rest of the paper is organized as follows. In section 3.2, we briefly describe our conceptual approach. Sections 3.3 and 3.4 describe the data collection and our empirical approach, respectively. In section 3.5, we present our empirical findings, and we conclude in section 3.6.

3.2 Conceptual approach

We consider a standard technology adoption framework (Hubbell et al., 2000) whereby a household adopts an innovation if the utility or benefit from the adoption is at least as great as the utility of not adopting. We use a random utility model (RUM) which assumes that a household acts rationally, is a utility maximizing agent, and knows its own utility function with certainty (Allenby and Rossi 1991). However, due to lack of information about preference parameters, the household's true utility function is unknown and considered to be random

(Cooper and Keim 1996).[10] Using this approach, we write a household's utility from innovation as,

$$U = V(A, C_A, y_A; X) + \xi_A \tag{3.1}$$

where V is potentially observed by the analyst, while ξ_A is an unobserved, independent and identically distributed (iid), and zero-mean component. A = 1, 0 denote adoption and nonadoption scenarios, respectively. C_1 and C_0 denote vectors of expected consumption volumes, and y_1 and y_0 denote expected net income levels (inclusive of profits) under adoption and non-adoption scenarios. X is a matrix of explanatory variables that affect individual consumption and net income.

Note that some innovations will be chosen by the household based on direct gains to consumption (C). For example, an individual may choose natural resource harvesting that is used for home consumption. Other activities, such as off-farm employment, may be chosen based on their contribution to the net income component (Y). Still other activities, such as gardening, may be adopted due to their contributions to both the consumption and net income components of benefits under a given future climate scenario. Given this setup, a household will adopt an innovation if,

$$V(1, C_1, y_1; X) + \xi_1 \geq V(0, C_0, y_0; X) + \xi_0 \ . \tag{3.2}$$

[10] Due to its consistency with neoclassical economics and relevance under imperfect information, RUM has been popular among different types of stated preference including choice experiments (e.g. Boxall et al. 1996) and contingent valuation (e.g. Scarpa et al. 2000).

In our data we do not observe differences in either expected consumption levels or expected profits due to adoption. We follow Qaim and de Janvry (2002) and assume that these variables can be explained by observed household characteristics, so that the consumption and net income differences caused by the innovation are implicitly embedded in reduced form within the matrix of explanatory variables, X. Thus we specify a households' indirect utility to be a linear function of X and characterized by parameters β_i. The probability that a household adopts a specific innovation, as

$$\begin{aligned}\Pr(A=1) &= \Pr(U(1) \geq U(0)) \qquad (3.3.1)\\ &= \Pr[(\xi_0 - \xi_1) = \xi \leq X'\beta = (X'\beta_1 - X'\beta_0)]\end{aligned}$$

$$\Pr(A=1) = F(X'\beta) \qquad (3.3.2)$$

where F denotes the cdf of ξ.

Households in the rural communities we study, consume a significant proportion of their own output. The households are also located in areas where poor transportation and infrastructure restrict market participation. Failures of labor and credit markets are common to many of these households. With market failures, the household's consumption, production and labor allocation decisions become interlinked through the price of nontradables (see de Janvry et al. 1991). Consequently, the same set of factors drive both utility and profit maximization. Production side variables, such as fixed land size, affect consumption decisions. Similarly, consumption side variables, such as illness of household members and household size, affect production decisions (beyond the direct labor productivity channels) and, thereby, profits.

3.3 Data Collection

The data collection for this study was undertaken, using household surveys, in villages in the Willowvale area. Willowvale area is located within the former Transkei in the Eastern Cape Province of South Africa. The area consists of low density rural settlements, surrounded by communal areas used for agriculture and grazing. Poor condition of roads and limited access to basic services such as schools add to the economic challenges of the local population. This area shows a high dependency on natural resources alongside multiple productive activities livelihood strategies such as livestock production, gardening, and small business.

Data collection took place in two phases. The first phase, i.e. the base-line survey, was undertaken during January and February, 2011. The sample contained 170 households randomly selected within the villages, stratified by the percent of the population in each village. The data on different types of capital stocks, and household demographics were collected in the base-line survey. The second phase was undertaken during July and August, 2011, to collect data on household contingent behavior to future climate change and risk aversion.

In rain-fed systems, such as the case in the Willowvale, the frequency in the occurrence of dry/wet periods can be crucial for crop and livestock production. Households in such economies may base their production decisions on events such as rainfall frequency, timing, and intensity (Smithers and Smit 1997; Roncoli et al. 2002; Vogel and O'Brien 2006; Thomas et al. 2007). Accordingly, as a part of our contingent behavior approach, we characterize the future with two types of climate change scenarios; dry-spell and wet-spell. These scenarios are constructed to represent plausible changes in rainfall that occur during the rainy season in the Willowvale area (i.e. November to March). Following the southern African research of Usman and Reason (2004), we defined a dry-spell as a period of 5 consecutive days which receives less than 5 mm of rainfall. There are two types of dry-spell scenarios, one in which temperature remains normal during the dry periods, and one in which temperature can reach a high of 37^0C. A wet-spell, following Hachigonta and Reason (2006), was defined as a period of five consecutive days which receive more than 20 mm of rainfall. The temperature remains as usual during the wet-spells. Relevance and credibility of the definitions of dry and wet spells that we used in the context of our study sites were verified by the local agricultural extension officers and survey respondents during the pre-test of the survey. Based on existing climate studies (e.g. Reason et al. 2005; Cook et al. 2004; Dai and Trenberth 1998; Hachigonta, and Reason 2006), we specify a baseline and plausible changes in dry and wet-spells in the future as mild, moderate and extreme change. Accordingly, we have six scenarios, as follows:

1) a mild increase in the number of dry-spells (increase of dry-spells from 5 to 8);

2) a moderate increase in the number of dry-spells (increase of dry-spells from 5 to 11);

3) an extreme increase in the number of dry-spells (increase of dry-spells from 5 to 14);

4) a mild increase in the number of wet-spells (increase of wet-spells from 5 to 8);

5) a moderate increase in the number of wet-spells (increase of dry-spells from 5 to 11); and

6) an extreme increase in the number of wet-spells (increase of wet-spells from 5 to 14).

Figure 3.1 shows the questions that were used to collect the contingent behavior data for a given climate scenario. The first section in the Figure 3.1 shows the information that was given to the respondents regarding the typical climate of the study area, followed by a description of a specific future climate change scenario. For example, for the case illustrated in Figure 3.1, the future climate change is specified as an extreme change in the frequency in the occurrence of dry-spells for normal temperature. The parts of Q.1 show the questions used to collect the contingent behavior data on the innovative strategies that facilitate adoption of livelihood activities. These data are used as explanatory variables as explained in the empirical approach section below. Section Q.2 shows the contingent behavior question that we asked to collect data on household adoption of future livelihood activities. We have data on binary choices of seven non-mutually exclusive livelihood activities, which will serve as the dependent variables for our empirical models. The potential livelihood activities were identified in the first phase of the survey, based on households historical coping behaviors with climate change related shocks.

Out of 170 households that were surveyed during the first phase, 157 households participated in the second phase. Each contingent behavior questionnaire was designed to elicit responses from an adult male and from an adult female in each household. Among the 157 households that we interviewed in the second phase, there were 30 households in which both an adult male and an adult female were available during the survey. Consequently, 187 individuals participated in the survey.

Each respondent answered one out of three possible dry-spell scenarios and one out of three possible wet-spell scenarios. Accordingly, all together, we have contingent behavior data form 374 observations. The individuals were randomly assigned to different versions of contingent behavior questionnaires.

3.4 Empirical Approach

In this section we discuss the empirical approach used to operationalize our conceptual model. First, we specify our baseline model and discuss the specification of the explanatory variables used. We then focus on addressing unobserved heterogeneity among households.

3.4.1 Empirical specification of the baseline model

Following equation 3.3.2, we specify our general empirical model of innovation adoption by characterizing the net utility (benefit) using the latent variable, A^*. Specifically,

$$A_i^* = x_i\beta + \varepsilon_i \text{ with } A_i = \begin{cases} 1 \text{ } if \text{ } A_i^* > 0 \\ 0 \text{ } otherwise \end{cases} \quad (3.4)$$

where we assume that ε has a standard normal distribution. A_i is an observed variable, that indicates whether a household adopts a particular livelihood activity (A_i=1), if $A_i^* > 0$, and 0 otherwise. There are six potential livelihood activities to be adopted (gardening, livestock, natural resource harvesting, casual labor, small business and formal employment), hence, six equations to be estimated.[11] The vector X represents variables that are hypothesized to affect the expected utility of adoption. Based on our conceptual framework, we allow both consumption and net income or profit components of the utility to be driven by both production and consumption side variables in our econometric specifications. We can obtain the effects of the variables contained in vector X on the household's adoption decision by estimating equation 3.4

Table 3.1 describes the explanatory variables and their expected signs in the six adoption models. We organize our explanatory variables with seven categories (X_i; i=1-7). First, in order to test our main hypothesis on impacts of climate change (X_1), we include five dummy variables that represent future climate change scenarios 2-5, described earlier. Scenario 1, which represents the least change in the current climate of the study area (i.e. an increase in the number of dry-spells from 5 to 8), is considered as the base case. Under rain fed conditions, the occurrence of dry periods may affect negatively gardens and livestock (Hachigonta and C. Reason 2006; Mogotsi et al. 2011). However, livestock may be less susceptible to droughts than gardens (Campbell et al. 2002). Accordingly, we expect that households are likely to reduce adoption of gardening in response to moderate and extreme increases in dry-spells, and livestock in response to an extreme increase in dry-spells. Wood is dried and stored during the dry seasons to be used in the rainy seasons (Brouwer et al. 1997). Moreover, due to the potential decrease in agricultural income under dry

[11] Due to a small number of non-zero choices, we do not estimate a model for dry-land agriculture.

climatic conditions, households may increase the participation in off-farm activities (Roncoli et al. 2001). Therefore, we expect that households are more likely to adopt natural resource harvesting, casual labor, and small business in response to increases in dry-spells. We capture the effects of high temperature (heat waves) that may occur during dry-spells on adoption decisions by including a dummy variable. The occurrence of heat waves may increase crop losses and livestock mortality (Sivakumar 2006), and hence, we expect high temperature to affect negatively the adoption of gardening and livestock.

Wet climatic conditions may ensure sufficient water available for crops and grasslands. Hence, we expect that households are more likely to adopt gardening, and livestock in response to a mild and moderate increase in wet-spells. However, extreme rain falls may not be favorable for both crops and livestock (Porter and Semenov 2005; Seo and Mendelsohn 2008). Accordingly, adoption of gardening and livestock are expected to be less, in response to an extreme increase in wet- spells. Frequent rains may also limit accessibility of forests, and time available for off-farm activities. Therefore, we expect that households are less likely to adopt natural resource harvesting, casual labor, and small business, in response to a moderate and extreme increase in wet-spells.

There are a number of different types of capital stocks (X_2) that could influence households' adoption of livelihood activities, including human, social, physical, and natural capital. For human capital, we include years of education of household head and a variable that indicates the number of skills available to the household. For social, physical and natural capital, we include, respectively, an index of social capital, an index of physical capital, and the size of the agricultural landholdings. The indices of physical capital and social capital were generated by applying Principal Component Analysis on the various measures of capital (see Appendix A for details). We expect that, depending on the nature of the livelihood activity, some types of capital stocks may be more important than others. For example, studies find that human and social capital are important in finding off-farm employment (e.g. Zhang et al. 2001). Thus, households with more of these stocks are expected to adopt casual labor, small business, and formal employment more, relative to others. Natural and physical capital owned by the household may represent wealth that could be important in adopting agricultural activities (Doss and Morris 2001). Accordingly, we expect households with larger landholdings and physical capital stocks to be more likely to adopt gardening and livestock.

Household choices of future livelihood activities may also be affected by innovative strategies (X_3) that households may adopt in response to climate change (Helgeson et al. 2012). We have contingent behavior data on households' adoption of four types of such strategies (Figure 3.1, Q.1). These data state whether a household, in response to future climate change, would: 1) increase the usage of domestic rain water harvesting; 2) increase efforts to obtain external assistance within and outside of its community; 3) reduce food intake; and 4) reduce personal expenditures. Households may use harvested water for watering home gardens and for small livestock (Worm and Hattum 2006). Therefore, we expect that households that adopt these strategies are more likely to adopt gardening and livestock than their counterparts. The adoption of other innovative strategies could either be substitute or complements to the adoption of future livelihood activities, depending on the type of livelihood activity. Therefore, we do not have *a priori* expectations on other innovative strategies.

In order to capture the potential effects of household health status on the adoption of future livelihood activities, we include a variable that is intended to identify the presence of a long term ill person in the household (X_4). Long-term illness such as HIV/AIDS may negatively affect household labor available for agricultural activities (Müller 2004; Bollinger et al. 1999). Therefore, we expect the households that have a long-term ill person are less likely to adopt gardening, and livestock. Further, having a long-term ill person in the household may increase expenditures on food and medicines (Drimie 2002; Masanjala 2005). Under such circumstances, wild foods could provide an alternative source of food (Feulefack et al. 2013). Therefore, we expect that households that have a long-term ill person in the household are more likely to adopt natural resource harvesting. In order to cover the additional expenses, households may also diversify income generating activities (Niehof 2004; FAO 1995, 1998). Accordingly, we expect that households that have a long-term ill persons to have a positive effect on adoption of casual labor and small business. Furthermore, due to absenteeism to care for sick family members, we expect long-term ill person to have a negative effect on the adoption of formal employment.

We include a variable that indicates the level of risk aversion of the survey respondent (X_5).[12] The literature, both theoretical and empirical, has identified risk aversion as an important factor that affects technology adoption (e.g. Feder 1980 for theoretical, and Knight et al. 2003 for empirical literature). Climate change may be associated with different types of risks such as losses in agricultural production, instable input and output prices and health risks. The decision to adopt a livelihood activity may depend on the individual's subjective assessment of the risk of climate change, and the risk of adoption of a certain livelihood activity. Since households' are highly unlikely to make financial investments in natural resource harvesting, adopting natural resource harvesting is associated with minimal risk (Campbell et al. 2002). Therefore, it is expected that the individual's risk aversion has a positive impact on the adoption of natural resource harvesting. Such relationships are difficult to ascertain for other livelihood activities that may involve more risk, such as gardening and small business. Therefore, we do not have expectations on the effect of individual's risk aversion on the other livelihood activities.

To further characterize households, we include household demographics (X_6). The literature finds empirical evidence for the effects of household demographics on adoption of new technology (Rahm and Huffman 1984; Norris and Batie 1987), and adoption of innovations in response to climate change

[12] Data on this variable were collected using a set of risk gamble questions that are analogues to the questions used in Spivey (2010). Based on the answers given to the risk gamble questions, each respondent was categorized into one out of four categories: weakly risk averse (1); moderately risk averse (2); strongly risk averse (4) and very strongly risk averse (See appendix B for details).

(Bryan et al. 2009; Gbetibouo 2009). We include six demographic variables: age and gender of the household head; gender of the survey respondent, the number of male adults; the number of female adults; and household size. Based on our field experience, we assume that women, relative to men, are more involved in gardening. We therefore expect that female-headed households, and female survey respondents relative to their counterparts, to be more likely to adopt gardening. However, under rural African contexts, women may be less engaged in livestock production (FAO 2011), and disadvantaged in off-farm labor markets (Fortin 2005; Brown and Haddad 1995). Hence, we expect, female-headed households, and female survey respondents to be less likely to adopt livestock, casual labor, small business and formal employment. Previous studies have found that women often seek out forest resources such as wild foods (e.g. Dovie et al. 2002; Shackleton et al. 2002). Based on such findings, we expect that female-headed households, female survey respondents and households with more adult women are more likely to adopt natural resource harvesting. Household size may reflect the quantity of the labor force available to households for agricultural activities (Croppenstedt et al. 2003). Moreover, in order to reduce the consumption pressure, large households are more likely to divert household labor force to off-farm activities (Yirga 2007). Taken together, we expect that larger households are more likely to adopt on-farm activities as well as off-farm activities. We do not have expectation on the age of the household head, and the number of male adults.

Finally, we include a dummy variable (X_7) that express whether the households have previously undertaken a specific livelihood activity to be adopted in the future. We expect that current experiences and historical exposures of households may positively influence their probabilities of adoption. Accordingly, for all the livelihood activities considered, we expect that households that have undertaken an activity in the past are more likely to adopt the same activity in the future.

3.4.2 Econometric problems associated with estimating the baseline model

Although we control for the observed heterogeneity of households by including the variables described above, adoption decisions may also vary among households due to unobserved household heterogeneity. Households may be heterogeneous in two ways. First, they can be heterogeneous due to unobserved but not systematic reasons. Second, and more importantly, households may be heterogeneous systematically due to unobservable household covariates such as household ability in a specific livelihood activity. Such unobservable household covariates may also create complementarities with other covariates that affect adoption decisions, such as households undertaking of innovative strategies. Therefore, in estimating equation 3.4, it is important to apply an econometric method that accounts for the possibility of systematic differences in the unobserved characteristics of households. To this end, we use a random parameter probit model.

Following Greene (2004), in order to allow for unobserved heterogeneity, equation 3.4 can be rewritten as:

$$\Pr[y_i = 1 | x_i \beta_i] = g(\beta_i' x_i), i = 1,...,n \quad (3.5)$$

$$\beta_i = \beta + \Delta z_i + \Gamma v_i \quad (3.6)$$

The y_i represents the dependent variable defined earlier. The vector x_i represents the explanatory variables described earlier. The random vector v introduces the distribution of the random parameters. According to equation 3.6, β, Δ and Γ define the random parameters. β is the vector of means of the random parameters. Γ is a diagonal matrix that contains the variances of the random parameters.

To capture systematic unobserved heterogeneity, we specify random coefficients on the intercept term. In order to identify interaction effects (complementarities) between unobservable and other covariates, we specify the mean of the intercept as a function of a vector of exogenous variables, z_i, that are most likely to have complementarities with unobserved characteristics. We assume that households' undertaking of different innovative strategies (e.g. increase of the use of rain water harvesting methods) in response to climate change may create complementarities with unobserved characteristics. Equation 3.5 was estimated using simulated maximum likelihood methods.[13]

3.5 Results

We refer to the probit models that are used to obtain the starting values for the random parameter models as the baseline models.[14] Baseline models include

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[13] NLOGIT 4 was used in estimating the random parameters models.

[14] Results of the baseline models are not reported, but available upon request.

non-random intercepts and all the explanatory variables included in the random parameter model, except the variables interacted with the random intercepts. The Likelihood ratio tests confirms that the baseline and random parameter specifications are significantly different from each other in three models (gardening, natural resource harvesting, and small business), suggesting that, in these models, random parameter models explain the adoption behavior better than baseline models. Most of the regression coefficients were statistically significant and have signs that are intuitively appealing. Specifically, most of the dummy variables that were used to represent different future climate scenarios are statistically significant in five of the six models. However, the dummy variable that indicates the occurrence of heat waves during dry-spells was not statistically significant in any model. Table 3.2 and 3.3 report the marginal effects and the coefficients of the factors affecting adoption of livelihood activities, respectively.[15]

3.5.1 Effects of climate variables on adoption

The marginal effects of a specific climate variable (Table 3.2) shows the probability of adopting a particular livelihood activity under a particular climate change scenario, relative to the probability of adopting the corresponding activity under the baseline scenario, all else held constant. As can be seen in Table 3.2, the effects of climate variables may vary depending on the specific climate change

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[15] By estimating a multivariate probit model, we econometrically test for the simultaneous adoption of livelihood activities. We find that, the null hypothesis that contemporaneous error correlation is equal to zero cannot be rejected. Hence, efficiency gains would not occur from estimating the adoption equations as a system.

scenario and the livelihood activity to be adopted. Most of the effects are statistically significant except in the model for adoption of formal employment. In order to examine the relationship between the future climate change and households' adoption decisions further, we graph the probabilities of adoption of different livelihood activities (except formal employment), relative to the base case, under dry-spell and wet-spell scenarios.

3.5.1.1 Adoption of livelihood activities in response to an increase in dry-spells

Figure 3.2 demonstrates the probabilities of adoption of different livelihood activities in response to a moderate and an extreme increase in dry-spells, relative to the probabilities of adoption of the corresponding activities in response to a mild increase in dry-spells (i.e. the base case). A moderate and an extreme increase in the number of dry-spells decrease the probability of adoption of gardening by 70% and 61% respectively. This result shows the need for rain in gardening. Different from the effect on gardening, a moderate increase in dry-spells increases adoption of livestock by 28%. This result may imply that households may shift from crop to livestock in response to the climatic conditions. Similar findings have been reported by previous studies (e.g. Seo and Mendelsohn 2008). However, unlike a mild increase, an extreme increase in dry-spells decreases the probability of adoption of livestock by 27%. Extreme scarcity of water under such climatic conditions would badly affect grasslands, and thereby livestock.

Figure 3.2 also shows that, relative to the base case, an increase in dry-spells increases the probabilities of adoption of all the off-farm activities. A moderate and an extreme increase in dry-spells increase the probability of adoption of natural resource harvesting by 44% and 49% respectively. Natural resources, mainly from forests, may be less susceptible to dry climatic conditions and forest products such as firewood and poles may be easily accessible under dry climatic conditions (Eaton and Sarch 1997). A moderate and an extreme increase in dry-spells increase the probability of adoption of casual labor by 39% and 36% respectively. For small business, the corresponding increases in the probabilities are 65% and 81%. This result implies that casual labor and small business are less likely to be affected by the increases in dry-spells.

3.5.1.2 Adoption of livelihood activities in response to increase in wet-spells

Figure 3.3 shows the probabilities of households' adoption of future livelihood activities in response to an increase in the number of wet-spells. Again, the probability of adoption of each activity is expressed relative to the corresponding probability under the baseline scenario (i.e. a mild increase in the number of dry-spells). As expected, a mild increase in the number of wet-spells increases the probabilities of adoption of gardening by 43%. The availability of water for longer periods during the cropping season may help garden production. However, in contrast to the mild increase, the moderate increase has no effect, and the extreme increase decreases the probability of adoption of garden by 89%. Extended periods of rainfall may cause flood and increase crop diseases and pests and thereby reduce the expected benefit of gardening. Figure 3.3 illustrates that a mild and a moderate increase in the number of wet-spells, relative to the base case, increases the probabilities of adoption of livestock by 37%, and 61% respectively. Increased availability of water may guarantee abundant feed is available for livestock.

The results also show that, relative to the base case, all three types of increases in wet-spells have no significant effects on the probabilities of adoption of natural resource harvesting. Moreover, a moderate and an extreme increase in wet-spells have no effects on adoption of casual labor and small business. However, an extreme increase in the number of wet-spells decreases the probabilities of adoption of casual labor by 46%. Prolonged periods of rainfall and may reduce the availability of off-farm work. In contrast, an extreme increase in the number of wet-spells increases the probability of adoption of small business by 37%. This result indicates that small business is less susceptible to the extremely wet climatic conditions.

3.5.2 Effects of capital stocks on adoption

The effects of capital stocks on households' adoption of livelihood activities vary depending on the type of capital, as well as the livelihood activity (Table 3.2). As expected, human capital, measured by the years of education of the household head, has a positive effect on the probability of adoption of natural resource harvesting, small business, and formal employment. The number of skills available in the household affects negatively on the probability of adoption of gardening, and positively on adoption of small business. Social capital has positive effects on the probabilities of adoption of gardening, natural resource harvesting, and small business. In general, these results reflect the importance of human and social capital in the livelihoods of rural households. We do not find statistically significant effects of physical capital on adoption decisions. However, natural capital, measured by the size of agricultural land, has a positive effect on the probability of adoption of livestock. Size of the agricultural land also has a positive effect on the probability of adoption of small business, suggesting that agricultural lands may be important in starting small business ventures. However, the size of the agricultural land has negative effects on the probability of adoption of natural resource harvesting and casual labor. A possible reason is that when a household has a relatively larger land, it may tend to adopt on-farm activities such as gardening and livestock, and thereby may be less likely to adopt off-farm activities such as natural resource harvesting and casual labor.

3.5.3 Effects of household and individual specific factors on adoption

Several household specific factors have statistically significant effects on adoption decisions (Table 3.2). The presence of a long-term ill person in a household decreases the probability of adoption of livestock, but increases the probability of adoption of natural resource harvesting and casual labor. The decrease in the probability of adoption of livestock may indicate the financial and labor constraints that households with a long-term ill person may face. Increase in the probability of adoption of natural resource harvesting may suggest that natural resources could play the 'safety net' function in rural livelihoods in crisis situations (see Shackleton and Shackleton 2004). The increase in the probability of adoption of casual labor suggest that people in HIV/AIDS affected households may tend to work off-farm to earn money to meet the needs of the sick person and the household (Munthali and Ali 2000). Our results show that the higher the risk aversion of the survey respondent, the greater will be the probability to adopt natural resource harvesting.[16] This result suggests that natural resource harvesting is associated with a low degree of risk, and may help to increase the food security among the households with risk averse individuals. Considering household demographics, our results show that age of the household head has a negative, and a positive effect, respectively on the probability of adoption of small business and formal employment. Male-headed households are less likely to adopt gardening, but more likely adopt natural resource harvesting, casual labor and small business than female-headed households. However, female respondents are more likely to adopt casual labor and small business than male respondents. The number of male adults has a positive effect on the probability of adoption of gardening while the number of female adults has positive effects on the probabilities of adoption of natural resource harvesting and small business. Household size has a negative effect on the probability of adoption of small business. Household's previous exposure to an activity has positive effects on the probabilities of adoption of gardening, casual labor and small business.

[16] We tried to introduce possible non-linear effects of risk perception on livelihood choices by interacting the risk variable with the variables related to future climate change. However, none of these interaction variables was statistically significant, so we did not include them in our final regressions.

3.5.4 Effects of unobserved heterogeneity and its complementarities on adoption

As shown in Table 3.3 (bottom panel), the standard deviations of the random intercepts are statistically significant in five of the six equations estimated.[17] This result confirms the presence of household specific unobserved heterogeneity (due to the attributes such as entrepreneurial ability) that may directly affect the adoption decisions. Further, adoptions of innovative strategies that were assumed to influence the heterogeneity in the means of the random intercept are also statistically significant in several models. The interaction effect of the random intercept with households' adoption of rain water harvesting under future climate change, has positive effects on the probability of adopting gardening and natural resource harvesting. The former result implies that, in the absence of sufficient rainfall, households cloud use harvested rain water to irrigate their garden plots. The interaction effect between the random intercept and households' search for external assistance has a positive effect on the probability of adopting gardening, natural resource harvesting, and small business. This result suggests that households could utilize the external assistance they would obtain in order to start gardens and new small business ventures. The interaction effects between the random intercept and reducing food intake and personal expenditures have negative effects on the probability to adopt natural resource harvesting. This result demonstrates that reducing food intake and personal expenditures could be

[17] Since the output of random parameter models do not report marginal effects of the variables interacted with the random intercept, we interpret the results based on the estimated coefficients.

substitutes to adopting natural resource harvesting (so that if a household reduces expenditures or food intake, their need to adopt natural resource harvesting is less). The interaction effects between the random intercept and reducing food intake has a positive effect on the probability of adoption of small business. This result suggests that reducing food intake may be a complement to adopting small business.

3.6 Conclusions

In this paper, we investigate households' adoption of livelihood activities in response to future climate change using the contingent behavior method. We use a unique dataset that was collected in South Africa in 2011. Using random parameter models, we econometrically account for unobserved heterogeneity of the households, which, is to our knowledge, new in the context of climate change studies. Apart from these methodological contributions to the economic literature, our study exposes a number of other policy implications regarding climate change adaptation.

The results show that households respond to an increase in the number of dry-spells by increasing adoption of off-farm activities (natural resource harvesting, casual labor, and small business). Accordingly, enabling factors that have significant positive effects on adoption of off-farm activities, mainly human and social capital, should be taken into consideration by policy markers. Further, an increase in the probability of adoption of natural resource harvesting emphasizes that policies and programs that enhance the sustainable use and management of natural resources are needed in the rural economies such as the case of rural South Africa. The results also suggest households respond to a mild and a moderate increase in the number of wet-spells by increasing adoption of on-farm activities. Therefore, under such climatic conditions, promoting gardening and livestock should be a policy focus. To this end, development of physical and natural capital are the policy levers. It is also important to note that, in response to an extreme increase in wet-spells, households increase only the adoption of small business. In other words, small business may serve as the safeguard for households under extremely wet climatic conditions.

We also find that adoption of innovative strategies that household are likely to adopt in response to future climate change can positively impact the adoption of some livelihood activities. For example, the households that increase the use of rain water harvesting methods are more likely to adopt gardening than the ones that do not increase the use of rain water harvesting methods. Such complementarities between adoption of innovative strategies and livelihood activities are important to policy makers in order to facilitate the adoption process. Further, we find that households with a long-term ill person, and more risk averse individuals are more likely to adopt natural resource harvesting. Accordingly, policies relating to sustainable use and management of natural resources can have direct welfare effects on households with the sick and risk averse individuals.

Table 3.1: Variable definitions and expected signs

Explanatory Variable		**Garden**	**Livestock**	**Natural resource harvesting**	**Casual Labor**	**Small Business**	**Formal Employment**
Climate variables (X1)							
Mild increase in dry- spells	The base case; 1= an increase in the number of dry-spells from 5 to 8, 0 = otherwise	NA	NA	NA	NA	NA	NA
Moderate increase in dry- spells	1= an increase in the number of dry-spells from 5 to 11, 0 = otherwise	-	+/-	+	+	+	+/-
Extreme increase in dry- spells	1= an increase in the number of dry-spells from 5 to 14, 0 = otherwise	-	-	+	+	+	+/-
Mild increase in wet- spells	1= an increase in the number of wet-spells from 5 to 8, 0 = otherwise	+	+	+/-	+/-	+/-	+/-
Moderate increase in wet-spells	1= an increase in the number of wet-spells from 5 to 11, 0 = otherwise	+	+	-	-	-	+/-
Extreme increase in wet- spells	1= an increase in the number of wet-spells from 5 to 14, 0 = otherwise	-	-	-	-	-	+/-
High temperature	1= if the temperature may reach high of 37C^0, 0 = otherwise	-	-	+/-	+/-	+/-	+/-
Capital stocks (X2)							
education	Years of education of the household head	+/-	+/-	+/-	+	+	+
Skills	Number of skills available to household	+/-	+/-	+/-	+	+	+
Social capital	Social capital index for the household	+/-	+/-	+/-	+	+	+
physical capital	Physical capital index for the household	+	+	+/-	+/-	+/-	+/-

Table 3.1 (continued)

Explanatory Variable		**Garden**	**Livestock**	**Natural resource harvesting**	**Casual Labor**	**Small Business**	**Formal Employment**
natural capital	Size of the agricultural land per capita	+	+	+/-	+/-	+/-	+/-
Innovative strategies (X3)							
rain water harvesting	1= if a household states to adopt “rain water harvesting”, 0=otherwise	+	+	+/-	+/-	+/-	+/-
search for assistance	1= if a household states to adopt “search for assistance”, 0=otherwise	+/-	+/-	+/-	+/-	+/-	+/-
reduce food intake	1= if a household states to adopt “reducing food intake”, 0= otherwise	+/-	+/-	+/-	+/-	+/-	+/-
reduce personal expenditures	1= if a household states to adopt “reducing expenditure”, 0=otherwise	+/-	+/-	+/-	+/-	+/-	+/-
Health status (X_4)							
long -term ill	1= if household has a long-term ill person, 0= otherwise	-	-	+	+	+	-
Risk aversion(X_5)							
risk	The level of risk aversion of the respondent	+/-	+/-	+	+/-	+/-	+/-

Table 3.1 (continued)

Explanatory Variable		Garden	Livestock	Natural resource harvesting	Casual Labor	Small Business	Formal Employment
Demographics (X_6)							
Age of the household head	Age of the household-head	+/-	+/-	+/-	+/-	+/-	+/-
Gender of the household head	Gender of the household head; 1= if the household is male headed, 0= female headed	-	+	-	+	+	+
Gender of the survey respondent	Gender of the respondent; 1= if the respondent is a female, 0= a male respondent	+	-	+	-	-	-
Number of male adults	Number of male adults in the household	+/-	+/-	+/-	+/-	+/-	+/-
Number of female adults	Number of female adults in the household	+/-	+/-	+	+/-	+/-	+/-
Household size	Number of the household members	+	+	+	+	+	+
Exposure (X_7)							
Exposed	1= if the household has previously undertaken the activity, 0= otherwise	+	+	+	+	+	+

Table 3.2: Marginal effects of the factors affecting the adoption of future livelihood activities

	Garden	Livestock	Natural resource harvesting	Casual Labor	Small Business	Formal Employment
Climate variables (X_1)						
Moderate increase in dry-spells	-0.706*** (0.187)	0.285** (0.120)	0.445*** (0.144)	0.396*** (0.141)	0.653*** (0.231)	-0.075 (0.104)
Extreme increase in dry-spells	-0.618*** (0.176)	-0.279** (0.128)	0.496*** (0.145)	0.361** (0.141)	0.818*** (0.258)	-0.025 (0.086)
Mild increase in wet- spells	0.432*** (0.146)	0.377*** (0.121)	0.213 (0.141)	0.059 (0.129)	0.267 (0.200)	-0.010 (0.081)
Moderate increase in wet-spells	-0.019 (0.133)	0.610*** (0.138)	-0.062 (0.143)	0.044 (0.137)	-0.042 (0.195)	-0.009 (0.083)
Extreme increase in wet-spells	-0.896*** (0.236)	0.137 (0.125)	0.101 (0.148)	-0.468*** (0.147)	0.378* (0.222)	0.002 (0.086)
High temperature	0.099 (0.110)	-0.126 (0.102)	0.091 (0.115)	0.094 (0.108)	0.055 (0.157)	-0.033 (0.077)
Capital stocks (X_2)						
Education	0.004 (0.011)	-0.009 (0.011)	0.021* (0.011)	0.018 (0.012)	0.043** (0.018)	0.012* (0.007)
Skills	-0.102** (0.051)	0.048 (0.045)	0.036 (0.047)	-0.016 0.046	0.150** (0.071)	0.004 (0.027)
Social capital	0.100* (0.054)	0.039 (0.046)	0.127** (0.056)	-0.006 (0.047)	0.187** (0.080)	0.004 (0.027)
Physical capital	0.111 (0.118)	0.198 (0.124)	0.007 (0.118)	-0.138 (0.113)	-0.174 (0.162)	-0.091 (0.062)
Natural capital	-0.044 (0.039)	0.074** (0.034)	-0.083** (0.039)	-0.066** (0.034)	0.149** (0.059)	0.026 (0.025)
Health status (X_4)						
Long-term ill	-0.062 (0.085)	-0.231*** (0.085)	0.201** (0.093)	0.262*** (0.089)	0.058 (0.116)	-0.075 (0.063)
Risk aversion (X_5)						
Risk	0.032 (0.028)	0.007 (0.027)	0.107*** (0.033)	-0.021 (0.028)	-0.014 (0.039)	-0.009 (0.019)
Demographics (X_6)						
Age of the household head	-0.001 (0.003)	0.003 (0.003)	-0.002 (0.004)	-0.002 (0.003)	-0.016*** (0.005)	0.003* (0.002)

Table 3.2 (continued)

	Garden	**Livestock**	**Natural resource harvesting**	**Casual Labor**	**Small Business**	**Formal Employment**
Gender of the household head	-0.321** (0.114)	0.091 (0.085)	0.225** (0.099)	0.262*** (0.096)	0.433*** (0.149)	-0.034 (0.063)
Gender of the survey respondent	0.151 (0.122)	-0.112 (0.128)	0.152 (0.131)	0.238* (0.138)	0.591*** (0.222)	-0.060 (0.098)
Number of male adults	0.121** (0.052)	0.007 (0.047)	-0.008 (0.055)	0.013 (0.052)	0.045 (0.072)	-0.042 (0.043)
Number of female adults	-0.084 (0.055)	-0.012 (0.054)	0.133** (0.064)	-0.027 (0.054)	0.200** (0.088)	0.027 (0.037)
Household size	0.009 (0.023)	0.018 (0.023)	-0.044 (0.027)	0.020 (0.025)	-0.114*** (0.040)	0.001 (0.017)
Exposure (X_7)						
Exposed	0.289*** (0.101)	0.081 (0.109)	0.141 (0.123)	0.599*** 0.130	0.689*** (0.239)	0.170 (0.128)
Constant	-0.092 (0.301)	-0.188 (0.285)	-0.725** (0.291)	-0.683** 0.351	-0.740 (0.512)	-0.352*** (0.002)

Note.1) Single asterisk (*) indicates significance at the 10% level, double asterisk (**) indicates significance at the 5% level and triple asterisk (***) indicates significance at the 1% level; 2) Standard errors are reported in parentheses; 3) Marginal effects are computed as the partial derivatives evaluated at the means.

Table 3.3: Parameter estimates of the factors affecting the adoption of future livelihood activities

	Garden	Livestock	NRH	Casual Labor	Small Business	Formal Employment
Climate variables (X_1)						
Moderate increase in dry-spells	-1.805*** (0.349)	0.717** (0.306)	1.120*** (0.363)	0.996*** (0.339)	1.646*** (0.510)	-0.260 (0.341)
Extreme increase in dry-spells	-1.581*** (0.357)	-0.702** (0.308)	1.247*** (0.371)	0.908*** (0.340)	2.064*** (0.538)	-0.085 (0.288)
Mild increase in wet- spells	1.105*** (0.380)	0.951*** (0.318)	0.537 (0.363)	0.149 (0.323)	0.674 (0.476)	-0.034 (0.280)
Moderate increase in wet-spells	-0.048 (0.339)	1.537*** (0.355)	-0.155 (0.359)	0.110 (0.342)	-0.105 (0.495)	-0.030 (0.286)
Extreme increase in wet-spells	-2.292*** (0.402)	0.345 (0.325)	0.254 (0.377)	-1.177*** (0.374)	0.953* (0.510)	0.006 (0.301)
High temperature	0.254 (0.291)	-0.318 (0.251)	0.229 (0.292)	0.236 (0.269)	0.138 (0.394)	-0.116 (0.252)
Capital stock (X_2)						
Education	0.011 (0.029)	-0.023 (0.027)	0.052* (0.029)	0.044 (0.028)	0.108*** (0.039)	0.043* (0.023)
Skills	-0.262** (0.117)	0.122 (0.115)	0.091 (0.119)	-0.039 (0.117)	0.379** (0.166)	0.015 (0.096)
Social capital	0.257** (0.128)	0.099 (0.115)	0.319** (0.139)	-0.015 (0.119)	0.473** (0.190)	0.015 (0.094)
Physical capital	0.284 (0.277)	0.499* (0.289)	0.017 (0.295)	-0.347 (0.272)	-0.439 (0.380)	-0.317 (0.251)
Natural capital	-0.112 (0.097)	0.187** (0.088)	-0.210** (0.097)	-0.166** (0.086)	0.376*** (0.134)	0.091 (0.079)
Health status (X_4)						
Long-term ill	-0.159 (0.217)	-0.582*** (0.209)	0.505*** (0.234)	0.658*** (0.217)	0.146 (0.291)	-0.262 (0.183)
Risk aversion (X_5)						
Risk	0.083 (0.072)	0.016 (0.067)	0.268*** (0.081)	-0.053 (0.071)	-0.036 (0.098)	-0.030 (0.062)

Table 3.3 (continued)

	Garden	**Livestock**	**NRH**	**Casual Labor**	**Small Business**	**Formal Employment**
Demographics (X_6)						
Age of the household head	-0.003 (0.008)	0.007 (0.007)	-0.004 (0.009)	-0.004 (0.008)	-0.042*** (0.013)	0.010 (0.007)
Gender of the household head	-0.822*** (0.249)	0.230 (0.214)	0.567** (0.249)	0.658*** (0.232)	1.092*** (0.340)	-0.119 (0.209)
Gender of the survey respondent	0.387 (0.326)	-0.282 (0.314)	0.382 (0.337)	0.598* (0.333)	1.490*** (0.475)	-0.209 (0.288)
Number of male adults	0.309** (0.139)	0.017 (0.119)	-0.020 (0.139)	0.033 (0.129)	0.113 (0.177)	-0.145 (0.117)
Number of female adults	-0.216 (0.136)	-0.030 (0.136)	0.336** (0.158)	-0.067 (0.137)	0.504** (0.210)	0.093 (0.121)
Household size	0.023 (0.058)	0.046 (0.059)	-0.111* (0.066)	0.049 (0.063)	-0.286*** (0.093)	0.004 (0.058)
Exposure (X_7)						
Exposed	0.740*** (0.249)	0.204 (0.279)	0.355 (0.316)	1.506*** (0.289)	1.737*** (0.534)	0.591 (0.369)
Mean	-0.237 0.808	-0.474 0.758	-1.826 0.874	-1.716** 0.777	-1.866* 1.072	-1.224* 0.669
Standard deviation of the mean	0.715*** (0.109)	0.891*** (0.109)	1.732*** (0.184)	1.201*** (0.134)	3.148*** (0.390)	0.158* (0.078)
Mean*Innovative Strategies (X_3)						
Mean* rain water harvesting	1.071*** (0.219)	0.100 (0.190)	0.505** (0.216)	-0.156 (0.197)	0.353 (0.285)	-0.131 (0.174)
Mean*search for assistance	0.343* (0.203)	0.172 (0.210)	0.401* (0.233)	0.354 (0.224)	1.658*** (0.363)	0.045 (0.196)
Mean*reduce food intake	0.263 (0.222)	-0.218 (0.203)	-0.581** (0.227)	-0.015 (0.205)	1.050*** (0.316)	-0.176 (0.177)
Mean*reduce personal expenditures	0.177 (0.215)	0.207 (0.201)	- 0.669*** (0.236)	0.121 (0.204)	-0.425 (0.293)	0.132 (0.183)
N	326	326	326	326	326	326
Chi2 difference from the baseline model	27.50*** (5)	3.56 (5)	11.14** (5)	1.93 (5)	13.10(**) (5)	2.80 (5)

Note: Note. 1) Single asterisk (*) indicates significance at the 10% level, double asterisk (**) indicates significance at the 5% level and triple asterisk (***) indicates significance at the 1% level; 2) Standard errors are reported in parentheses; 3) Baseline model is specified as a probit model without random intercept and its interactions.

Dry Period Scenarios

<u>A Brief Description of Current Climate in Willowvale</u>

Rainfall
Willowvale normally receives most rainfall during the summer. But it experiences dry periods as well as wet periods during the summer rainfall season (November to March).

Temperature
Normally the region is hottest during the summer rainfall season and is sometimes exposed to heat waves

Scenario
Imagine that the summer climate in Willowvale is going to change in the future. Typically there are 5 dry periods **<u>during November to March</u>** in Willowvale, where it doesn't rain much (less than 5 mm of rainfall) for 5 consecutive days. In the next ten years, imagine that instead of 5, there will be 14 dry periods. Temperature will remain as usual during these periods.

(Q.1) In response to these changes, which of the following adaptation strategy or strategies would you consider? Tick columns.

Would you,	Yes	No	If yes, what exactly would you do?	If yes, why would you do it?
(Q.1d) increase the use of rain water harvesting (e.g. Jojo tanks)?				
(Q.1h) increase efforts to obtain external assistance? (Grants, Government, NGOs)?				
(Q.1i) reduce food intake?				
(Q.1j) reduce personal expenditure?				

(Q.2) As mentioned earlier, in the next ten years, imagine that instead of 5, there will be 14 dry periods. Temperature will remain as usual during these periods. Considering the potential impacts of this change on your household, which of the following livelihood activity or activities would you undertake during the next ten years *(please put X where relevant)*?

Q.2a Dry-land Ag	Q.2b Gardening	Q.2c Livestock	Q.2d Natural resource harvesting	Q.2e Casual labor	Q.2f Small Business	Q.2g Formal job

Figure 3.1: Sample of questions used to elicit households' stated choices of future livelihood activities

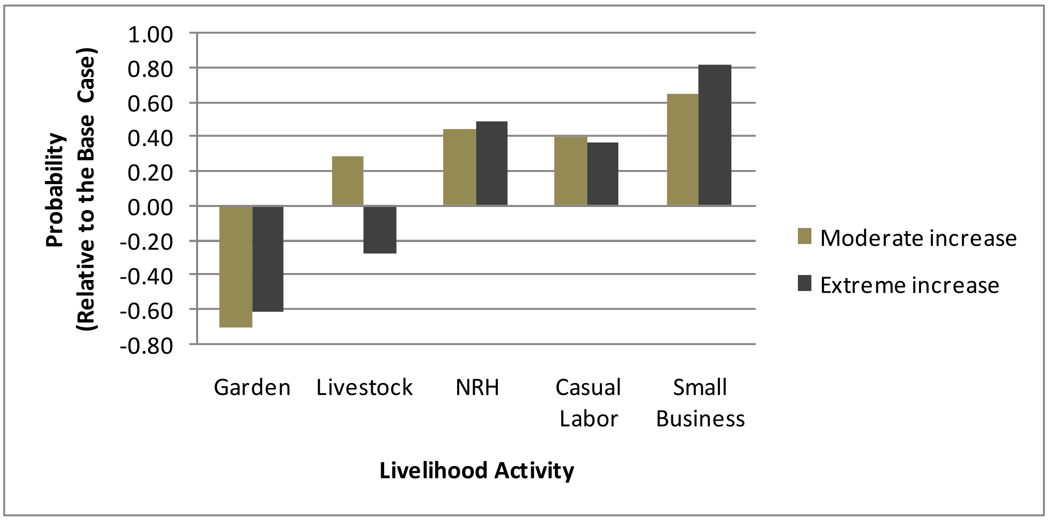

Figure 3.2: Adoption of livelihood activities in response to an increase in dry-spells

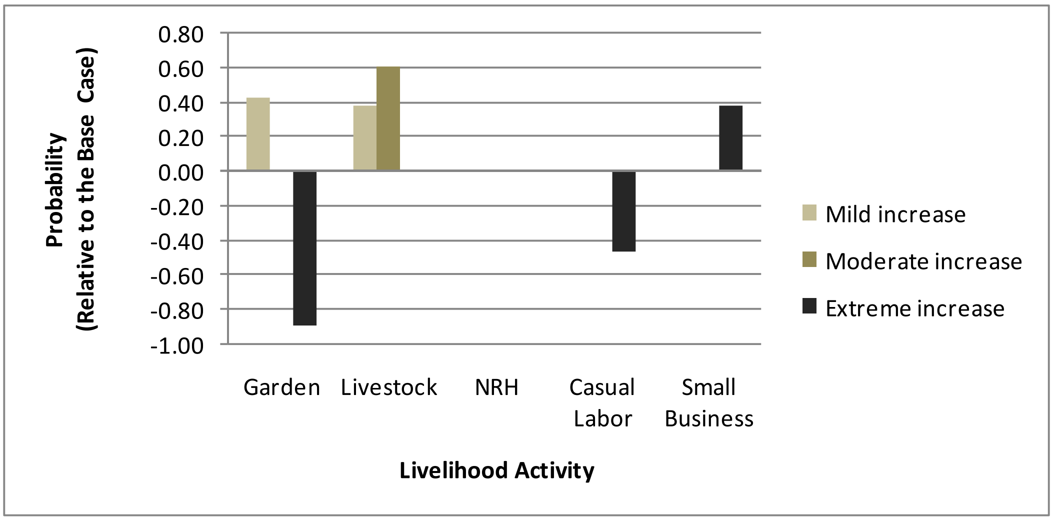

Figure 3.2: Adoption of livelihood activities in response to an increase in wet-spells

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Chapter 4: Gender, Household Innovations and Climate Change: A Contingent Behavior Study of South African Households

4.1 Introduction

Innovations adopted by households can be critical safeguards against the adverse effects of climate change. For example, studies have shown that innovations have been successful in increasing household food productivity and income in the face of adverse changes in climatic conditions (e.g. Falco et al. 2011; Molua, 2002). These innovations refer to a wide array of activities that households adopt, encompassing technological changes (e.g. adoption of new crop varieties), adjustments in existing technologies (e.g. change in planting and harvesting dates), adjustments in household labor supply (e.g. increase in supplying labor in off-farm labor markets) and changes in household expenditure patterns (e.g. reducing personal consumption).[18]

In this study, we test the hypothesis that innovations are gender specific. Gender differences in innovations may occur due to three main reasons. First, men and women often have unequal access to productive resources that can be important inputs necessary for the adoption of innovations. Second, men and

[18] The adjustments that households may adopt in response to future climate change may not be totally new to them. For example, households may change the crops in response to future reduction of rainfall. However, households may have already done the same adjustment during past droughts. Accordingly, our definition of innovations may be narrower than the standard definitions of innovations used in the economic literature (e.g. Feder and Umali 1993).

women may adopt innovations that are closely related to the specific gendered tasks they have taken responsibility for within the household. Third, men and women may have different preferences in allocating household resources towards alternative activities.

The consequent differences in innovation patterns across genders can have large welfare implications. Depending on the specific innovation to be promoted, welfare policies may need to target a specific gender. Policies that target men, to promote the innovations that are 'owned' by women, and vice versa, may cause misallocations of scarce aid resources. Moreover, differences in the adoption of innovations between men and women may contain implicit information about asymmetries in household resource allocations within and across households. For example, women's lack of adoption of off-farm labor market activities as a way of coping with adverse climate change may be symptomatic of the time scarcity that women face within households, as well as potential disadvantages they face in off-farm labor markets. A lack of understanding of these issues can hinder policy intervention and may even exacerbate the problem. For instance, if policy variables (such as transfers of subsidies) are correlated with resource access, task assignment, or preferences then they may have second order unintended consequences on adoption.

Based on the importance of gender differentiated innovation patterns, several studies have attempted to incorporate gender dimensions into adoption models. To this end, some studies include the gender of the household head in empirical models (e.g. Hassan and Nhemachena 2008; Deressa et al. 2009). Such studies often find that female-headed households are less likely to adopt innovations than male-headed households (e.g. Smale et al. 1991). However, these studies have not revealed adoption behavior of women living in male-headed households or men living in female-headed households. Some other studies seek to identify gender differences in adoption of innovations by including the gender of the individual adopting as an explanatory variable (e.g. Swai et al. 2012). These studies, however, do not distinguish between the adoption behaviors of men or women who live in male-headed households and female-headed households. Particularly, the constraints faced by women could vary depending on the type of headship of the household where they live (Doss and Morris 2001). Generally, the constraints faced by women in female-headed households in accessing productive resources are considered to be more severe (Doss 1999). In order to obtain a more complete picture of gender differentiated innovation patterns, studies need to incorporate the gender of the household head and the gender of the individual simultaneously in adoption models. However, despite a growing body of literature on households' innovations in response to climate change, no study investigates the differences in the adoption of innovation between men and women who live in households with different headships.

Ideally, understanding gender differentiated adaptation to climate change requires time series data on households' behavioral responses to clearly varying shifts, variability, and extreme events in climate (Chambwera and Stage 2010; Smit and Wandel 2006). However, such data is usually not available, particularly in developing country contexts. Most of the literature on this issue, therefore, relies on variability in weather across climate zones in cross sectional data as a proxy for the effects of climate change on households' economic behavior (e.g. Mendelsohn et al. 1994, 1996; Seo et al. 2005). This approach has limited previous studies in several ways. First, the literature fails to consider adoption of innovations in response to changes in specific climate variables that may not be reflected by varying weather across geographic spaces, but that vary over time. Second, in order to get sufficient variability in weather variables that vary across space, the empirical models require data to be collected across large geographical areas. Third, with a reliance on cross sectional data, innovative responses identified by the studies are limited to current activities of households. That is, cross-sectional data precludes the adoption of innovations that people may use in the long-run, but may not use currently.

In this paper, we use an alternative approach based on the contingent behavior method. The contingent behavior method is a stated preference technique that is used to assess individual's behavioral responses to a given change in environmental conditions (Morton et al. 1995). Using a hypothetical scenario that explains the status quo and a change from the status quo, the contingent behavior method directly elicits the information about the behavior of individuals under the new state (Whitehead et al. 2010). Accordingly, the contingent behavior method is similar to the other stated preference methods, such as contingent valuation and choice experiments, in a sense that individuals do not make actual behavioral changes, but individuals state their behavioral responses to proposed environmental changes.

The contingent behavior method offers two advantages in evaluating the efficacy of household innovations in response to climate change. First, the method can exploit variability in climatic conditions incorporated into the study design as future scenarios and, therefore, is not reliant on cross sectional climate variability. Thus, the method does not require sampling over a large geographical area and can also include time varying climate variables that do not change across space. Second, the contingent behavior method can yield information about long-run behavioral responses to climate change. Due to its flexibility, the contingent behavior method has been used widely in developed economies in order to assess changes in recreation demand in response to changes in environmental conditions, (e.g. Richardson and Loomis 2004; Chase et al. 1998; Christie et al. 2007; Cameron et al. 1996).

The contingent behavior method may have some limitations. A major concern may be whether model estimates of the contingent behavior studies subject to hypothetical bias. However, Hanley et al. (2002) in assessing changes in trip frequency by beach users in relation to environmental quality conclude that contingent behavior models do not suffer from hypothetical market bias. Further, Richardson and Loomis (2004) compare stated preference and revealed preference analyses in visitation behavior in response to changes in climate, and find that the two approaches produce statistically identical estimates of future visitation. Another issue is whether preferences regarding unfamiliar or complex goods or attributes are well-formed and consistent (Groom et al. 2007). However, this limitation could be minimized by proper designing of contingent behaviour questions.

The main objective of this study is to examine, empirically, differences in the adoption of innovations in response to climate change between men and women using the contingent behavior method. Based on a household measure of the amount of male presence, we focus on men and women who live in different headship types. We hypothesize that asymmetries in resources allocations between men and women, within and across households, could vary depending on the degree of male presence in the household. The use of contingent behavior data allows us to identify gender differentiated patterns in the innovations that households may use in the long-run, but may not adopt currently. Our econometric approach explicitly models the simultaneous adoption of innovations, and allows for correlations among the unobserved attributes of the respondents. To our knowledge, no study has previously used the contingent behavior method to investigate the adoption of gender differentiated innovation patterns in response to future climate change.

In addition to investigating gender differentiated innovation patterns, we are particularly interested in the effects of three sets of factors on the adoption of innovation in response to climate change. First, we investigate whether different types of future climate change may lead to the adoption of different innovations. Second, we seek to exploit the role of capital stocks on adoption. Third, we examine effects of individual specific characteristics such as risk aversion, and health status and household specific factors such as household size, and composition on adoption of innovations. The contingent behavior method allows us to treat the explanatory variables as exogenous.

We designed and deployed our contingent behavior survey in the Eastern Cape Province of South Africa in 2011. The Eastern Cape, with a population of approximately seven million, is the poorest province in South Africa, The region is predicted to be highly vulnerable to climate change, with the western sections getting hotter and drier, while the coastal zone in the east experiencing an increase in later summer rainfall, floods, greater variability in climate and rising sea levels (Pyle 2007). The Eastern Cape also has high HIV prevalence, with rates that were predicted to peak at just over 20% for the adult population by 2012 and at over 30% for adult woman (UNAIDS 2007). The contingent behavior survey design yields a total of 326 observations and exploits detailed information on households' contingent choices on the adoption of different innovations (e.g. changing crops, changing planting dates, increase in use of domestic rain water harvesting, etc.) across a grid of climate scenarios.

The rest of the paper is organized as follows. In section 4.2, we discuss the background on gender relations in the context of developing countries. In section 4.3, we present our conceptual approach. Section 4.4 and 4.5 describe data collection and our empirical approach respectively. In section 4.6, we present our empirical findings, and we conclude in section 4.7.

4.2 Background on gender relations in developing countries and the South African context

Access and ownership of productive resources are vital for the adoption of innovations. Access to land is fundamental to adopt agricultural innovations such as crop diversification, crop-livestock integration, and changing crops and crop varieties (FAO 2011). Household labor endowments are also important because of the non-substitutability of own and hired labor and for diversifying earnings into off-farm and migrant labor markets (Doss 1999). Access to input and output markets are important for mobilizing land and labor endowments, aligning production incentives, and directly facilitating innovations such as planting modern seed varieties, fertilizers, and irrigation technologies (Zeller et al. 1997; Doss and Morris, 2001). Similarly, credit and insurance markets are critical for financing operating costs of the innovations and for offsetting the risks of adopting new innovations (Simtowe et al. 2006).

However, as is well known, the control over productive assets and access to markets varies significantly between men and women in developing countries. Within individual households, women usually have less access and control over productive assets than men (Doss 2001a; Fafchamps and Quisumbing 2002). This is particularly true in the case of land and labor resources. Cultural norms often do not allow women to inherit land (Horrell and Krishnan 2006; Seebens 2011). Women may sometimes obtain rights to use land, either for household or personal crops, only through men (Abbas 1997; Mehra 1995). Land cultivated by women tends to be smaller (FAO 2011). Further, landholdings of women tend to be less fertile compared to those of men (Barnes 1983; Alwang and Siegel 1994; Gladwin 2002). Women also face gender-specific constraints as family laborers and in hiring non-family labor (Dolan 2004; Doss 1999). Low levels of human capital may affect negatively on women's labor productivity (Quisumbing and Pandolfelli 2010). Differential access to labor may reduce productivity of women controlled plots (Udry 1996).

The disadvantages that women face relating to resource allocations could extend beyond the households. In some economies, social norms limit women's access to communal lands by upholding male authority (Kevane and Gray 1999; Lele 1986). Women's land rights are often less secured than men's (Meinzen-Dick 1997; Deininger et al. 2006). Insecure land rights can translate into credit constraints for women since land is used as collateral by rural financial markets (Migot-Adhollaet al. 1991). Women may also be disadvantaged in finding employment outside the household, particularly in the formal wage sector (Fortin 2005; Brown and Haddad, 1995; Fafchamps and Quisumbing 1999). Women also receive fewer visits from extension workers compared to men (Doss and Morris 2001; Arun 1999). In output markets, compared with men, women often receive lower prices (Randriamaro 2006). In input markets, women receive less fertilizer for their land as compared to male controlled plots (Udry 1996). Communal water is often controlled by men and thus limited in its access to women (Seebens 2011).

In the household, men and women may be involved in different activities and tasks. Such gender division of labor may originate from social and cultural norms prevalent in rural economies (Pant 2000). In the context of rural Africa, women are primarily responsible for domestic work, such as fostering children, cooking, cleaning, and fetching wood and water (Pant 2000; Sikod 2007). Men, on the other hand, are mainly responsible for providing cash income to the household, and hence involved in activities such as growing cash crops and supplying off-farm labor (Doss 2001b; Ilahi 2000; White et al. 1981). However, women also play a dominant role in production (FAO 2011; Campbell 2002). They generally take up activities such as growing subsistence crops, and raising small livestock (Gladwin et al. 2001; Kristjanson et al. 2010). In recent years, women are increasing taking part in cash-oriented production activities, such as cultivating plantation crops and doing small business (Doss 2001b; Berger and White 1999; Guyer 1980). Within the African context, women and men may also undertake different tasks relating to productive activities. In crop framing, in most areas in Africa, women undertake activities such as planting, harvesting and threshing, while men undertake activities such as land preparation, irrigation, selling, and supervising (Netting 1993). Considering livestock, for example in Kenya, men dominate in activities such as grazing and watering the herds (mainly cattle), and prevention and treatment of diseases, while women dominate activities such as fodder and manure collection, milking and selling milk (Wangui 2003).

Men and women may also have different preferences in allocating household resources. Women's control over household resources has been found to have positive effects on household food expenditures, household calorie availability, and child health and nutrition outcomes (Quisumbing 2003; Smith 2003; World Bank 2001; Hoddinott and Haddad 1995; Thomas 1990). For example, the greater a woman's asset holdings at marriage, the larger the share the household may spend on children's education (Quisumbing and Maluccio 2003b). In Bangladesh, a higher share of women's assets is associated with better health outcomes for girls (Hallman 2000). However, welfare gains driven by women are not often identical towards girls and boys. For example, some studies find that women allocation of resources benefit boys over girls (e.g. Haddad and Hoddinott 1994) while others find the opposite effects (Duflo 2000). In contrast, men's assets holdings have been found to increases the share spent on leisure goods such as alcohol and tobacco (Quisumbing and Maluccio 2003a).

4.3 Conceptual Framework

4.3.1 Innovation likelihood

We consider a standard technology adoption framework (Hubbell et al. 2000) whereby an individual adopts an innovation if the utility or benefit from the adoption is at least as great as the utility of not adopting. The individual's decision is modeled using the random utility model, with utility specified as,

$$U = V(A, C_A, y_A; X) + \xi_A \qquad (4.1)$$

where V is potentially observed by the analyst, while ξ_A is an unobserved, independent and identically distributed (iid) and zero-mean component; A = 1 indicates adoption of an innovation by the individual and 0 indicates non-adoption; C_1 and C_0 denote vectors of expected consumption volumes, and y_1 and y_0 denote expected net income levels (inclusive of profits) under adoption and non-adoption scenarios; and X is a matrix of explanatory variables that affect individual consumption and net income. Some innovations will be chosen based on direct gains to consumption, for example, an individual may increase harvesting of natural resources to be used for home consumption. Other innovations, such as increase in the participation in off-farm employment, may be chosen based on their contribution to the net income component. Still other innovation, such as changing crops, may be adopted due to their contributions to both the consumption and net income components of benefits under a given future climate scenario. Given this setup, an individual will adopt an innovation if,

$$V(1, C_1, y_1; X) + \xi_1 \geq V(0, C_0, y_0; X) + \xi_0 \; . \qquad (4.2)$$

In our data we do not observe differences in either expected consumption levels or expected profits due to adoption. However, as argued by Qaim and de Janvry (2002), these variables can be explained by observed individual and household characteristics, so that the consumption and net income differences caused by the innovation are implicitly embedded in reduced form within the matrix of explanatory variables, X. We assume an individual's indirect utility to be a linear function of X and characterized by parameters β_i. We calculate the probability that a household adopts a specific livelihood activity, A, as

$$\Pr(A=1) = \Pr(U(1) \geq U(0)) \qquad (4.3.1)$$
$$= \Pr[(\xi_0 - \xi_1) = \xi \leq X'\beta = (X'\beta_1 - X'\beta_0)]$$
$$\Pr(A=1) = F(X'\beta) \qquad (4.3.2)$$

where F denotes the cdf of ξ .

Households in the rural communities we study, consume a significant proportion of their own output. The households are also located in areas where poor transportation and infrastructure restrict market participation. Failures of labor and credit markets are common to many of these households. With market failures, the household's consumption, production and labor allocation decisions become interlinked through the price of nontradables (see de Janvry et al. 1991). Consequently, the same set of factors drive both utility and profit maximization. Production side variables, such as fixed land size, affect consumption decisions. Similarly, consumption side variables, such as illness of household members and household size, affect production decisions (beyond the direct labor productivity channels) and, thereby, profits.

4.3.2 Incorporation of gender into the adoption model

Based on potential differences in constraints and preferences discussed in section 4.2, we expect that probability of adoption of innovations may differ between men and women. Further, we believe that constraints and preferences, and thereby the adoption probabilities, may also vary within group of men and women depending on the type of household headship that govern their households. Depending on the amount of adult male presence, we distinguish four household headship types. The first category (a), with the highest adult male presence, is male-headed and has the male spouse and other male adults present. The second category (b), with the second highest adult male presence, is male-headed without other male adults present. The third category (c), with the third highest adult male presence, is female-headed with other male adults present. The category (d), with no adult male presence, is female-headed without a male spouse and no other male adults are present. The first three headship types may contain male or female respondent or both, while the forth type has only a female respondent. Accordingly, the respondents regarding adoption of innovations can be grouped into seven different gender structures: 1) males in male-headed households with other male adults; 2) females in male-headed households with other male adults; 3) males in male-headed households without other male adults; 4) females in male-headed households without other male adults; 5) males in female-headed households with male adults; 6) females in female-headed households with male adults; 7) females in female-headed households without male adults. In order to examine gender differentiate patterns of adoption of innovations, we will compare the probabilities of adoption across these seven gender structures.

4.4 Data Collection

The data collection for this study was undertaken, using household surveys, in villages located in the Willowvale area. Willowvale area is located within the former Transkei in the Eastern Cape Province of South Africa. The area consists of low density rural settlements, surrounded by communal areas used for agriculture and grazing. Poor condition of roads and limited access to basic services such as schools add to the economic challenges of the local population. This area shows a high dependency on natural resources alongside multiple productive activities livelihood strategies such as livestock production, gardening, and small business.

Data collection took place in two phases. The first phase, i.e. the base-line survey, was undertaken during January and February, 2011. The sample contained

170 households randomly selected within the villages, stratified by the percent of the population in each village. The data on different types of capital stocks, and household demographics were collected in the base-line survey. The second phase was undertaken during July and August, 2011, to collect data on household contingent behavior to future climate change and risk aversion.

In rain-fed systems, such as the case in the Willowvale, the frequency in the occurrence of dry/wet periods can be crucial for crop and livestock production. Households in such economies may base their production decisions on events such as rainfall frequency, timing, and intensity (Smithers and Smit 1997; Roncoli et al. 2002; Vogel and O'Brien 2006; Thomas et al. 2007). Accordingly, as a part of our contingent behavior approach, we characterize the future with two types of climate change scenarios; dry-spell and wet-spell. These scenarios are constructed to represent plausible changes in rainfall that occur during the rainy season in the Willowvale area (i.e. November to March). Following the Southern African research of Usman and Reason (2004), we defined a dry-spell as a period of 5 consecutive days which receives less than 5 mm of rainfall. There are two types of dry-spell scenarios, one in which temperature remains normal during the dry periods, and one in which temperature can reach a high of 37^0C. A wet-spell, following Hachigonta and Reason (2006), was defined as a period of five consecutive days which receive more than 20 mm of rainfall. The temperature remains as usual during the wet-spells. Relevance and credibility of the definitions of dry and wet spells that we used in the context of our study sites were verified by the local agricultural extension officers and survey respondents during the pre-test of the survey. Based on existing climate studies (e.g. Reason et al. 2005; Cook et al. 2004; Dai and Trenberth 1998; Hachigonta, and Reason 2006), we specify a baseline and plausible changes in dry and wet- spells in the future as mild, moderate and extreme change. Accordingly, we have six scenarios, as follows:

1) a mild increase in the number of dry-spells (increase of dry-spells from 5 to 8);

2) a moderate increase in the number of dry-spells (increase of dry-spells from 5 to 11);

3) an extreme increase in the number of dry-spells (increase of dry-spells from 5 to 14);

4) a mild increase in the number of wet-spells (increase of wet-spells from 5 to 8);

5) a moderate increase in the number of wet-spells (increase of dry-spells from 5 to 11); and

6) an extreme increase in the number of wet-spells (increase of wet-spells from 5 to 14).

Figure 4.1 shows, the questions that were used to collect the contingent behavior data for a given climate scenario. The first section in the Figure 4.1 shows the information that was given to the respondents regarding the typical climate of the study area, followed by a description of a specific future climate change scenario. For example, for the case illustrated in Figure 4.1, the future climate change is specified as an extreme change in the frequency in the occurrence of dry-spells for normal temperature. Parts of Q.1 show the questions used to collect the data on individual's adoption of innovations. We have data on binary adoption decisions related to ten types of innovations which will serve as the dependent variables for our empirical models: 1) changing crops; 2) changing planting and harvesting dates; 3) changing livestock breeds; 4) increase the use of rain water harvesting methods; 5) increase of the use of soil moisture conservation methods in farming; 6) increase natural resource harvesting; 7) increase involvement in off-farm employment; 8) increase efforts to obtain external assistance; 9) reducing food intake; and, 10) reducing personal expenditures. These innovations were identified in the first phase of the survey, based on households historical coping behaviors with climate change related shocks.

Out of 170 households that were surveyed during the first phase, 157 households participated in the second phase. Each contingent behavior questionnaire was designed to elicit responses from an adult male and from an adult female in each household. Among the 157 households that we interviewed in the second phase, there were 30 households in which both an adult male and an adult female were available during the survey. Consequently, 187 individuals participated in the survey.

Each respondent answered one out of three possible dry-spell scenarios and one out of three possible wet-spell scenarios. Accordingly, all together, we have contingent behavior data form 374 observations. The individuals were randomly assigned to different versions of contingent behavior questionnaires.

4.5 Empirical Approach

There are ten potential innovations to be adopted, hence, ten equations to be estimated. Due to the possibility of simultaneous adoption of multiple innovations, it is possible that errors of the adoption equations are correlated. Allowing for such contemporaneous correlation could increase the efficiency in parameter estimation. In doing so, directly based on equation 4.3.2 in our conceptual model, we employ a multivariate probit model of innovation adoption as follows.

$$A_i^* = x_i\beta + \varepsilon_i \text{ with } A_i = \begin{cases} 1 \; if \; A_i^* > 0 \\ 0 \; otherwise \end{cases} \tag{4.4}$$

In equation 4.4, the latent variable, A^*, characterizes the net utility (benefit) of adoption. A_{ij} is an observed variable, that indicates whether a household adopts an innovation (A_{ij}=1), if $A_{ij}^* > 0$, and 0 otherwise (j=10). X represents variables that affect the expected utility of adoption, β_j is a vector of parameters to be estimated, and ε_{ij} is the unobserved error term which is assumed to have multivariate normal distributions with mean vector equal to zero and a covariance matrix R with diagonal elements equal to one. We can obtain the effects of the variables contained in vector X on the household's adoption decision and the variance covariance matrix of the multivariate normal distribution of the error terms by estimating equation 4.4.[19]

Table 4.2 describes the explanatory variables and their expected signs in the ten adoption models. We organize our explanatory variables with six categories (X_i; i=1-6). First, to test our hypotheses on impacts of gender structure (X_1), we include six dummy variables that represent gender structures 2-6 described in sub-section 4.3.2. The gender structure 1, i.e. male in male-headed

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[19] The Model was estimated using simulated maximum likelihood method in STATA 12 (see Cappellari, L. and S. Jenkins 2003).

households with adult males present, is considered as the base case. We assume that men and women are likely to adopt innovations that are closely related to their tasks and preferences subject to the resource constraints they face. Accordingly, we compare the adoption probabilities across different gender structures, relative to the base case. We expect that different gender structures affect differently on the adoption of a particular innovation.

In our study sites, crop cultivation is mainly done in home gardens. Previous studies find that, in Africa, women are more involved in gardens than men (Campbell et al. 2002; FAO 2011). However, the adoption of innovations related to gardening may require access to productive resources such as land, inputs, and extension services (Shiferaw et al. 2009; Diederen et al. 2002). Moreover, as notated in section 2, women may often be disadvantaged with respect to ownership and access to productive resources outside the household. We assume that the presence of an adult male in the household may improve women's access to productive resources. Accordingly, we expect that women living in male-headed households, and female-headed household with adult males present are more likely to change crops, planting and harvesting dates, and increase the use of moisture conservation methods.

Resource constraints could negatively affect the adoption of rain water harvesting (Shikur and Beshah 2013). Hence, we expect that women in female-headed households without adult male presence are less likely to increase the use of rain water harvesting. Due to high vulnerability, we expect that women in female-headed households without adult male presence are more likely to increase the efforts to obtain external assistance, reduce food intake, and reduce personal expenditures. In rural Africa, although women are involved in tasks relating to livestock production, they are less likely to own livestock relative to men (FAO 2011; Covarrubias et al. 2012). Accordingly, we expect that women in all types of household headships are less likely to change livestock type in response to future climate change. Within the household, women are generally considered to be responsible for collecting natural resources such as firewood and wild foods (Wan et al. 2011; Musaba and Sheehama 2009). Therefore, we expect that women living in all types of households are more likely to increase natural resource harvesting relative to the base case. Further, women may have limited employment opportunities in the off-farm sector (Fortin 2005; Brown and Haddad 1995; Fafchamps and Quisumbing 1999). Accordingly, we expect that women in all headship types are less likely to increase their involvement in off-farm employment in response to future climate change. Other than those described above, we have no further expectations on the signs of gender structures on the adoption of innovations.

Second, to test the impacts of climate change (X_2), we include five dummy variables related to scenarios, 2 - 6 given earlier. Scenario 1, which represents the least change in the current climate of the study area (i.e. an increase in the number of dry-spells from 5 to 8), is chosen as the base case. We also include a dummy variable to indicate whether or not heat waves occur during the dry-spells. We expect that, people are more likely to change planting and harvesting dates, crops, and livestock in response to a moderate and extreme increase in dry and wet-spells relative to the base case. We also expect that people are more likely to increase the use of soil moisture conservation and rain water harvesting methods in response to an increase in dry-spells, and to decrease the use of these innovations in response to an increase in wet-spells. Natural resources, such as forest and ocean products, may be easily accessible under dry climatic conditions (Eaton and Sarch 1997). Further, less interruption from rains and lack of agricultural activities during dry-spells may ensure that people have more time to spend on off-farm activities. Taken together, we expect that people are more likely to increase natural resource harvesting, and involvement in off-farm employment in response to an increase in dry-spells. In contrast, frequent rains may limit accessibility of forests, and time available for off-farm activities, and increase the payoff from agriculture. Therefore, we expect that people are less likely to increase natural resource harvesting, and involvement in off-farm employment in response to an increase in wet-spells. We do not have *a priori* expectations on the sign of the climate change variables on the probability of the adoption of other innovations.

Third, there are a number of different types of capital stocks (X_3) that could influence the adoption of innovations, including human, social, physical, and natural, capital. For human capital, we include individual's education, and a dummy variable that indicates whether or not people are endowed with skills. For social and physical capital, we use indexes generated by using principal component analysis (see appendix A). For natural capital, we use the size of agricultural land owned by the household. Studies find that human and social capital may be important in finding off-farm employment (Zhang et al. 2001). Accordingly, people with more of these stocks are expected to be more involved in off-farm employment. Social capital may also facilitate an individual's search for external assistance during shocks. Hence, individuals with more social capital endowments are expected to be more likely to increase efforts to obtain external assistance. Agricultural land and physical capital may represent the wealth of the household which could be important in adopting agricultural and capital intensive innovations (Doss and Morris 2001). Therefore, we expect that people with more of these capital stocks are more likely to change crops, planting and harvesting dates, livestock, and to increase the use of soil moisture conservation methods and rain water harvesting methods. Studies argue that people endowed with greater amounts of capital stocks are less vulnerable during the periods of adversities (e.g. Fussel et al. 2006; Jakobsen 2011; Ludi and Slate 2008). Accordingly, we expect that people with more of all types of capital stocks are less likely to reduce food intake, and personal expenditures, in response to future climate change.

Fourth, we include a variable that indicates the level of risk aversion of the individual (X_4).[20] Climate change may be associated with different types of risks such as losses in agricultural production, instable input and output prices and health risks. We believe that, increasing efforts to obtain external assistance, reducing food intake, and reducing personal expenditures may involve minimal

[20] Data on this variable were collected using a set of risk gamble questions that are analogues to the questions used in Spivey (2010). Based on the answers given to the risk gamble questions, each respondent was categories into one out of four categories: weakly risk averse (1); moderately risk averse (2); strongly risk averse (4) and very strongly risk averse (See appendix B).

risk. Hence, it is expected individuals who are more risk averse are more likely to adopt these innovations than individuals who are less risk averse. Such relationships are difficult to ascertain for innovations that may involve more risk, such as changing planting and harvesting dates, and changing crops. Therefore, we do not have expectations on the effect of individual's risk aversion on the other innovations.

Fifth, in order to capture the potential effects of individual's health status on adoption of innovations, we include a dummy variable that indicates whether the individual is suffering from long term illness (X_5).[21] Illnesses of household members may limit the choices that people have for their livelihoods. Individuals who suffer from long-term illness are likely to be physically unfit, and hence unlikely to actively participate in on-farm and off-farm activities (Bollinger et al. 1999). Therefore, we expect that individuals with long-term illnesses are less likely to change crops, planting and harvesting dates, livestock breeds, and to increase the use of soil moisture conservation methods and involvement in off-farm employment. Under such circumstances, wild foods could provide an alternative source of food (Feulefack et al. 2013). Therefore, individuals with long-term illnesses are expected to be more likely to increase natural resource harvesting. Also, due to their greater vulnerability to climate change impacts, we expect that individuals with long-term illnesses are more likely to increase efforts to obtain external assistance. We do not have *a priori* expectations on the effect of individual's health status on adoption of other innovations.

[21] Individual's health status can also be considered as a component of human capital (Bleakley2010).

Sixth, we include four demographic variables, (X_6): 1) age of the individual; 2) number of teen males (aged 10-16 years) in the household; 3) number teen females (aged 10-16 years) in the household; and 4) household size. Age of the individual can be used to capture farming experience (Deressa et al. 2009). Previous studies find that experience in farming increases the probability of undertaking innovations in response to climate change (e.g. Maddison 2007; Hassan and Nhemachena 2012). Accordingly, we expect that older people are more likely to change crops, planting and harvesting dates, increase the use of soil moisture conservation methods. Previous studies have found that women and children often seek out forest resources such as wild foods (e.g. Dovie et al. 2002; Shackleton et al. 2002). Based on such findings, we expect that household size and the two child profile variables to have positive effects on increasing natural resource harvesting. Larger households may indicate a greater stock of family labor that may be complementary to adopting agriculture based innovations (Croppenstedt et al. 2003). Household labor endowments may also affect positively adoption of rain water harvesting methods (Shikur and Beshah 2013). Moreover, in order to reduce consumption pressure, large households are more likely to divert household labor resources to off-farm activities (Yirga 2007). Taken together, we expect that household size will positively affect changing crops, planting and harvesting dates, and livestock breeds, increasing of the use of soil moisture conservation methods, rain water harvesting methods and involvement in off-farm activities.

4.6 Results

The parameter estimates from the multivariate probit model is presented in Table 4.2. The null hypothesis that contemporaneous error correlation is equal to zero is rejected at 0.05 probability level. This confirms that estimating the adoption equations as a system is more efficient than estimating them separately. Most of the regression coefficients are statistically significant and have the expected signs. Below, we discuss the effects of gender structure, climate variables, household and individual specific variables, and correlations between adoption of innovations.

4.6.1 Effects of gender structure on the adoption of innovations

As shown in Table 4.2, most of the dummy variables used to represent different gender structures are statistically significant in the ten adoption models, and the effects vary depending on the type of innovation. The findings on the impact of gender structure on changing crops are mixed. Relative to the base case (men in male-headed households with other male adults present), men and women in male-headed households without other adult males present, and men in female-headed households are more likely to change crops. However, women in all four headship types, relative to the base case, are more likely to adjust planting and harvesting dates. Women in male-headed households with other male adults present innovate also by increasing the adoption of soil moisture conservation methods. Taken together, these results imply that, in economies such as rural South Africa, women are more involved in crops than men. Alternatively, these results suggest that women are usually more likely to innovate in crop cultivation than men. Women, particularly the ones that live in male-headed households are less likely to change livestock breeds. This result implies that women may be less involved in livestock production, and hence may not make decisions on the breeds of livestock to be raised.

Women in male-headed households with other adult males present and in female-headed households without adult male presence are less likely to increase the use of rain water harvesting methods. This result suggests that women may not undertake capital intensive innovations when adult males are available in the households. Further, this result may also reflect the constraints that women face in accessing information and credit markets in the absence of adult male presence in the household. Women in male-headed households with other adult males present and in female-headed households without adult male presence are also less likely to increase their involvement in off-farm employment. This result is consistent with the notion that women face disadvantages in finding off-farm employment in developing economies (e.g. Fortin 2005; Brown and Haddad 1995).

In the absence of the opportunities in off-farm activities, women seem to adopt alternative types of innovations. To this end, women that live in male-headed households and female-headed households without adult males present are more likely to increase natural resource harvesting and reduce food intake. Women that live in female-headed households without adult male presence also tend to reduce food intake, personal expenditures and increase the efforts to obtain external assistance. However, our results show that women that live in male-headed households with other adult males present, and in female-headed households with adult males, are less likely to increase the efforts to obtain external assistance. A possible reason for this result may be that women are less involved in interacting with the external environment when adult males are present in the household. We also find that men living in male-headed households without adult males are more likely to increase the efforts to obtain external assistance.

4.6.2 Effects of climate variables on the adoption of innovations

As can be seen in Table 4.2, the effects of climate variables on adoption vary depending on the type of innovation. In response to a moderate increase in the number of dry-spells, people are more likely to change crops and livestock breeds, relative to the base case. This result may indicate that, people switch to drought tolerant crops and livestock in response to the decrease in the water available for farming. People are also likely to increase of the use of soil moisture conservation methods. Application of moisture conservation practices may decrease the vulnerability of plants to dry climatic conditions.

Under a moderate increase in the number of dry-spells, people also tend to increase the use of rain water harvesting methods and natural resource harvesting, and to decrease food intake. Domestic rainwater harvesting is considered as one of the effective technological innovation that can be used to cope with future climate change (Pandey et al. 2003; Mukheibir 2008). People may use harvested rain water in small garden plots (Worm and Hattum 2006). Wood, the main natural resource based product in the study area, is dried and stored during the dry seasons to be used in the rainy seasons (Brouwer and Hoorweg 1997). Therefore, dry climatic conditions may induce people's use of natural resources. Reducing food intake may also accompany the innovations that people may adopt in response to a moderate increase in dry-spells.

In response to an extreme increase in the number of dry-spells, people tend not to adopt agriculture-based innovations. For example, relative to the base case, people are less likely to change livestock breeds in response to an extreme increase in dry-spells. Under extremely dry climatic conditions, innovations within agriculture such as changing crops and livestock breeds may not be effective. Consequently, people seem to be more likely to reduce food intake and personal expenditures, and increase the efforts to obtain external assistance.

Under wet-spell scenarios, our results show that in response to a mild and a moderate increase in the number of wet-spells, people are more likely to adjust planting and harvesting dates. The availability of water for longer periods during the cropping season may ensure enhanced performances in current crops. However, planting and harvesting dates may need to be adjusted according to increases in the wet-spells. Different from the responses to a mild increase, people are more likely to change crops and livestock breeds in response to a moderate increase in the number of wet-spells. In order to take advantage of the increase in wet spells, people may shift to crops and livestock breeds that are resistant to wet climatic conditions. Furthermore, in response to all three types of increases in wet spells, people are less likely to increase their involvement in off-farm activities. Under the climatic conditions that are likely to be favorable for agriculture, people may not need to increase their labor supply in off-farm activities. We also find that people are more likely to reduce food intake in response to a moderate increase and reduce personal expenditures, in response to an extreme increase in wet-spells.

The dummy variable used to indicate the occurrence of heat waves during dry-spells is statistically significant and has positive signs for increasing of the use of soil moisture conservation methods and reducing food intake. Heat waves could increase the evaporation and create stress on plants. Use of moisture conservations methods such as mulching, and spreading manure may help to reduce vulnerability of plants to heat waves. Households' reduction in food intake may indicate the negative impact of heat waves on household's food supply.

4.6.3 Effects household and individual specific variables on the adoption of innovations

The effects of capital stocks vary depending on the type of capital, as well as the innovation (Table 4.2). Our results show two distinct effects regarding human capital. First, more educated people seem to be more likely to change crops, and to increase use of soil moisture conversation methods, and natural resource harvesting. Second, skilful people are more likely to increase involvement in off-farm activities than non-skilful people. People with more physical capital endowments are more likely to change crops, adjust planting and harvesting dates, and to increase rain water harvesting. Similarly, people with more natural capital endowments are more likely to change crops, and to increase use of moisture conservation methods, increase the use of rain water harvesting methods, and natural resource harvesting. Furthermore, those people who have more natural capital stocks are less likely to reduce personal expenditures.

Our results also show that more risk averse people are more likely to reduce personal expenditures, indicating that these people may attempt to offset the adverse effect of climate change at the expense of their short run economic welfare. People with long-term illnesses are more likely to: change planting and harvesting dates; increase natural resource harvesting; increase the efforts to obtain external assistance; and less likely to increase their involvement in off-farm activities. Age of the individual has a positive effect on changing crops and increasing the use of soil moisture conservation methods. This result suggests a positive effect of experience on the adoption of agricultural innovations. As expected, having male and female teenagers in the households make people more likely to increase natural resource harvesting. Household size has positive effects on increasing efforts to obtain external assistance, and reducing personal expenditures. This result may imply that the larger households could be more vulnerable to climate change than small households.

4.7 Conclusions

In this study, we test the hypothesis that adoption of innovations in response to climate change is gender specific, using the contingent behavior method. We estimate a multivariate probit model, and compare the adoption probabilities across seven gender structures. The gender structure is taken as a combination of the gender of the respondent, and the type of household headship.

In addition to gender structures, the models include other factors that drive the adoption of innovations such as climate change scenarios and capital stocks.

Our results confirm that adoption of innovations vary between men and women. For example, women, in general, are more likely to adopt innovations relating to gardens, such as adjusting planting and harvesting dates, and the use of soil moisture conservation methods. Further, the results show that adoption probabilities vary even within men and women depending on the headship structure of these households. For example, women in male-headed households without other male adults present and in female-headed households without adult male presence are more likely to increase natural resource harvesting, while women in other types of households do not show significant differences, relative to the base case. In addition to the effects of gender structures, our results also reveal the impacts of climate change variables on adoption decisions. One key finding is that people seem to adopt agriculture-based innovations in response to increase in dry-spells as well as wet-spells, except in the case of extreme increase in dry-spells. However, the specific type of innovation may vary depending on the severity of change. For example, people are more likely to adjust planting and harvesting dates in response to mild increase in wet-spells, and change crops in response to extreme increase in wet-spells.

This study contributes to the existing literature in two ways. First, we contribute methodologically to the economic literature by using the contingent behavior method to investigate adoption of gender differentiated innovations patterns in response to future climate change. The contingent behavior method has not previously been used in analyzing gender differentiated innovations patterns. Second, to our knowledge, this study is the only study that examines the differences in adoption of innovations in response to climate change between men and women who live in different headship types.

Our results have several important policy implications. First, based on our results relating to the effects of gender structures, we argue that, depending on the specific innovation to be promoted, welfare policies may need to target a specific gender structure. Second, our results indicate some specific vulnerabilities relating to women when adult males are not present in the households. For example, we find that female-headed household without adult male presence are less likely to increase the use of rain water harvesting, and involvement in off-farm employment, and more likely to increase the efforts to obtain external assistance, to reduce food intake and personal expenditures. These results reflect an underlining disadvantage that such women may face. Third, our results demonstrate that capital stocks are important for adoption. The effects of capital stocks vary depending on the type of innovation. For example, the endowments of physical and natural capital are found to be important in adopting agriculture-based innovations. Accordingly endowing households with the specific type of capital stocks may help to facilitate adoption of innovations in response to future climate change.

Table 4.1: Variable definitions and expected signs

	Dependent Variable	Change crops	Change planting and harvesting dates	Change livestock breeds	Increasing moisture conservation	Increasing rain water harvesting	Increasing natural resource harvesting	Increasing off-farm work	Reducing food intake	Reducing personal expenditures	Increase in external assistance
Explanatory Variable											
Gender structure (X_1)											
female respondent - male headed-with adult males	Female respondent in male headed households with adult males	+	+	-	+	+/-	+	-	+/-	+/-	+/-
female respondent - male headed-without adult males	Female respondent in male headed households without adult males	+	+	-	+	+/-	+	-	+/-	+/-	+/-
male respondent - male headed-with adult males (Base case)	Male respondent in male headed households with adult males	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
male respondent - male headed-without adult males	Male respondent in male headed households without adult males	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-
female respondent - female headed-with adult males	Female respondent in female headed households with adult males	+	+	-	+	+/-	+	-	+/-	+/-	+/-

Table 4.1(continued)

		Change crops	Change planting and harvesting dates	Change livestock breeds	Increasing moisture conservation	Increasing rain water harvesting	Increasing natural resource harvesting	Increasing off-farm work	Reducing food intake	Reducing personal expenditures	Increase in external assistance
female respondent - female headed- without adult males	Female respondent in female headed households without adult males	+/-	+/-	-	+/-	-	+	-	+	+	+
male respondent - female headed	Male respondent in female headed households with adult males	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-
Climate variables (X_2)											
Mild increase in dry- spells	The base case; 1= an increase in the number of dry-spells from 5 to 8, 0 = otherwise	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Moderate increase in dry- spells	1= an increase in the number of dry-spells from 5 to 11, 0 = otherwise	+	+	+	+	+	+	+	+/-	+/-	+/-
Extreme increase in dry- spells	1= an increase in the number of dry-spells from 5 to 14, 0 = otherwise	+	+	+	+	+	+	+	+/-	+/-	+/-

Table 4.1(continued)

		Change crops	Change planting and harvesting dates	Change livestock breeds	Increasing moisture conservation	Increasing rain water harvesting	Increasing natural resource harvesting	Increasing off-farm work	Reducing food intake	Reducing personal expenditures	Increase in external assistance
Mild increase in wet- spells	1= an increase in the number of wet-spells from 5 to 8, 0 = otherwise	+/-	+/-	+/-	-	-	-	-	+/-	+/-	+/-
Moderate increase in wet-spells	1= an increase in the number of wet-spells from 5 to 11, 0 = otherwise	+	+	+	-	-	-	-	+/-	+/-	+/-
Extreme increase in wet- spells	1= an increase in the number of wet-spells from 5 to 14, 0 = otherwise	+	+	+	-	-	-	-	+/-	+/-	+/-
High temperature	1= if the temperature may reach high of $37C^0$, 0 = otherwise	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-
Capital stocks (X_3)											
Education	Years of education of the respondent	+/-	+/-	+/-	+/-	+/-	+/-	+	-	-	+/-
Skillfulness	1= if the respondent is skilful, 0 = otherwise	+/-	+/-	+/-	+/-	+/-	+/-	+	-	-	+/-
Social capital	Social capital index for the household	+/-	+/-	+/-	+/-	+/-	+/-	+	-	-	+

Table 4.1(continued)

		Change crops	Change planting and harvesting dates	Change livestock breeds	Increasing moisture conservation	Increasing rain water harvesting	Increasing natural resource harvesting	Increasing off-farm work	Reducing food intake	Reducing personal expenditures	Increase in external assistance
Physical capital	Physical capital index for the household	+	+	+	+	+	+/-	+/-	-	-	+/-
Natural capital	Size of the garden plot per capita	+	+	+	+	+	+/-	+/-	-	-	+/-
Risk aversion(X_4)											
Risk	The level of risk aversion of the respondent	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+	+	+
Health status(X_5)											
Long-term ill	1= if the respondent is long-term ill, 0= otherwise	-	-	-	-	+/-	+	-	+/-	+/-	+
Demographics (X_6)											
Age	Age of the respondent	+	+	+	+	+/-	+/-	+/-	+/-	+/-	+/-
Number of male children	Number of male adults	+/-	+/-	+/-	+/-	+/-	+	+/-	+/-	+/-	+/-
Number of female children	Number of female adults	+/-	+/-	+/-	+/-	+/-	+	+/-	+/-	+/-	+/-
Household size	Number of the household members	+	+	+	+	+	+	+	+/-	+/-	+/-

Table 4.2: Results of the multivariate probit estimation

	Change crops	Change planting and harvesting dates	Change livestock breeds	Increase moisture conservation	Increase rain water harvesting	Increase natural resource harvesting	Increase off-farm activities	Increase in external assistance	Reduce food intake	Reduce expenditure
Gender structure (X_1)										
Female respondent - male headed-with adult males	0.015 (0.445)	1.358*** (0.468)	-1.066** (0.457)	0.846** (0.429)	-0.842** (0.434)	0.670 (0.421)	-0.996** (0.452)	-0.736* (0.421)	0.708 (0.431)	-0.340 (0.425)
Female respondent-male headed-without adult males	1.096** (0.442)	1.356*** (0.463)	-1.330*** (0.453)	0.693 (0.422)	-0.214 (0.428)	0.956** (0.413)	-0.675 (0.450)	-0.465 (0.417)	0.749 (0.424)	0.067 (0.420)
Male respondent-male headed-without adult males	1.015** (0.521)	0.309 (0.537)	-0.645 (0.529)	-0.223 (0.523)	-0.254 (0.498)	0.757 (0.501)	0.078 (0.537)	1.514*** (0.540)	0.071 (0.500)	0.910 (0.508)
Female respondent-female headed-with adult males	0.610 (0.418)	1.098** (0.437)	-0.317 (0.423)	-0.006 (0.401)	-0.051 (0.407)	0.571 (0.384)	-0.329 (0.428)	-0.660* (0.394)	0.023 (0.402)	0.012* (0.397)
Male respondent-female with adult males headed-	1.042* (0.602)	0.249 (0.601)	-0.531 (0.566)	0.105 (0.585)	-0.101 (0.576)	0.326 (0.569)	-0.560 (0.590)	0.052 (0.554)	0.114 (0.561)	0.592 (0.558)
Female respondent-female headed-without adult males	0.466 (0.442)	1.249*** (0.461)	-0.740 (0.452)	0.326 (0.424)	-0.907** (0.429)	1.297*** (0.424)	-0.815* (0.450)	0.952** (0.428)	0.730* (0.429)	1.055** (0.425)

Table 4.2(continued)

	Change crops	Change planting and harvesting dates	Change livestock breeds	Increase moisture conservation	Increase rain water harvesting	Increase natural resource harvesting	Increase off-farm activities	Increase in external assistance	Reduce food intake	Reduce expenditure
Climate variables(X_2)										
Moderate increase in dry-spells	0.536** (0.273)	0.363 (0.263)	0.891*** (0.271)	0.762*** (0.275)	0.883*** (0.276)	0.679** (0.290)	-0.188 (0.269)	0.268 (0.274)	0.691*** (0.264)	0.267 (0.262)
Extreme increase in dry- spells	-0.340 (0.259)	0.232 (0.254)	-0.535* (0.281)	-0.273 (0.268)	0.246 (0.255)	0.146 (0.259)	0.281 (0.278)	0.945*** (0.271)	0.658*** (0.253)	0.492* (0.258)
Mild increase in wet- spells	0.103 (0.262)	0.586** (0.268)	-0.180 (0.278)	-0.236 (0.262)	0.178 (0.261)	0.341 (0.287)	-0.636** (0.265)	0.069 (0.281)	0.377 (0.257)	-0.434 (0.264)
Moderate increase in wet-spells	0.955** (0.279)	0.975*** (0.290)	1.312*** (0.294)	-0.005 (0.271)	0.352 (0.270)	-0.012 (0.281)	-0.804*** (0.274)	-0.147 (0.292)	0.551** (0.270)	-0.351 (0.274)
Extreme increase in wet- spells	0.366 (0.278)	0.200 (0.270)	0.436 (0.281)	-0.329 (0.279)	-0.420 (0.276)	0.394 (0.288)	-0.934*** (0.278)	-0.445 (0.311)	0.444 (0.271)	0.499* (0.274)
High temperature	-0.187 (0.222)	-0.103 (0.219)	-0.056 (0.234)	0.513** (0.229)	0.055 (0.220)	-0.299 (0.228)	0.102 (0.230)	-0.015 (0.230)	0.489** (0.216)	-0.339 (0.220)
Capital stocks(X_3)										
Education	0.046** (0.022)	0.002 (0.022)	-0.003 (0.022)	0.055** (0.021)	-0.027 (0.022)	0.058** (0.023)	-0.016 (0.021)	0.024 (0.023)	-0.017 (0.021)	0.003 (0.021)
Skillfulness	0.110 (0.170)	-0.142 (0.171)	-0.075 (0.176)	0.013 (0.172)	-0.014 (0.168)	-0.015 (0.180)	0.303* (0.170)	-0.302* (0.181)	0.168 (0.167)	-0.101 (0.170)
Social capital	-0.073 (0.091)	0.011 (0.090)	0.012 (0.093)	0.159* (0.090)	0.023 (0.091)	0.015 (0.097)	0.006 (0.090)	-0.139 (0.097)	0.101 (0.090)	0.072 (0.090)
Physical capital	0.525** (0.228)	0.498** (0.231)	-0.343 (0.233)	-0.145 (0.220)	0.582** (0.227)	0.273 (0.240)	0.150 (0.225)	0.373 (0.227)	0.145 (0.215)	0.231 (0.219)

Table 4.2 (continued)

	Change crops	Change planting and harvesting dates	Change livestock	Increase moisture conservation	Increase rain water harvesting	Increase natural resource harvesting	Increase off-farm activities	Increase in external assistance	Reduce food intake	Reduce expenditure
Natural capital	0.231*** (0.071)	-0.066 (0.071)	-0.051 (0.072)	0.214*** (0.071)	0.116* (0.068)	0.161** (0.076)	-0.028 (0.070)	-0.077 (0.072)	-0.008 (0.068)	-0.150** (0.068)
***Risk aversion* (X_4)**										
Risk	0.002 (0.059)	-0.090 (0.059)	-0.025 (0.060)	-0.048 (0.058)	0.044 (0.058)	0.037 (0.060)	0.042 (0.058)	0.068 (0.062)	0.056 (-0.620)	0.162*** (0.057)
***Health status*(X_5)**										
Health status	-0.210 (0.177)	0.330* (0.177)	-0.122 (0.179)	0.126 (0.174)	-0.226 (0.172)	0.378** (0.182)	-0.355** (0.171)	0.339* (0.181)	0.171 (0.710)	0.247 (0.173)
***Demographics*(X_6)**										
Number of female children	-0.131 (0.145)	-0.101 (0.143)	0.064 (0.148)	0.097 (0.144)	-0.110 (0.142)	0.368** (0.161)	0.151 (0.142)	-0.160 (0.151)	0.141 (-1.610)	0.025 (0.145)
Number of male children	0.059 (0.114)	-0.120 (0.113)	-0.206 (0.114)	-0.027* (0.111)	-0.062 (0.110)	0.208* (0.123)	0.074 (0.109)	-0.003 (0.112)	0.110 (-0.400)	-0.139 (0.109)
Household size	0.014 (0.042)	0.023 (0.043)	0.014 (0.044)	0.011 (0.042)	0.001 (0.042)	-0.035 (0.045)	0.006 (0.043)	0.108** (0.045)	0.042 (1.190)	0.112** (0.043)
Age	0.014** (0.007)	0.004 (0.007)	-0.001 (0.007)	0.021*** (0.007)	-0.001 (0.007)	-0.001 (0.007)	-0.007 (0.007)	0.010 (0.007)	0.006 (-0.330)	0.000 (0.007)
Constant	-1.575** (0.733)	-0.687 (0.747)	0.317 (0.741)	-2.150*** (0.730)	0.832 (0.725)	-0.848 (0.737)	1.573** (0.747)	-1.286 (0.759)	0.710 (-0.410)	-0.907 (0.721)
N	326	326	326	326	326	326	326	326	326	326

Dry Period Scenarios

A Brief Description of Current Climate in Willowvale

Rainfall

Willowvale normally receives most rainfall during the summer. But it experiences dry periods as well as wet periods during the summer rainfall season (November to March).

Temperature

Normally the region is hottest during the summer rainfall season and is sometimes exposed to heat waves

Scenario

Imagine that the summer climate in Willowvale is going to change in the future. Typically there are 5 dry periods during November to March in Willowvale, where it doesn't rain much (less than 5 mm of rainfall) for 5 consecutive days. In the next ten years, imagine that instead of 5, there will be 14 dry periods. Temperature will remain as usual during these periods.

(Q.1) In response to these changes, which of the following adaptation strategy or strategies would you consider? Tick columns.

Would you,	Yes	No	If yes, what exactly would you do?	If yes, why would you do it?
(Q.1a) change the types of crops you are growing (including changing varieties)?				
(Q.1b) change the dates of crop planting and harvesting?				
(Q.1c) change livestock (e.g. types or breeds) you are rearing?				
(Q.1d) increase the use of rain water harvesting (e.g. Jojo tanks)?				
(Q.1e) increase of the use of soil moisture conservation methods in farming (e.g. Mulching)?				
(Q.1f) increase harvesting of natural/wild products (e.g. wild fruits, marine resources, fuel wood, etc.)?				
(Q.1g) increase involvement in off-farm employment (e.g. Casual labour, small business)?				
(Q.1h) increase efforts to obtain external assistance? (Grants, Government, NGOs)?				
(Q.1i) reduce food intake?				
(Q.1j) reduce personal expenditure?				
(Q.1k) do nothing?				
(Q.1l)Other (specify)				

Figure 6: Sample of questions used to elicit households stated choices of innovations

4.8 References

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Chapter 5: General Discussion and Conclusions

5.1 Summary

This thesis conducts an empirical investigation into the livelihoods of rural households living in southern Africa. The first study examines household structures and their implications for the earnings of households. Using two unique data sets collected in Zimbabwe and South Africa, we find three sources of heterogeneity that affect household income. First, household income varies significantly across different headship types that vary with respect to the levels of adult male presence. Second, the effects of child dependency ratios on household income vary depending on the age, gender of the child, and the type of household headship. Third, due to unobserved heterogeneity, the effects of different headship types and child dependency ratios on income vary even within the households.

The second and third studies, using the contingent behavior method, examine the adoption of innovations in response to future climate change. Both studies use a set of data collected in the Eastern Cape, South Africa, in 2011. The second study finds that households increase the adoption of natural resource harvesting, casual labor and small business in response to increases in dry spells, and gardening and livestock in response to increases in wet-spells. The third study reveals that people adopt agriculture-based innovations in response to increases in dry-spells as well as wet-spells, except in the case of extreme increase in dry-spells. However, the specific type of innovation may vary depending on the frequency of change. Further, the third study finds that people are more likely to increase natural resource harvesting, reduce food intake and personal expenditures, and increase the efforts to obtain external assistance in response to increases in dry-spells.

5.2 Crosscutting chapter results

5.2.1 Gender

Household headship, disaggregated according to the presence of adult male presence, influences household earnings. However, broad categories of household headship types (male-headed vs. female-headed households) do not necessarily characterize gender differences in income. Rather, household income increases with increasing adult male presence, although there is some evidence of diminishing returns at higher levels of adult male presence. In both economies that we studied, female headed households without adult male presence have less income than male-headed households that other male adults are present.

Impact of household headship on households' livelihoods is not limited to household income. Female and male-headed households are also likely to adopt different livelihood activities in response to future climate change. Female-headed households tend to do more gardening, but less natural resource harvesting, casual labor, and small business than male-headed households. Furthermore, within the choice of multiple livelihood activities, women and men living in different household headship types are likely to adopt different innovations. Considering women, for example, the ones living in male-headed households are less likely to change livestock breeds. Considering men, for example, the ones living in male-headed households without other male adult presence are more likely to increase the efforts to obtain external assistance. However, in general, women are more likely to adopt agriculture-based innovations such as changing crops, and planting and harvesting dates, and increasing the use of soil moisture conservation methods.

5.2.2 The role of Capital stocks

Human capital stocks have positive effects on household income in both Zimbabwe and South Africa. Human capital also increases the adoption of natural resource harvesting, small business and formal employment, in response to future climate change. Furthermore, people with more human capital endowments are more likely to change crops, increase the use of soil moisture conservation methods, increase natural resource harvesting and increase in the involvement in the off-farm activities. Social capital impacts positively on household income in South Africa. Further, social capital has a positive effect on adoption of gardening natural resource harvesting, small business, and increasing the use of soil moisture conservation methods in response to future climate change. Households with larger natural capital stocks have relatively higher incomes in both Zimbabwe and South Africa. Natural capital also increases the adoption of livestock and small business in response to future climate change. Moreover, households with more natural capital stocks are more likely to change crops, increase the use of soil moisture conservation methods, and increase the use of rain water harvesting methods. Physical capital endowments increase household income in Zimbabwe. We also find that physical capital positively impact changing crops and planting and harvesting dates, increasing the use of rain water harvesting methods.

5.3 Policy insights

Based on our results, we draw the following policy insights.

I. The use of male versus female household headship could mask important gender dimensions in the empirical relationships between household structures and income. Our results suggest that finer divisions of headship types are needed to identify vulnerable households.

II. Children contribute positively to household income. This impact is greater among female headed households without adult male presence. However, such positive effects of children may be resulting from child labor. If child labor reduces human capital development, there may be a potential intergenerational cost.

III. Local people have well-developed ideas about the potential changes in livelihood activities in response to climate change. Policies to facilitate adaptation based on these local tendencies will depend on the specific nature of climate change. If the future climate is dry, policies to promote natural resource harvesting, casual labor and small business opportunities would be important. If the future climate is wet, policies to promote gardening, livestock and small business could be helpful.

IV. Natural resources (mainly forests) may function as a safety net for households under dry climatic conditions. Long-term ill people, and households with long-term ill persons and risk averse individuals, are more likely to harvest natural resources. Therefore, sustainable management of natural resources may help households and specifically vulnerable groups in responding to future climate change.

V. Innovative strategies complement the adoption of livelihood activities. For example, households' increasing tendency to use rain water harvesting methods has a positive effect on the adoption of gardening in response to future climate change. Accordingly, facilitating such strategies may support the adjustments that households would make in their livelihood activities in response to climate change.

VI. Adoption of innovations is impacted by the gender of the survey respondent and gender of the household head. Accordingly, extension policies are likely to be more effective if specific types of innovations are targeted based on the gender of the individuals who is adopting, as well as the type of household headship.

VII. In the absence of adult male presence, women are more likely to adopt innovations such as reducing food intake and personal expenditure and less likely to adopt capital intensive innovations (e.g. rain water harvesting). These results may indicate the underlining constraints that women may face responding to climate change in the absence of adult males that may need special attention in adaptation policies.

VIII. Augmenting capital stocks could be used for poverty reduction. Further, specific capital stocks are important for facilitating specific livelihood activities, and other innovations that households may adopt within the choice of multiple livelihood activities.

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Appendix A: Construction of capital stock variables using Principle Component Analysis (PCA)

Index variables for physical and social capital are derived using principal component analysis (PCA). The physical assets index is derived from 17 physical asset characteristics (see Table A1). The PCA generates factor scores for each asset characteristic. The factor scores are computed by assuming a regression method based on uncorrelated rotated factors. The 17 factors are standardized to zero mean and unit variance. Table A1 shows factor scores from factor 1, which is the factor that explained most of the variation in the asset characteristics. Factor 1 is used to generate the physical asset index. The physical asset index is generated by weighting the asset characteristics with the scoring coefficient and adding them up.

Table A1

Descriptive statistics and scoring coefficients for retained factors of the variables included in the PCA model for physical assets

Physical Capital Factors	N	Mean	Std. Dev	Min	Max	Factor 1 Scores
Do you have a kraal?	340	0.9	0.296	0	1	0.378
Do you have a car?	340	0.0559	0.23003	0	1	0.365
Do you own a bicycle?	340	0.0235	0.1518	0	1	-0.104
Do you own a cell?	340	0.8794	0.32613	0	1	0.514
Do you own a TV?	340	0.5059	0.5007	0	1	0.82
Do you own a radio?	340	0.5235	0.50018	0	1	0.397
Do you own a DVD?	340	0.3441	0.47578	0	1	0.697
Do you own a stove?	340	0.5912	0.49234	0	1	0.699
Do you own a fridge?	340	0.4676	0.49969	0	1	0.792
Do you own a plough?	340	0.1324	0.33937	0	1	-0.327
Do you own a cart?	340	0.0618	0.24108	0	1	-0.2
Do you own a bed?	340	0.9824	0.13186	0	1	0.007
Do you own a solar panel?	340	0.0647	0.24637	0	1	0.035
Do you own a sewing machine?	340	0.0676	0.62269	0	11	-0.101
Do you own a jojo tank?	340	0.2059	0.40494	0	1	-0.13
Do you own a wheelbarrow?	340	0.2941	0.45632	0	1	0.131
Do you own a generator?	340	0.2824	0.45081	0	1	0.561

The social capital index is generated using the same procedure as for the physical assets index. The social capital index is derived from 21 variables that measure social capital. Table A2 presents descriptive statistics for the scoring coefficients for retained factors of the variables included in the PCA model for social capital.

Table A2

Descriptive statistics and scoring coefficients for retained factors of the variables included in the PCA model for social capital

Social Capital Factors	N	Mean	Std. Dev.	Min	Max	Factor 1 Scores
How long have you been established in this village?	340	4.61	1.522	1	7	-0.129
Does anyone in this household take part in community decision making?	340	2.37	0.858	1	3	0.135
Is household involvement in community activities L/S/M compared to 10 yrs ago?	340	1.76	0.97	1	3	0.186
Do you have free access to human rights advice?	340	0.19	0.389	0	1	0.444
Do you have free access to legal advice?	340	0.18	0.384	0	1	0.311
Do you have free access to medical advice?	340	0.62	0.487	0	1	0.409
Do you have free access to veterinary advice?	340	0.2	0.403	0	1	0.542
Do you have free access to medical advice?	340	0.22	0.417	0	1	0.569
Do you have free access to building advice?	340	0.12	0.326	0	1	0.519
Do you have free access to schooling advice?	340	0.21	0.407	0	1	0.588
Do you have free access to moving/relocating advice?	340	0.04	0.192	0	1	0.448
Do you have free access to market/business advice?	340	0.1	0.296	0	1	0.592
Do you have free access to credit/financial advice?	340	0.17	0.374	0	1	0.494
People around here are willing to help their neighbors.	340	3.21	0.751	1	4	0.291
This is a close-knit or 'tight' neighborhood where people generally know one another?	340	3.19	0.914	1	4	0.389

Table A2 (Continued)

Social Capital Factors	**N**	**Mean**	**Std. Dev.**	**Min**	**Max**	**Factor 1 Scores**
If I had to borrow R50 in an emergency, I could borrow it from a neighbor	340	3.1	1.036	1	4	0.22
People in this neighborhood generally get along with each other	340	3.14	0.822	1	4	0.241
People in this neighborhood can be trusted	340	2.71	0.983	1	4	0.209
If I were sick I could count on my neighbors to shop for groceries for me	340	3.14	0.787	1	4	0.236
People in this neighborhood share the same beliefs, culture and values	340	2.94	1.143	-5	4	-0.202

A summary of the PCA scoring criteria used to generate the physical and social capital indices is presented in Table A3. As mentioned, the indices are based on component one scores, which explain the greatest amount of variation in factors.

Table A3
Components extracted from Principal Component Analysis and proportion of variation in factors explained by components.

	Physical capital Index			Social capital Index		
Component	**Eigen value**	**Proportion**	**Cumulative %**	**Eigen value**	**Proportion**	**Cumulative %**
1	3.215	17.863	17.863	2.821	14.104	14.104
2	2.078	11.547	29.411	2.318	11.588	25.692
3	1.677	9.314	38.725	2.008	10.04	35.732
4	1.573	8.738	47.463	1.583	7.917	43.648
5	1.33	7.39	54.852	1.42	7.098	50.746
6	1.242	6.9	61.753	1.143	5.714	56.459

Appendix B: Risk aversion questions

Suppose that your family income (cash and in-kind) that you get from your livelihood activities is guaranteed for every year for life. An extension agent comes and gives you an opportunity to adopt a new technology that would change your income. There is a 50-50 chance that this new technology will double your family income and a 50-50 chance that it will cut your family income by a third. Would you adopt this new technology, Yes or No?

If the answer is ‘‘no,’’ please answer the following question **(Gamble 2):**

Suppose the chances were 50-50 that the new technology would double your family income and 50-50 chances that it would cut it by 20 percent. Would you adopt this new technology, Yes or No?

If the answer to the first question is ‘‘yes,’’ please answer the following question **(Gamble 3):**

Suppose the chances were 50-50 that the new technology would double your family income and 50-50 that it would cut it by half. Would you adopt this new technology, Yes or No?

These three questions allow categorization of respondents into four groups.

Respondents who answered ‘‘no’’ to both questions: **very strongly risk averse**

Respondents who answered ‘‘yes’’ to both questions: **weakly risk averse**

Respondents who answered ‘‘no’’ to the first question but ‘‘yes’’ to the second: **strongly risk averse**

Those who answered ‘‘yes’’ to the first question and ‘‘no’’ to the second: **moderately risk averse**