Labor adaptation to agricultural risk and shocks

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Abstract

An overwhelming majority of rural households in sub-Saharan Africa depend on agriculture. In spite of this, the sector is predominantly rainfed making it highly vulnerable to vagaries of weather. This paper investigates whether and to what extent rural households engage in *ex ante* and *ex post* labor adaptation to agricultural risk and shocks, respectively. I use water balance risk and adverse shocks calculated using high resolution precipitation and potential evapotranspiration data to proxy agricultural income risk and adverse shocks, respectively, matched with detailed panel data on farm households from rural Mozambique. The results reveal suggestive evidence that households engage in *ex ante* labor adaptation by sending out migrant members internationally. Robust evidences show that households significantly engage in contemporaneous e*x post* labor adaptation by sending out migrant members both domestically and internationally. However, one and two periods following adverse agricultural shocks they adapt locally by taking up other labor activities with less correlated incomes compared to on-farm agriculture. With potential increases in agricultural risk and shocks due to the projected increases in weather variability and frequency of shocks in the region, the results suggest increased local movement out of agriculture into non-agricultural activities and migration could result as households adapt family labor. This may eventually stress the existing limited rural resources available for non-agricultural expansion and urban employment opportunities both domestically and elsewhere.

Key words: labor adaptation, migration, agricultural risk, shocks, Mozambique
JEL Codes: J22, J61, O15, Q54

1. Introduction

An overwhelming majority of rural workers in sub-Saharan Africa work on agriculture. Income from this activity constitutes the lion's share of total household income. However with only 4% of the cropland irrigated, it remains being the most vulnerable region to vagaries of weather (Cline (2008), Svendsen et al. (2009), IPCC (2014)). The fact that formal crop insurance and credit markets are thin in this part of the globe leave households to experience significant declines in income (and consumption) in the wake of extreme weather conditions. This effect is not just temporary but might well persist in the long-term leading to poverty persistence unless otherwise appropriate risk management and shock-coping strategies are put in place (Dercon et al. (2005), Clarke and Dercon (2009)). Although rural households use informal risk sharing schemes to shield themselves from risks and cope with shocks, these schemes are not feasible to deal with covariate ones, like the ones from weather, which affect an entire network (Townsend (1994), Dercon (2002)). Hence, they rely mainly on *ex ante* and *ex post* self-insurance schemes, which includes adaptation to such risks and shocks.

While there is a growing literature assessing rural households' different on-farm adaptations[1] and other risk management and shock coping mechanisms[2] to weather-induced agricultural risk and shocks, occupational and locational family labor adaptation did not get as much attention as it should. Given it is among the most important household assets in developing countries, studying how farmers adapt family labor is critically important to understand their risk mitigation and shock coping capabilities and help evidence-based policy design that supports the effectiveness of households' adaptation under the ever increasing weather variability and shocks. In the face of these risks and shocks to agricultural income, theoretically farm households could mitigate risks and cope with shocks locally by taking up other labor activities with less correlated incomes compared to agriculture (Rose (2001)) or/and elsewhere by migrating to places with less correlated incomes compared to home (Rosenzweig and Stark (1989)).

To shed light on this, I combined a nationally representative detailed panel survey on farm households from all ten rural provinces of Mozambique with high resolution precipitation and

[1]On-farm adaptations include irrigation, altering planting dates, changing and diversifying crop varieties, planting trees and soil conservation, etc. Farmers also change livestock species as an adaptation strategy (see for example, Kurukulasuriya et al. (2006), Seo and Mendelsohn (2008), Bryan et al. (2009), Deressa et al. (2009), Di Falco et al. (2010), World Bank (2010), Salazar-Espinoza et al. (2015)).

[2]Other risk management mechanisms include holding spatially separated plots of land (Townsend (1994)), depleting productive assets (Rosenzweig and Wolpin (1993), Fafchamps et al. (1998), Kazianga and Udry (2006)), engaging in low-risk and low-return investments (Rosenzweig and Binswanger (1993), Morduch (1995)), and marrying out of daughters to spatially distant households (Rosenzweig and Stark (1989)).

potential evapotranspiration data and address two main questions: (1) Do and to what extent rural households adapt family labor *ex ante* and *ex post* to agricultural risk and shocks, respectively, by taking up other labor activities with less correlated incomes compared to on-farm agriculture?[3] And if they do so, (2) do they do it locally or elsewhere involving domestic and/or international migration? Some adaptations to agricultural income shock might take time before they materialize, and hence I also investigate the medium term (after one and two periods) *ex post* labor adaptation responses in addition to the contemporaneous ones.

Mozambique particularly makes an interesting setting to investigate these research questions since agriculture in the country is predominantly rainfed with only 0.5% of the cropland irrigated despite being the main source of household income (World Bank (2010)), there exists substantial rural off-farm labor market activity (Mather et al. (2008), Jones and Tarp (2015)), and work-related migration is becoming increasingly common (Jones and Tarp (2015)). With spatially diverse weather condition the country has, agro-ecologically representativeness[4] of the survey also provides a unique setting to study *ex ante* labor adaptation to weather-induced agricultural risk. Moreover, it ranked the third most vulnerable African country to multiple weather shocks (UNISDR (2009)).[5] In this respect, the timing of the two surveys is particularly important as 2004/5 is generally a more drought year in the country compared to year 2001/2 (Mather et al. (2008))[6], thus providing a 'natural experiment' to investigate the effects of weather-induced adverse agricultural income shocks on households' *ex post* labor adaptation responses.

Following the standard agricultural household model (Singh et al. (1986)) and the new economics of labor migration framework (Stark and Bloom (1985)), I model these joint occupational and locational family labor allocations as collective decisions by a household, and hence the unit of analysis is a farm household. All the outcome variables indicate a household's allocation of at least one family labor to the respective type of labor activity, implying labor adaptations to agricultural risk and shocks are investigated at the extensive margin.

Agricultural income risk is proxied by water balance (the difference between precipitation and potential evapotranspiration) risk which is measured as the coefficient of variation of water balance over a long term. Agricultural income shock is proxied by water balance shock which is

[3] The Intergovernmental Panel on Climate Change (IPCC) define adaptation as: *'In human systems, the process of adjustment to actual or expected climate and its effects, which seeks to moderate harm or exploit beneficial opportunities*' (IPCC (2014)). Hence, *ex post* and *ex ante* labor adaptations in this paper refer adjustments to actual and in expectation to weather-induced adverse agricultural income effects, respectively.

[4] The survey is representative at agro-ecological, provincial and national levels (Mather et al. (2008)).

[5] Section 2 discusses these and other relevant contexts of the rural economy in Mozambique.

[6] I confirm this notion by objectively measuring droughts (see Table 1).

measured as the number of standard deviations of current water balance from the long-term average. Hence, I first empirically show how good these variables are to proxy agricultural risk and shock. Then, I run reduced form regressions linking weather risk and shocks to household decisions regarding which labor market activities to take up and where to undertake them, within the village or migrate outside the village to adapt. Water balance risk is time-invariant and hence I rely on correlated random effects (linear) model to estimate its effect on income and *ex ante* labor adaptation, while water balance shock is time-variant and hence I use semiparametric fixed effects model to estimate its effect on income and household fixed effects (linear) model to study *ex post* labor adaptation responses. These later models get rid of all time invariant household and village specific observable and unobservable factors which might bias the results. Another econometric concern that needs to be taken care of in all regressions is the potential cross-sectional correlation in incomes and labor adaptation decisions among households within a village. To circumvent this problem, I clustered the standard errors at the village level, the lowest available cluster. The survey covering over 396 villages with each of them having on average eight households provides sufficient number of clusters (Bertrand et al. (2004), Wooldridge (2010)).

Several interesting results emerge from my analysis. Riskier distribution of water balance measured over the long-term is negatively related to net household crop income, while it is positively related to non-crop income. This suggests that labor adaptation into non-agricultural activities in villages with riskier distribution of water balance potentially do not just mitigate weather-induced income risk but has the potential to maximize total household income. Negative water balance (drought) shocks lead to significant negative effects on net household crop income, but do not have any effect on non-crop income. This confirms that movement out of crop agriculture into off-farm labor activities during drought shocks has the potential of serving as a drought-induced adverse income shock coping mechanism. Taken together, the results imply that the coefficient of variation of water balance over the long-term and negative water balance (drought) shock are a good proxy of agricultural income risk and adverse shock, respectively.

The results on labor adaptation responses suggest that households significantly engage in both *ex ante* and *ex post* labor adaptation to agricultural risk and shocks, respectively. At the extensive margin, aggregate adaptation responses suggest that households adapt family labor *ex ante* to agricultural risk by taking up salaried non-agricultural activities while withdrawing from salaried agricultural employment. Locational differences show that households do withdraw from local salaried agricultural employment but engage significantly more on the same activity and salaried non-agricultural activities by sending out migrant members internationally.

Ex post labor adaptation responses to contemporaneous drought shock reveal that households significantly increase participation in salaried non-agricultural activities, but withdraw from forestry, fishery and fauna activities. I empirically show that labor adaptation into the former labor activity exclusively involves sending out migrant members both domestically and internationally. I further investigated medium term (after one and two periods) *ex post* labor adaptations to drought shocks. Aggregate results reveal that households withdraw from self-employment in forestry, fishery and fauna activities one period after drought shocks. Two periods after drought shocks, they engage more on self-employment activities in trade services and small and micro enterprises but withdraw from salaried agricultural activities. Locational differences reveal that households do increase local participation in salaried non-agricultural activities one period after drought shocks. Both increased self-employment in trade services and small and micro enterprises and withdrawal from salaried agricultural activities two periods after drought shocks takes both locally. The fact that households withdraw from local salaried agricultural activities only two periods after drought shocks, but not contemporaneous to and one period after drought shocks, is puzzling given this labor activity is highly vulnerable to droughts. I argue that this result is driven by *ganho-ganho* - an informal risk sharing system in rural Mozambique whereby well-off households employ on their farms poorer ones to help the later cope with shocks - offsetting the potential negative impacts of droughts on salaried employment in agriculture during and one period following droughts.

This paper adds value to the existing literature in several ways. First, it contributes to the literature linking migration to weather risk and shocks. This literature is more geared towards studying permanent migration and international migration (Rosenzweig and Binswanger (1993), Halliday (2006), Feng. et al. (2010), Gray and Mueller (2012a,b), Gray and Bilsborrow (2013), Mueller et al. (2014), Kubik and Maurel (2016), Cai et al. (2016)). Although important by itself, permanent migration is not easily accessible to rural households in sub-Saharan Africa due to liquidity constraints to finance migration costs (Kleemans (2014), Hirvonen (2016)), inability to pay for labor in place of migrants (Zezza et al. (2011)), and low returns to migration arising from low access to social networks and other language and skill related barriers at the destination (Chiswick and Miller (2003)). On top of this, most of these studies do not identify whether the purpose of migration is for work or other reasons (see for example, Dillon et al. (2011), Kubik and Maurel

(2016), Dou et al. (2016)). Spatial mobility takes place for a variety of reasons, and not all forms of migrations are equally important as a risk management and shock-coping strategy for the migrant sending households, or more specifically as an adaptation to agricultural risk and shocks.[7] It may even indicate an undesirable result of a failure to successfully adapt. As a point of departure, I address these shortcomings as migrants considered in this study are entirely work related and they do not just migrated but also undertake some form of labor activity. Labor activity which involves domestic migration also includes short-term labor activity, that spans as small as one month. I further distinguish these labor activities which involve migrating outside the village based on the type of activities which opens a room to appropriately pinpoint the type of activity providing opportunities for migrant labor adaptation.

Second, it contributes to the literature related to income diversification as a risk management and shock-coping tool against weather risks and shocks, respectively. This literature mostly relies on a binary measure of off-farm labor activity (Rose (2001), Haggblade et al. (2007), Deichmann et al. (2009), Mueller and Quisumbing (2011), Dimova et al. (2015), Mathenge and Tschirley (2015)). This is an oversimplification given the correlation of incomes of off-farm activities and on-farm agriculture differs substantially across the types of off-farm activity. Hence, a more compelling and policy-wise relevant analysis can be obtained through rich classification of all the available off-farm labor activities. I add value on this capitalizing on the sufficient list of activities from the survey. In this regard, there are papers which provide sufficient classification of activities including Cunguara et al. (2011), Skoufias et al. (2016) and Dou et al. (2016). The former two studies are cross-sectional implying the results are not potentially well identified owning to lack of randomness of weather variables at a cross-section. On top of this, all of these studies do not distinguish whether labor adaptation is taking place locally or elsewhere involving migration.[8] I improve up on these studies by using panel data, which enables me to control for both location and time fixed effects and hence guarantee the randomness of variables which define weather shocks. On top of this, I will also investigate locational diversification by differentiating whether labor activities are taking place locally or involve migration.

[7] Gray and Wise (2016) disentangles labor migration from other forms of migration and studies labor migration as an *ex post* response to weather variations. Although the unit of analysis is a household in this study, this study don't rely on household fixed effects regression. They only included district fixed effects implying that the results are potentially biased due to time-invariant household characteristics that are not controlled for in the regression.

[8] Dou et al. (2016) includes migration as an outcome variable in addition to the different categories of labor activities. But, this variable do not differentiate whether migration is work related or not.

Traditionally, the literature on the impacts of weather conditions on economic outcomes relied very much on respondents' self-reported measures of weather conditions. Recent studies are using more objectively measured indicators of weather conditions although they are mostly based on a single climate variable of either rainfall or temperature except Mueller et al. (2014) and Kubik and Maurel (2016). Agricultural income depends on a multitude of weather factors, and hence characterizing weather conditions using just a single weather variable is less sound (Rose (2001), Vicente-Serrano et al. (2010)) and owning to the potential correlation between them, econometric estimation without controlling one or the other leads to omitted variable bias (Auffhammer et al. (2013)). In light of this, I contribute to the existing literature by characterizing weather risk and shocks using water balance which is the difference between precipitation and potential evapotranspiration following the climatology literature (Vicente-Serrano et al. (2010), Beguería et al. (2014)), whereby the latter is calculated taking into account the effect of temperature, wind speed, vapor pressure and cloud cover (Harris et al. (2014)).

The rest of the paper is organized as follows. Section 2 discusses agriculture, rural labor market activity and climate condition in Mozambique. Section 3 presents data and Section 4 discusses the measures of weather risk and shocks. Section 5 presents the empirical strategies and Section 6 presents descriptive results. I present and discuss the main results in Section 7. Section 8 describes checks and Section 9 concludes.

2. Context

The Mozambican economy has achieved an impressive growth over the past two decades (World Bank (2010)). The agricultural sector has played a major role behind this overall economic growth, and continues to be one of the important sectors in the economy absorbing over 70% of the population (World Bank (2010), Jones and Tarp (2015)) and being at the heart of addressing poverty in the country (Arndt et al. (2012), Arndt et al. (2015)). In spite of the sector's contribution to these and other key development indicators, almost all (over 99.8%) the farms are owned by smallholder (small and medium-sized) farmers cultivating 90.7% of the total cultivated land (Deininger and Xia (2016)). These farmers operate on a very fragmented land, with majority of them cultivating one or less hectares of land (Arndt et al. (2012)).

There are also more concerns with regard to agricultural development in the country. First, the growth in the sector is achieved mainly through agricultural land expansion, but not improved productivity. Agricultural productivity is quite low with, for instance, productivity of maize, the most important staple crop, being 1.4 tons per hectare which is far below the potential productivity of 5 - 6.5 tons per hectare (Howard et al. (2003)), and aggregate agricultural productivity has been stagnant since then until near present (Arndt et al. (2012), Deininger and Xia (2016)). One of the major reasons behind this is low adoption of productivity-enhancing agricultural technologies. In this respect, of the total smallholder farmers, not more than 12% use improved seeds, 5% use fertilizers, 7% use pesticides, and 4% use animal tractions over the period 2002-2014 (Deininger and Xia (2016)). World Bank (2010) also estimates not more than 0.5% of the total cropland is irrigated, which is almost entirely used by sugarcane farms and the rest of it by rice and vegetable farms. Although recent estimates show less than 18% of the country's agriculturally suitable land is being cultivated for crop production and there still remains large potential to boost agriculture through land expansion, modernization of the sector is something that needs to be taken seriously. The other and most important concern is lack of sufficient attention from the policy sphere to improve smallholder productivity (Arndt et al. (2006), Arndt et al. (2012)).

Although labor market activity in Mozambique, and to a greater degree in rural areas, is dominated by smallholder farming (Jones and Tarp (2015)), there is substantial off-farm and non-farm labor market activity in rural parts of the country. With respect to off-farm agricultural labor, over 15% and 17% of farm households hired seasonal labor to work on their farms in exchange for cash, kind or both in 2002 and 2005, respectively. Similarly, 2.2% and 1.8% of farm households hired permanent labor in 2002 and 2005, respectively (Jones and Tarp (2013)). A significant portion of farm households also allocate at least one family labor in non-farm labor activities. In this respect, Mather et al. (2008) estimated that 57% and 70.2% of farm households engage in either wage or self-employment non-farm labor activities in 2002 and 2005, respectively. Notice that this figure would have been much higher if agriculture related forestry, fishery and fauna activities were included. With this, income from these two labor activities constitute significant portion of total household income with off-farm agricultural labor income making up 2% and 3.7% of total household income and non-farm income constituting 22.4% and 30.5% of total household income in 2002 and 2005, respectively (Mather et al. (2008)). Labor migration is also being used increasingly aa a livelihood diversification strategy (World Bank (2006), Jones and Tarp (2013)), which might have led to increased receipt of remittances from 2002 to 2005 (Mather et al. (2008)).

Mozambique has a diverse climatic condition which is mostly arid and semi-arid in the south and southwest, sub-humid and humid in the center, and sub-humid in the north (World Bank (2006)). The main rainy season runs from October to March in the south and from November to March in the center and north (Silva et al. (2015)). Annual rainfall ranges from 400 to 1000 mm in the south, 1000 to 1200 mm in the center and 1000 to 1800 mm in the north (World Bank (2006)). The country is highly vulnerable to extreme climate conditions (World Bank (2006; 2010), Arndt et al. (2011)), ranking the third most vulnerable African country to multiple weather-induced risks (UNISDR (2009)). Droughts and floods are the most common weather-related shocks (World Bank (2006; 2008; 2010)), with the former being the most frequent disaster (World Bank (2010)). Southern and central regions of the country are particularly vulnerable to droughts with drought frequency of 7 in 10 and 4 in 10 years, respectively. Floods also occur most frequently in southern and central regions of the country, but also along river basins, in low-lying regions, and in areas with underdeveloped drainage systems. Although less frequent compared to droughts, floods in Mozambique can last for several months and become disastrous. For instance, the flood in 2000 was the worst flood over 50 years in the country, killing and displacing over 800 and 540, 000 people, respectively (World Bank (2010)). In addition to these, weather-induced shocks have had serious effects on the performance of agriculture and the national economy of Mozambique (World Bank (2010)). Projected climate conditions show that the frequency and intensity of these shocks will increase, implying they will continue to be a setback for the Mozambican economy. Arndt and Thurlow (2015) predicted a 4%, and possibly up to 10%, lower agricultural value added in Mozambique by 2050 due to climate change compared to a "no climate change" scenario if appropriate adaptations are not put in place. This points to the importance of understanding how farmers in rural Mozambique adapt to changes in weather conditions. And family labor being one of the most important assets of the rural economy, family labor adaptation remains to be the integral part of the overall adaptation by farm households.

3. Data

The empirical analysis is undertaken by combining two different datasets. The first is a two wave panel survey from *Trabalho de Inquérito Agrícola* (TIA)[9] for the years 2001/2 and 2004/5 on small and medium-sized farm households in rural Mozambique.[10] It is collected by the Ministry of Agriculture of Mozambique in collaboration with Michigan State University. The sample

[9] The TIA (and since 2012 Inquérito Agrícola Integrado (IAI)) survey has been conducted since 1996 and has 10 surveys thus far in 1996, 2002, 2003, 2005, 2006, 2007, 2008, 2012, 2014 and 2015. These surveys are all nationally representative (representative at the provincial and agro-ecological levels) of small and medium-sized farm households in the country. The sample households in 2002 were re-interviewed in 2005, and I use these TIAs to exploit the panel nature of the survey, while the rest of the surveys are cross-sectional.

[10] Characterization of small and medium-sized farm households follows the definition by the Ministry of Agriculture of Mozambique. According to the ministry, they are defined as those having less than 50 hectares of cultivated land, a herd of 100 heads of cattle, 500 goats, sheep, pigs etc., and 20, 000 fruit trees. Farms having at least equal to the stated number for any of the categories are large-sized farms and are not included in the survey.

households were drawn from the year 2000 agricultural census using stratified, clustered sampling design with the aim of making it representative of small and medium-sized farm households for each of the ten rural provinces and agro-ecological zones of the country. With this, it makes the first nationally representative panel survey of rural Mozambique (Mather et al. (2008)). It contains information on various characteristics of farm households including household demographics, employment conditions, access to services, land holding, agricultural production and sale, self-reported occurrence of natural disasters, indicators of well-being and food security, and diseases (morbidity). Using this survey, I constructed a balanced panel of 2936 households residing in 407 villages in all rural provinces of the country for which village centroid Global Positioning System (GPS) coordinates are available in the community survey, a supplement to the household survey. Important to the objectives of this study, the survey has a rich list of over 37 salaried and self-employment activities in addition to on-farm agriculture. This list is based on information from previous cross-sectional TIA and hence includes almost all the available labor activities in the rural economy of the country. Moreover, it provides the option to households to specify themselves if they are undertaking anything that is not included in the list. Capitalizing on this I constructed appropriate categories of labor activities based on similarities in risks and returns involved, which will eventually serve as outcome variables in this study. These categories are: salaried agricultural activities, salaried non-agricultural activities, self-employment in non-farm businesses, and self-employment in forestry, fishery and fauna activities.

Households have the option of undertaking any of the labor activities, except self-employment in fishery, forestry and fauna activities, either locally or elsewhere by sending out at least one household member to other villages within the country or countries.[11] These two locations involve different costs, risks and returns even for the same type of activity. I accounted for this by differentiating each of the categories of activities whether they are undertaken locally or elsewhere. For the same reason, I also differentiated the activities which are undertaken outside the village whether it is within or outside the country, i.e. involve domestic or international migration. Summary statistics for the aforementioned outcome variables is presented in Table 1.

The second data is gridded monthly precipitation and potential evapotranspiration. It comes from the Climate Research Unit (CRU) of University of East Anglia, Norwich, UK. The community

[11] The survey doesn't provide the location of fishery, forestry and fauna activities. Most of these activities require ownership of land or water resources, and hence I treat these activities as if they are undertaken locally because it is hardly possible to own those resources outside the village. So, with regard to location based differences in labor adaptation, I focus on the other four categories of activities other than on-farm agriculture.

survey of TIAs include village centroid GPS coordinates. I matched these coordinates with the corresponding grid cells of the CRU data to pull the relevant values for the two climate variables for each village.[12] The gridded data has a high spatial resolution of 0.5 degrees latitude and longitude (Harris et al. (2014)). It contains the two variables, among others, from year 1901 to near present, but the actual years used in this study spans from 1971 to 2005. This period is chosen based on two criteria: (1) It should be long enough so that it is insensitive to recent shocks. In this regard, Mckee et al. (1993; 1995) recommends to use at least a 30 years monthly data in order to appropriately characterize weather shocks and variability. (2) And the number of years should not be so many so that calculation of weather shocks and variability will not miss out recent averages incase the long-run mean of weather variables change (Burke et al. (2013)). Moreover, the object of interest in this paper being to estimate how farmers allocate labor to agricultural income risk and adverse shocks, the relevant weather condition is the one during the main agricultural growing season. The main growing season in rural Mozambique runs from October to March in the south and from November through March in the north (Silva et al. (2015)). For consistency purposes, I used values for the two climate variables from October through March.

4. Risk and shock measures

In this section I describe the measures of weather risk and shocks used to proxy agricultural risk and shocks, respectively. Weather is defined based on monthly water balance which is the difference between monthly precipitation and potential evapotranspiration. The latter is calculated using monthly maximum, minimum and average temperature, wind speed, vapor pressure and cloud cover (Harris et al. (2014)), making the risk and shock measures take into account the effect of all these weather variables. Most of the previous studies which used weather variables to proxy agricultural risk and shocks relied on a single variable of either precipitation or temperature. However, this is less sound to proxy agricultural risk (Rose (2001), Vicente-Serrano et al. (2010)) since agriculture is dependent on a multitude of weather variables and evaporation and transpiration could consume up to 80% of rainfall and are time varying (Abramopoulos et al. (1988), Vicente-Serrano et al. (2010)). This problem is more severe if one or the other of these weather variables is not controlled for in the econometric estimation when weather is characterized based solely on a single variable as it leads to the classic omitted variable bias due to the potential correlation among

[12] This implies that climate variables vary only across villages for a survey year. However, the survey includes 407 villages providing sufficient variation in these variables for the study. This is further complemented by the variation in these variables over time.

them (Auffhammer et al. (2013)). Hence, using water balance to define weather risk and shocks not only provides a better proxy for agricultural risk and shocks, respectively, but also improves the identification of the effects of weather risk and shocks on economic outcomes.

Water balance shock is defined based on an extended version of the Standardized Precipitation Index (SPI)[13] called the Standardized Precipitation Evapotranspiration Index (SPEI) on a six months scale over the main growing period (Vicente-Serrano et al. (2010), Beguería et al. (2014)). Calculation of SPEI involves: (1) Fitting the water balance data for each village into a log-logistic distribution. The water balance data in this study are positively skewed and fitting it into such a distribution takes care of non-normality of it. (2) Then, transforming it into a standard normal distribution with zero mean and standard deviation of unity. This allows comparability of SPEI values across villages and over time (Vicente-Serrano et al. (2010), Beguería et al. (2014)).

The resultant standardized variable is the number of standard deviations of water balance from the long-term average, whereby negative values refer to dry spells (droughts) and positive values refer to wet spells. Higher negative values in absolute terms indicate more severe drought episodes and higher positive values indicate more severe wet spells. Using this variable, I show empirically, in section 7, that negative water balance shocks (droughts) have adverse impacts on crop income, and hence used as an adverse income shock measure. This variable can be specified in different ways where one immediate option is to use a dummy variable indicating whether a household experienced drought shock or not. This gives equal weight for each and every household which experienced negative water balance irrespective of the intensity of the shock. Instead, I used the whole continuum of the negative water balance shocks which weighs each and every household by the intensity of the dry spell it experienced. For ease of interpretation I take these values in absolute terms. Moreover, taking advantage of the two years gap in between the two data points and using the two years immediately preceding the first survey year, I constructed one year and two years lagged drought shock variables in a similar fashion. This opens a room to investigate the medium term *ex post* labor adaptation responses in addition to the contemporaneous ones.

Water balance risk is measured by the coefficient of variation of water balance over the main growing period from 1971 through 2005. This definition of risk is analogues to the risk defined based on rainfall and temperature by Rose (2001) and Dillon et al. (2011), respectively. It

[13] The SPI has been extensively used as a drought (Mckee et al. (1993, 1995)) and flood (Seiler et al. (2002)) monitoring in the climatology literature. The main drawback of the SPI is the use of only precipitation to characterize relative dryness (drought episodes) and wetness. The SPEI extends the SPI in that it is based on water balance, the difference between precipitation and potential evapotranspiration (PET) (Vicente-Serrano et al. (2010), Beguería et al. (2014)).

measures the riskiness of the water balance distribution and hence the household's environment, and hence forms the basis for *ex ante* adaptation. Unlike drought shocks, water balance risk is time invariant and hence cannot be used in a household fixed effects specification. Summary statistics of these water balance shocks and risk is reported in Table 1.

5. Empirical strategies

The goal of this paper is to investigate how households adapt family labor to weather-induced agricultural income risk and shocks. Hence, the empirical analysis will be of two steps. I start by investigating how crop income is affected by water balance risk and shock with the aim of showing that these variables can proxy agricultural risk and shock, respectively. I complement this analysis by investigating how non-crop income is affected by water balance risk and shock with the aim of showing that movement out of on-farm agriculture into off-farm activities can potentially serve as a risk mitigating and shock-coping mechanism to weather risk and shocks, respectively. Then, I empirically assess households' *ex ante* and *ex post* labor adaptation responses using reduced form regressions.[14]

Water balance risk is time invariant and hence limits the use of household fixed effects specification. As a result, I rely on a random effects specification of the following form to investigate its effect on incomes and labor allocation:

$$Y_{ht} = \alpha + \beta W_v + \theta X_{ht} + \delta\, YR_t + C_h + \varepsilon_{ht} \qquad \dots\dots(1)$$

where h indexes the household and t indexes year (2004/5 and 2001/2). Y_{ht} is the dependent variable which takes either net crop or non-crop income of household h at time t in the first part of the analysis. In the second part of the analysis, it indicates whether household h allocates at least one family labor to a particular category of labor activity at time t. To account for the different risks and returns involved with respect to where households are undertaking the adaptation, I next disaggregate whether adaptations into different activities are local which refers to adaptation within the village or involve migration if the adaptation is undertaken outside the village. Households also have the option of undertaking labor activities that involve migration within and/or outside the country, and hence labor activities outside the village are further disaggregated into these two

[14] The ideal analysis would have been to follow a two stage least squares (2SLS) whereby in the first stage agricultural incomes are predicted by weather risk and shocks and in the second stage the predicted values are used to predict labor adaptation responses. Such analysis requires that weather shocks must affect labor adaptation only through agricultural incomes. Although it can be argued that agricultural incomes are the major mechanisms, there could well be other channels. This motivates the analysis in this way instead of a 2SLS.

categories to appropriately pinpoint where actually households are adapting their family labor. W_v is the coefficient of variation of water balance of village v over the long-term. It varies only across villages. X_{ht} is a vector representing time-varying socio-economic variables of the household (including household size, share of labor, land size in hectares, etc.), household head (including head's age, gender, and education) and village (access to electricity and telephone). In order not to run the risk of reverse causality, appropriate care has been taken. For instance, all the demographics variables refer to the beginning of the respective survey period which is pre migration or other labor allocation decisions. YR_t is a year fixed effect which takes 1 if it is 2004/5 and 0 otherwise. This variable is included to capture the general trends in the outcome variables that resulted from the changes in living conditions over time. C_h is unobserved household heterogeneity. ε_{ht} is a statistical noise term. α, β, θ *and* δ are parameters to be estimated. The coefficient of interest is β which measures the effects of water balance risk on the respective outcome variable.

The central assumption in estimating a random effects model as in (1) above is exogeneity of unobserved household heterogeneity. This assumption is very strong as there could be unobserved household characteristics that are correlated with both any of the explanatory variables and the outcome variable. To partially circumvent this problem, I use Mundlak's correction which explicitly models the dependence of unobserved household heterogeneity on the mean of time-varying control variables as (Mundlak (1978), Wooldridge (2010)):

$$C_h = \eta + \xi \bar{X}_h + \alpha_h, \quad \alpha_h / X_h \sim Normal(0, \sigma_\alpha^2) \qquad \ldots (2)$$

This provides the estimable Mundlak's correlated random effects (linear) model:

$$Y_{ht} = (\alpha + \eta) + \beta W_v + \theta X_{ht} + \delta\, YR_t + \xi \bar{X}_h + \alpha_h + \varepsilon_{ht} \qquad \ldots . (3)$$

where $\bar{X}_h$ is the mean of time-varying variables in X_{it}. The estimates of θ of the time varying-variables in (3) are fixed effect estimates. Although this model enables to control for a wide range of control variables by circumventing problems of unobserved household heterogeneity that might be correlated with the outcome variable and time varying controls, there still remains a concern that there could be unobserved heterogeneity which can be correlated with both the outcome variable and the main variable of interest, the coefficient of variation of water balance. For instance, if households living in more risky environments are also poorer or risk averse, the fact that the later variables are also high likely correlated with the outcome variable (s) leads to the classic omitted variable bias which makes it difficult to interpret the estimates of β as causal effects. However, it is important to note that this is the best one will ever get to identify the effect of the variable of interest in this case.

Another econometric concern that needs to be dealt with in regressions of the form in equation (3) is the potential cross-sectional correlation among households within a village regarding incomes and household labor allocation decisions. To account for this, I clustered the standard errors for all regressions at the village level, which is the lowest available cluster, across a survey. The survey covers over 396 villages and each of the villages having few number of households, on average less than 8 households, makes clustering the standard errors at this level pretty much commendable (Bertrand et al. (2004), Wooldridge (2010)).

Water balance (and drought) shock, on the other hand, is time-variant and hence I rely on household fixed effects (linear probability model) specification of the following form to investigate its effect on income and *ex post* labor allocation:

$$Y_{ht} = \alpha + \beta D_{vt} + \theta X_{ht} + \delta \, YR_t + C_h + \varepsilon_{ht} \qquad \ldots \ldots (4)$$

where D_{vt} is water balance shock (or drought shock) experienced by household h living in village v in year t. It varies across villages and years, but not within a village. It forms the basis for *ex post* labor adaptation when the outcome variable is labor allocation. The other variables are as defined before. The coefficient of interest is β which measures the effects of contemporaneous water balance (drought) shocks on the respective outcome variable. In order to study medium term labor adaptation responses due to drought shocks, I further include one year and two years lagged drought shocks at the same time controlling for contemporaneous drought shocks using the same household fixed effect specification as in (4).

Household fixed effects specification of the form in (4) gets rid of all observed and unobserved time invariant household and village characteristics. Moreover, the disturbance terms are allowed to be correlated within a village but remain independent across villages and over time similar to the estimation in (3). Since time (YR_t) and location (C_i) fixed effects are controlled for in this specification, I assume water balance (and drought) shocks are random and hence the estimates of β have causal interpretation.

6. Descriptive statistics

Table 1 presents descriptive statistics of all the variables used in the study by survey year. The outcome variables are presented in panel (a). Labor allocation variables measure households’ average participation in the respective labor activity at the extensive margin along with the sample size and standard deviation. Similarly, the mean and standard deviation of net household crop and non-crop incomes expressed (in real terms) in 2005 *Meticais da Nova Familia* (MTN) are presented. The statistics shows that almost all rural households work on on-farm agriculture, but opportunities to work on activities other than on-farm agriculture are considerably large. Agriculture itself provides off-farm employment opportunities for about 7 % of households in 2001/02. Majority of this employment takes place locally with domestic markets outside the village and international markets providing small portion of this type of employment . In the same year, about 12% of households engage in salaried non-agricultural activities, out of which 8% involve migrating outside the village mainly outside the country. A large 29% of them also engage in self-employment activities in non-farm business. This labor activity includes self-employment in trade services and small and micro enterprises which is mainly undertaken within the village with almost the rest of such employment being provided by the domestic market outside the village. Participation in each of these off-farm activities is even larger in 2004/5, whereby the largest growth is in salaried agricultural activities followed by self-employment in non-farm businesses. Moreover, the statistics shows that almost all households engage in forestry, fishery and fauna activities 2001/2. The proportion of households undertaking this activity drops from 2001/2 to 2004/5 unlike other off-farm activities. Panel (a) further shows that crop agriculture is an important source of income providing around 40% and 38% of the total household income in 2001/2 and 2004/5, respectively. Moreover, total household income shows around 19% growth from 2001/2 to 2004/5.

The other variables of interest are measures of water balance risk and shocks. Panel (b) of Table 1 presents the descriptive statistics of these variables by survey year, and Figure 1 and Figure 2 present the whole distribution of drought shocks and water balance risk across villages, respectively. The statistics from Table 1 shows that both 2001/2 and 2004/5 were considerably drought years, but 2004/5 had a more severe dry growing season compared to 2001/2 by about a half standard deviation. A more complete picture of this difference can also be observed from Figure 1. The growing seasons in 2003/4 and 2000/1 are characterized by a wet and dry season, respectively. There were only a few villages which were affected by drought in the former year. However, many villages were affected by drought, albeit many of them had mild drought, in 2003/4 leading the average dryness to be a half standard deviation more severe compared to 200/1. This difference between the two survey years resulted mainly because the growing season in 2000/1 was characterized by excess water balance. This result is not surprising given the country experienced one of the worst floods over 50 years in this period which led to loss of many lives and displacement of over half a million people (World Bank (2010)). The growing seasons in 2002/3 and 1999/2000 were both comparatively less drought seasons with an average drynesss of 0.26 and 0.21 standard deviation water balance below the long term mean, respectively. The other variable of interest is the coefficient of variation of water balance which is on average 28% with a standard deviation of around 5%. This variation measure could be influenced by a few outliers and hence the whole distribution of this variable across villages is presented in Figure 2. This figure also confirms that this variable has substantial variation across villages. Notice that this variable is time-invariant and hence the same value is reported for both survey years in Table1.

Panel (c) of Table 1 presents the other control variables. It shows that three-quarters of household heads are male with an average age being in the middle of forties. The household heads' education is on average 2 years in 2001/2 and 3 years in 2004/5. The average household size is relatively stable across the two surveys with around six members, and almost half of them are young dependents aged 15 years old or below. Households own around 2.3 hectares of land in 2001/2, while they own around 2.4 hectares in 2004/5. The measure of household asset, i.e., asset index, remains stable across the two survey years. Village level access to electricity services is quite low in 2001/2, but it grew significantly over the three years period. Other control variables include ownership of bicycle, receipt of extension service and membership in farmers' association all of which grow from 2001/2 to 2004/5, while animal traction usage declined over these two survey years.

7. Estimation results

This section is structured into two sub-sections. In the first sub-section, I present the results of the effects of water balance risk and shock on net household crop and non-crop incomes. In the next sub-section, I present *ex ante* and *ex post* labor adaptation responses to water balance risk and drought shock, respectively. In addition to the contemporaneous *ex post* labor adaptation responses, I will also present and discuss the medium term (after one year and two years) *ex post* labor adaptation responses to drought shocks.

7.1. Income and weather

Table 2 presents how water balance risk is related to incomes using random effects (1) and correlated random effects (2 and 3) models. The results show that riskier distribution of water balance is negatively related to net household crop income which is significant at conventional significance levels. On the other hand, the results show that water balance risk is positively and significantly related to non-crop income. Both of these results are robust to the three alternative specifications. This suggests that movement out of crop agriculture into off-farm labor activities potentially not only mitigates weather-induced crop income risk but also maximizes total household income.

Table 3 presents the impacts of water balance shock on crop and non-crop incomes using household fixed effects specification. The results are presented for alternative set of controls whereby in regressions with column labels (1) no other control variable is included except the variable of interest, i.e. water balance shock, in regressions with column labels (2) predetermined variables are included in addition to (1), and all the available control variables are included in regressions labeled as (3). The results show that water balance shock is significantly related to household crop income at the conventional levels. Specifically, it shows that an increase in water availability significantly increases net household crop incomes. This result is robust to alternative set of controls. However, water balance shock do not have any significant effect on non-crop income although the point estimate remains negative across all specifications. These results suggest movement out of on-farm crop agriculture into off-farm activities potentially serve as a shock-coping mechanism against weather-induced adverse income shocks for a very low level of water availability (high water deficit). However, these results do not show the exact cut-off point of the water balance shock distribution that leads to such benefits of movement into off-farm activities.

The fact that the water balance shock is constructed in such a way that there is no shock in the middle of the variable, when the water balance is equal to the long-term water balance, and the intensity of the shocks gets stronger on both sides as we move away from this value necessitates the need to estimate the whole distribution of the relationship between water balance shock and crop and non-crop incomes. This will help to appropriately identify the region of water balance shock which leads to adverse crop income effects. To this end, I estimated a semiparametric fixed effects model where the only non-parametrical variable is water balance shock while controlling for all other control variables linearly following Baltagi and Li (2002). Figure 3 presents these results separately for crop and non-crop income.

As can be clearly seen from Figure 3, negative water balance shocks are translated into adverse crop income effects and positive water balance shocks are translated into positive crop income effects. The result on non-crop income, on the other hand, shows that water balance shocks do not have any effect for most of the domains of the water balance shock distribution. But, it has significantly positive effects on non-crop income roughly after one standard deviation above the long term mean. This positive effect of water balance shock on non-crop income is potentially a result of improved wages from salaried agricultural activities and general equilibrium effects of improved crop incomes. Overall, these results suggest movement out of on-farm crop agriculture into off-farm labor activities during negative water balance shocks can potentially serve as a shock coping mechanism. Hence, negative water balance shocks (droughts[15] hereafter) are used to proxy adverse crop income shocks which forms the basis for *ex post* labor adaptation responses. For empirical estimation, these drought shocks can be specified in a variety of ways. One immediate candidate is to use a dummy variable indicating whether a household experienced droughts. This specification gives equal weight for each and every household which experienced drought shocks irrespective of the intensity of the shock. The results from Figure 1, however, show that the effect of drought shocks on crop-income is not linear. More specifically, the adverse crop-income effects of drought shocks gets substantially stronger with the intensity of drought shock beginning roughly from 1.5 standard deviation. This necessitates weighting each household which experienced drought shock with the respective intensity of the shock. And for ease of interpretation, non-negative values of the shock are used.

The results of other control variables from tables 2 and 3 and from the semiparametric fixed effects regressions, not reported but can be available upon request, are also interesting. Both usage of animal traction and ownership of bicycle do positively and significantly affect household crop incomes. Head's education, household size, asset index, ownership of bicycle, animal traction usage, receipt of extension services and membership in farmers' association do all positively and significantly affect household non-crop incomes. These results are robust to alternative set of controls and across different model specifications.

7.2. Labor adaptation responses

Tables 4 to 6 report *ex ante* aggregate and locationally disaggregated labor adaptation results to water balance risk. The results suggest that households significantly engage in *ex ante* labor adaptation. At the extensive margin, aggregate adaptation responses suggest that households adapt family labor *ex ante* to water balance risk by taking up salaried non-agricultural activities. The result further shows that households withdraw from salaried agricultural activities which is potentially as vulnerable as on-farm agriculture to weather risk. This aggregate result show no

[15] This definition is standard in the literature (see for example, Mckee et al. (1993;1995) , Vicente-Serrano et al.(2010) and Beguería et al.(2014)

significant effect of water balance risk on self-employment activities in non-farm businesses and forestry, fishery and fauna activities.

Locational differences in *ex ante* labor adaptation responses show that households' increased engagement in salaried non-agricultural activities involves migrating outside the village while their withdrawal from local salaried agricultural activities takes place from local employment. A further analysis on the locational differences in adaptation that involve migrating outside the village reveal that households' increased labor adaptation into salaried non-agricultural activities is significantly taking place by migrating internationally. Households also appear to significantly engage more on salaried agricultural activities that involve migrating internationally, while they withdraw from self-employment in non-farm businesses that involves domestic migration. The combined marginal impact of this withdrawal appears to be relatively smaller compared to the combined marginal impacts of increased labor engagements that involve international migration. This implies that the later form of labor adaptation which takes place by migrating internationally is partly driven by substitution of the former labor activities by the later.

Tables 7 to 9 report *ex post* aggregate and locationally disaggregated labor adaptation results to contemporaneous drought shock. Aggregate results reveal that households significantly increase participation in salaried non-agricultural activities but withdraw from forestry, fishery and fauna activities in responses to contemporaneous drought shock. The result regarding the later labor activity is not strange given it is undertaken locally and highly vulnerable to drought shock. These aggregate labor supply responses to contemporaneous drought shock are at the odds with the findings of Dou et al. (2016) in East Africa in which they show rural workers are non-responsive to temperature shocks. However, other studies from Asia (Kochar (1999), Rose (2001)) show results in line with this study, whereby workers adapt to alternative weather shocks. Unlike this later group of studies, I further empirically show that labor adaptation into the former labor activity exclusively involves migration. This result supplements the small but growing literature which shows that different forms of contemporaneous adverse weather shocks leads to more general migratory responses by specifically assessing migration for work-related purposes (see for example Halliday (2006), Feng. et al. (2010, Gray and Mueller (2012a,b), Gray and Bilsborrow (2013), Mueller et al. (2014), Kubik and Maurel (2016), Cai et al. (2016)). The aforementioned studies focused on international migration, but I empirically show that (in Table 9) domestic migration is as important as international migration to labor adaptation to contemporaneous drought shock.

I next explore the medium term (after one and two periods) *ex post* labor adaptation responses to drought shocks. Tables 10 to 12 report these aggregate and locationally disaggregated labor adaptation results, controlling for contemporaneous drought shock. Aggregate results reveal that one period after a drought shock, households significantly withdraw from self-employment in forestry, fishery and fauna activities. Two periods following drought shocks they significantly engage more on self-employment activities in non-farm businesses, but withdraw from salaried agricultural activities. Locational differences in these adaptation responses show that households' increased engagement in self-employment activities of non-farm businesses is mainly undertaken locally. Similarly, households' withdrawal from salaried agricultural activities two periods after drought shock occurs from local employment. On top of these results, households' appear to participate more on local salaried non-agricultural activities one period after a drought shock. The fact that households engage in this activity one period after drought shocks but engage more on local self-employment in non-farm businesses only two periods after drought shocks is straightforward as the later activities have entrepreneurial risks embedded in it and hence sufficient time is needed to study the profitable ventures. On top of this, establishing some of these businesses also takes some time as they require acquisition of new skills to manage and undertake the daily activities of these businesses.

Households' withdrawal from self-employment in forestry, fishery and fauna activities contemporaneous to and one period after drought shocks is not strange given it is undertaken locally and vulnerable to drought shocks. Moreover, the results show that marginal impacts get smaller over time whereby higher impacts are contemporaneous to drought shocks. Although marginally insignificant, the coefficient estimate for this same activity two periods after drought shocks is negative and in terms of size smaller in absolute value. Unlike this pattern, the fact that households withdraw from local salaried agricultural activities only two periods after drought shocks, but not contemporaneous to and one period after drought shocks is puzzling given this labor activity is highly vulnerable to droughts like on-farm agriculture and forestry, fishery and fauna activities.

In this respect, World Bank (2006; 2008) argue that *ganho-ganho* is one of the coping strategies to weather shocks in rural Mozambique. Specifically, World Bank (2008, p.49) writes:

> In rural areas (of Mozambique), coping usually includes casual day labor—often referred to locally as *ganho-ganho*—on someone's farm in exchange for food or money. Although *ganho-ganho* is also practiced in normal times, it takes on particular

importance as a coping strategy in times of shocks and stress, when few regular activities are available to the poor.

Motivated by this and the fact that the survey question for salaried agricultural activities over the 12 months right before the survey is framed as "Agriculture (cropping or livestock) including *ganho-ganho*?", I empirically assessed if it is this customary risk sharing system, i.e. *ganho-ganho*, offsetting the potential negative effects on salaried agricultural employment for the first two periods. To this end, I distinguished local salaried agricultural activities based on the type of employer (and labor): unskilled labor employment on household farms, unskilled labor employment on large commercial farms and skilled labor employed by other economic agents (like factories, NGOs, government and others). Informal risk sharing exists among households and hence similar result needs to be obtained for the first category of labor activity. Table 13 reports these *ex post* adaptation results to drought shocks which reveals that the aforementioned result is in fact driven by unskilled labor employment on small household farms. This provides suggestive evidence that these results do reflect the off-setting effects of *ganho-ganho* on the potential negative effect of drought shocks on local salaried agricultural employment in the first two periods. The fact that this scheme cannot provide this benefit indefinitely is in line with empirical evidences of the informal risk literature (see for example, Townsend (1994), Dercon (2002)). The results further show that drought shocks do not have any significant effect on the other two categories of salaried agricultural activities. These results are reasonable given contractual agreements of skilled labor with the government, NGOs, factories, etc. are mostly permanent, and it is mostly long-term with large commercial farms. Moreover, these two groups of employers are better connected to modern financial markets which help them cope with drought shocks and hence to lay off workers in response to drought shocks might not be the optimal option.

The results of other control variables are also interesting. Tables 4 and 7 report the effects of these variables on aggregate occupational choices. Although the coefficient estimates of these variables in these two tables are both fixed effect coefficients, the other variable included in Table 4, i.e. coefficient of variation of water balance, is time invariant and hence the estimation is not based on a fully household fixed effects specification. Due to this, I rely on Table 7 to discuss the effects of the other control variables on aggregate labor allocation decisions. The results reveal that household demographics are important determinants of labor allocation decision. For instance, male-headed households are more likely to engage in salaried agricultural and non-agricultural activities. Human capital, measured using head's education, is a strong predictor of participation in salaried non-agricultural activities. Similarly, having more household member is positively associated with participation in salaried non-agricultural activities and self-employmnt in non-farm businesses. Wealthy households, as measured by land holding, are less likely to engage in salaried non-agricultural activities while they engage more on non-farm businesses. Ownership of bicycle is positively related to participation in all categories of labor activities but salaried agricultural activities. Animal traction usage and receipt of extension services are both positively related to participation in salaried agricultural activities and self-employment in non-farm businesses. Households' social capital, measured using membership in farmers' association, predicts positively self-employment in non-farm businesses.

8. Robustness checks

I conducted two robustness checks of the main results presented in the previous section.

Alternative definition of the growing period:

Mozambique has a diverse weather condition and hence the growing period differs across the country. Specifically, it runs approximately from October to March in the south and from November through March in the center and north. For consistency purposes, the main results are presented by defining the growing period from October through March for all villages irrespective of their location. This definition will not have any effects in the fixed effects specification as I am not comparing across villages, but might have effects in the correlated random effects specification owning to the fact that the identification in this specification relies on across village differences in the riskiness of the water balance distribution. To check if the main results are influenced by this definition, I calculated the water balance risk and drought shock measures by using growing periods which run from October to March and from November to March for the south and other parts of the country, respectively. The main results remain robust qualitatively to this alternative definition of the growing period.

Non-linear models:

The main labor adaptation results are from linear probability models although all the outcome variables are binary. Angrist and Pischke (2009) argue that linear model provides a robust approximation independent of the true functional forms even when the outcome variable is binary. But, these models also have well documented pitfalls when it comes to binary outcome variables. The practical relevance of these shortcomings are unclear but to see the robustness of the main results, I re-estimated the main results deploying non-linear models. Specifically, I estimated correlated random effects probit model and compared the average marginal effects from this model with marginal effects from the correlated random effects linear model of the main results. As a robustness to the household fixed effects results, I run conditional (fixed effects) logit models and compared the sign and significance of the odds ratio of these models with the marginal effects of the fixed effects results. The sign and significance of the main results, not reported here, remain unchanged in both cases.

9. Conclusions

Income of rural households in sub-Saharan Africa is highly vulnerable to vagaries of weather since the main economic stay in this region is rainfed agriculture. Households use a variety of adaptation strategies to shield themselves from and cope with weather-induced agricultural risks and shocks, respectively. However, how households occupationally and locationally adapt family labor to such risks and shocks has not been very well documented in the literature despite family labor being among the most important household assets in developing countries. This paper sheds light on this self-insurance scheme by matching a panel survey on Mozambican small and medium-sized farm households with proxies of agricultural risk and shocks calculated using high resolution geo-referenced precipitation and potential evapotranspiration data.

I find suggestive evidence that households adapt family labor *ex ante* to agricultural income risk by sending out household members internationally. Robust evidences show that households participate in contemporaneous *ex post* labor adaptation to adverse agricultural income shock by sending out migrant members both domestically and internationally. However, one and two periods following adverse agricultural income shocks they adapt locally by taking up other labor activities with potentially less correlated incomes compared to on-farm agriculture. It is a good news that households adapt family labor to agricultural risk and shocks as it helps them smooth income and potentially consumption.

There is a solid scientific evidence that weather variability and frequency of weather shocks will increase in sub-Saharan Africa (IPCC (2014)), which implies that agricultural risk and shocks will increase as well. In light of this, the results of this paper suggest increased local movement out of agriculture into non-agricultural activities and migration could result as households adapt family labor. This may eventually stress the existing limited rural resources available for non-agricultural expansion and labor market opportunities available in the cities both domestically and elsewhere.

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Table 1: Descriptives by survey year

	Survey Year					
	2001/2			2004/5		
Panel (a): Outcome Variables	N	Mean	SD	N	Mean	SD
Self-Employment (SE) in Agriculture (Ag)	2,936	0.990	0.097	2,936	0.995	0.069
Wage Employment (WE) in Ag	2,936	0.073	0.259	2,936	0.177	0.382
Local	2,936	0.050	0.219	2,936	0.146	0.353
Domestic	2,936	0.018	0.134	2,936	0.032	0.175
International	2,936	0.005	0.069	2,936	0.002	0.045
Wage Employment (WE) in Non-Ag	2,936	0.118	0.322	2,936	0.156	0.363
Local	2,936	0.035	0.184	2,936	0.058	0.234
Domestic	2,936	0.066	0.248	2,936	0.078	0.268
International	2,936	0.022	0.148	2,936	0.026	0.160
SE in non-farm businesses	2,936	0.291	0.454	2,936	0.421	0.494
Local	2,936	0.235	0.424	2,936	0.371	0.483
Domestic	2,936	0.058	0.234	2,936	0.065	0.247
International	2,936	0.009	0.095	2,936	0.006	0.076
SE in forestry, fishery and fauna activities	2,936	0.946	0.226	2,936	0.799	0.401
Net crop income	2,936	4650.641	9754.359	2,936	5107.146	11365.830
Net non-crop income	2,936	6529.019	35063.630	2,936	8267.188	32936.540
Panel (b): Risk and Shock Variables						
Drought shock (t)	407	0.405	0.301	407	0.905	0.566
Drought shock (t-1)	407	0.009	0.063	407	0.609	0.428
Drought shock (t-2)	407	0.205	0.368	407	0.263	0.374
CV of WB	407	28.386	5.282	407	28.386	5.282
Panel (C): Control Variables						
=1 Male Head	2,936	0.783	0.412	2,936	0.753	0.431
Head Age	2,934	42.878	14.527	2,935	45.276	14.482
Head Education	2,932	2.223	2.406	2,936	2.630	2.626
Household Size	2,936	5.503	3.140	2,936	5.902	3.488
Young Dependents	2,934	2.628	2.109	2,935	2.805	2.240
Elderly Dependents	2,934	0.146	0.406	2,935	0.663	1.186
Land Size	2,936	2.329	3.999	2,888	2.425	2.783
Asset Index	2,936	0.447	0.316	2,936	0.465	0.330
=1 HH Owns Bicycle	2,936	0.286	0.452	2,928	0.369	0.482
=1 HH Used Animal Traction	2,936	0.162	0.369	2,928	0.003	0.052
=1 HH Received Extension Service	2,936	0.158	0.365	2,928	0.178	0.382
=1 HH is Farmers' Association Member	2,936	0.047	0.212	2,928	0.080	0.272
=1 Village has Electricity	407	0.081	0.273	397	0.194	0.396

Notes: N=Number of observations, SD=Standard Deviation, and HH= household. All labor related outcome variables measure labor participation of a household at the extensive margin in the last 12 months immediately preceding the survey. 'Local' refers to employment within the village, 'Domestic' stands for employment outside the village but within the country and 'International' refers to employment outside the country. Household incomes are expressed (in real terms) in 2005 *Meticais da Nova Familia* (MTN).

Table 2: Income effects of weather risk

	(1)	(2)	(3)	(1)	(2)	(3)
	log (Crop income)			log (Non-crop income)		
Coefficient of Variation of WB	-0.070***	-0.064***	-0.059***	0.082***	0.046***	0.030***
	(0.009)	(0.009)	(0.009)	(0.016)	(0.012)	(0.011)
=1 Male Head		0.045	-0.05		0.776**	0.513
		(0.171)	(0.172)		(0.328)	(0.327)
Head Age		0.004	0.003		-0.003	-0.002
		(0.009)	(0.008)		(0.016)	(0.015)
Head Education		0.02	0.035		0.133**	0.169***
		(0.037)	(0.038)		(0.065)	(0.065)
Household Size		0.033	0.045		0.174***	0.186***
		(0.038)	(0.036)		(0.061)	(0.058)
Young Dependents		0.018	0.009		-0.054	-0.07
		(0.039)	(0.039)		(0.077)	(0.076)
Elderly Dependents		0.019	0.054		-0.063	-0.011
		(0.041)	(0.042)		(0.072)	(0.070)
Land Size		0.01	0.008		0.035*	0.031
		(0.018)	(0.017)		(0.021)	(0.020)
Asset Index			0.255*			0.531**
			(0.146)			(0.252)
=1 HH Owns Bicycle			0.177*			0.993***
			(0.100)			(0.142)
=1 HH Used Animal Traction			0.712**			0.889***
			(0.327)			(0.208)
=1 HH Received Extension Service			-0.07			0.389**
			(0.107)			(0.157)
=1 HH is Farmers' Assoc. Member			-0.006			0.440**
			(0.156)			(0.220)
=1 Village has Electricity			0.183			-0.063
			(0.185)			(0.275)
Constant	9.716***	8.900***	8.528***	3.182***	1.957***	2.172***
	(0.265)	(0.297)	(0.273)	(0.454)	(0.399)	(0.375)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.03	0.026	0.059	0.021	0.036	0.07
# of villages	407	406	396	407	406	396
N	5872	5764	5626	5872	5764	5626

Notes: This table provides estimates from random effects (1) and correlated random effects (2 and 3) regressions of the impact of weather variability on household incomes. The outcome variable in the first two regressions is (log of) net household crop income and in the last two regressions is (log of) net household non-crop income. Incomes are all expressed (in real terms) in 2005 *Meticais da Nova Familia* (MTN). From (2) and (3), the results for mean of the time-varying variables is not reported here but can be available upon request. Standard errors are clustered at the village level and reported in parenthesis. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table 3:Impacts of water balance shock on household incomes

	(1)	(2)	(3)	(1)	(2)	(3)
	Log(Crop income)			Log (Non-crop income)		
Water Balance Shock	0.295*	0.368**	0.304**	-0.132	-0.156	-0.151
	(0.168)	(0.169)	(0.151)	(0.203)	(0.204)	(0.201)
=1 Male Head		0.009	-0.08		0.791**	0.528
		(0.173)	(0.173)		(0.326)	(0.324)
Head Age		0.004	0.003		-0.002	-0.002
		(0.009)	(0.008)		(0.016)	(0.015)
Head Education		0.022	0.037		0.132**	0.168***
		(0.037)	(0.038)		(0.065)	(0.064)
Household Size		0.027	0.039		0.177***	0.188***
		(0.039)	(0.036)		(0.061)	(0.058)
Young Dependents		0.021	0.012		-0.055	-0.072
		(0.038)	(0.039)		(0.077)	(0.075)
Elderly Dependents		-0.006	0.031		-0.052	0.000
		(0.044)	(0.044)		(0.072)	(0.071)
Land Size		0.012	0.009		0.034	0.03
		(0.018)	(0.017)		(0.021)	(0.020)
Asset Index			0.221			0.548**
			(0.144)			(0.253)
=1 HH Owns Bicycle			0.194**			0.984***
			(0.099)			(0.142)
=1 HH Used Animal Traction			0.674**			0.908***
			(0.319)			(0.211)
=1 HH Received Extension Service			-0.06			0.384**
			(0.103)			(0.157)
=1 HH is Farmers' Assoc. Member			0.005			0.435**
			(0.150)			(0.221)
=1 Village has Electricity			0.169			-0.056
			(0.181)			(0.274)
Constant	7.790***	7.379***	7.139***	5.488***	3.740***	3.052***
	(0.064)	(0.377)	(0.352)	(0.075)	(0.687)	(0.679)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.033	0.032	0.052	0.021	0.037	0.7
# of Villages	407	406	396	407	406	396
N	5872	5764	5626	5872	5764	5626

Notes: This table provides estimates from household fixed effect regressions (with alternative set of controls) of the impact of weather shocks on household incomes. The outcome variable in the first two regressions is (log of) net household crop income, and in the last two regressions is (log of) net household non-crop income. Incomes are all expressed (in real terms) in 2005 *Meticais da Nova Familia* (MTN). Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. Standard errors are clustered at the village level and reported in parenthesis. HH=Household, FE=fixed effect, and N=Number of observations.

Table 4:*Ex ante* labor adaptation to water balance risk

	(1)	(2)	(3)	(4)
	WE_Ag	WE_NAg	SE_NFB	SE_FFF
CV of WB	-0.002**	0.006***	0.002	0.002
	(0.001)	(0.001)	(0.002)	(0.001)
=1 Male Head	0.060*	0.051*	-0.054	0.054
	(0.035)	(0.030)	(0.050)	(0.038)
Head Age	-0.001	-0.003*	-0.003	-0.002
	(0.001)	(0.002)	(0.002)	(0.002)
Head Education	0.001	0.026***	0.007	-0.005
	(0.007)	(0.006)	(0.008)	(0.007)
Household Size	0.006	0.036***	0.020**	0.008
	(0.007)	(0.007)	(0.010)	(0.007)
Young Dependents	-0.003	-0.026***	-0.002	0.009
	(0.010)	(0.009)	(0.013)	(0.009)
Elderly Dependents	-0.004	0.016**	0.003	0.052***
	(0.008)	(0.007)	(0.010)	(0.009)
Land Size	0.000	-0.004**	0.010**	-0.004*
	(0.001)	(0.002)	(0.004)	(0.002)
Asset Index	-0.048*	0.014	0.06	0.029
	(0.027)	(0.023)	(0.038)	(0.031)
=1 HH Owns Bicycle	0.01	0.035***	0.102***	0.026
	(0.015)	(0.012)	(0.020)	(0.017)
=1 HH Used Animal Traction	0.043*	0.01	0.071**	0.019
	(0.024)	(0.023)	(0.034)	(0.037)
=1 HH Received Extension Service	0.033*	0.024*	0.040*	-0.008
	(0.018)	(0.014)	(0.023)	(0.019)
=1 HH is Farmers' Association Member	-0.006	0.024	0.070**	0.025
	(0.026)	(0.025)	(0.034)	(0.026)
=1 Village has Electricity	-0.013	-0.017	-0.034	0.063*
	(0.032)	(0.026)	(0.042)	(0.038)
Constant	0.217***	-0.228***	0.178***	0.958***
	(0.037)	(0.041)	(0.058)	(0.047)
Year FE	Yes	Yes	Yes	Yes
R-squared	0.061	0.046	0.073	0.115
# of villages	396	396	396	396
N	5626	5626	5626	5626

Notes: This table provides estimates from correlated random effects (linear) regressions of households' *ex ante* labor adaptation to water balance risk. WE_Ag=Wage employment in agricultural activities, WE_NAg=Wage employment in non-agricultural activities, SE_NFB=Self-employment in non-farm businesses, and SE_FFF=Self-employment in forestry, fishery and fauna activities. Coefficient estimates for mean of the time-varying variables is not reported here but can be available upon request. Standard errors are which are clustered at the village level are reported in parenthesis. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. HH=Household, FE=fixed effect, and N=Number of observations.

Table 5:Locational differences in households' *ex ante* labor adaptation to water balance risk

	WE_Ag		WE_NAg		SE_NFB	
	L	M	L	M	L	M
CV of WB	-0.003***	0.001	0.001	0.005***	0.002	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
=1 Male Head	0.042	0.018	-0.007	0.057**	-0.066	0.016
	(0.031)	(0.019)	(0.017)	(0.028)	(0.050)	(0.026)
Head Age	0.000	-0.001	0.000	-0.003*	-0.002	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Head Education	0.001	0.000	0.010**	0.018***	0.013	-0.004
	(0.006)	(0.004)	(0.005)	(0.006)	(0.008)	(0.005)
Household Size	0.001	0.005	0.017***	0.023***	0.014	0.014**
	(0.007)	(0.003)	(0.005)	(0.007)	(0.009)	(0.007)
Young Dependents	0.001	-0.003	-0.014**	-0.017**	0.001	-0.004
	(0.009)	(0.004)	(0.006)	(0.008)	(0.012)	(0.008)
Elderly Dependents	-0.005	0.002	0.004	0.016**	0.006	0.001
	(0.008)	(0.003)	(0.006)	(0.007)	(0.011)	(0.007)
Land Size	0.001	0.000	0.000	-0.004**	0.008**	0.002*
	(0.001)	(0.001)	(0.002)	(0.002)	(0.004)	(0.001)
Asset Index	-0.054**	0.005	-0.014	0.027	0.033	0.03
	(0.026)	(0.013)	(0.017)	(0.019)	(0.038)	(0.019)
=1 HH Owns Bicycle	0.003	0.008	0.023**	0.014	0.097***	0.023**
	(0.014)	(0.007)	(0.009)	(0.010)	(0.020)	(0.011)
=1 HH Used Animal Traction	0.047**	-0.004	0.023	-0.004	0.077**	0.005
	(0.022)	(0.013)	(0.015)	(0.020)	(0.033)	(0.016)
=1 HH Received Extension Service	0.033**	0.002	-0.011	0.035***	0.059***	-0.011
	(0.016)	(0.009)	(0.010)	(0.012)	(0.022)	(0.011)
=1 HH is Farmers' Assoc. Member	-0.022	0.018	0.052***	-0.017	0.058*	0.021
	(0.025)	(0.012)	(0.018)	(0.019)	(0.033)	(0.019)
=1 Village has Electricity	-0.017	-0.001	-0.039*	0.028	-0.051	0.029
	(0.034)	(0.014)	(0.021)	(0.023)	(0.044)	(0.020)
Constant	0.195***	0.019	-0.028	-0.215***	0.123**	0.075***
	(0.031)	(0.018)	(0.020)	(0.037)	(0.057)	(0.026)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.062	0.006	0.023	0.033	0.075	0.012
# of villages	396	396	396	396	396	396
N	5626	5626	5626	5626	5626	5626

Notes: This table provides estimates from correlated random effects (linear) regressions of locational differences in households' *ex ante* labor adaptation to water balance risk. Coefficient estimates for mean of the time-varying variables is not reported here but can be available upon request. Standard errors are clustered at the village level and reported in parenthesis. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. FE=fixed effects, N=Number of observations, L=Local employment, and M=Adaptation by migrating outside the village.

Table 6:Locational differences in households' *ex ante* labor adaptation trough migration

	WE_Ag_M		WE_NAg_M		SE_NFB	
	D	I	D	I	D	I
CV of WB	0.000	0.001**	0.001	0.004***	-0.001*	0.000
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
=1 Male Head	0.007	0.01	0.029	0.03	0.008	0.009
	(0.017)	(0.008)	(0.023)	(0.019)	(0.025)	(0.007)
Head Age	-0.001	0.000	-0.001	-0.001	-0.001	-0.000**
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
Head Education	0.002	-0.002	0.011**	0.008**	0.001	-0.005**
	(0.003)	(0.001)	(0.005)	(0.004)	(0.005)	(0.002)
Household Size	0.005*	0.000	0.019***	0.007*	0.01	0.004
	(0.003)	(0.002)	(0.005)	(0.004)	(0.006)	(0.003)
Young Dependents	-0.005	0.002	-0.017***	-0.001	-0.001	-0.003
	(0.004)	(0.002)	(0.007)	(0.004)	(0.007)	(0.003)
Elderly Dependents	0.004	-0.001	0.012**	0.006	0.002	-0.001
	(0.003)	(0.001)	(0.006)	(0.005)	(0.006)	(0.004)
Land Size	0.000	-0.001	-0.003**	-0.001	0.002*	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Asset Index	0.000	0.005	0.022	0.002	0.029	0.000
	(0.012)	(0.004)	(0.015)	(0.013)	(0.018)	(0.009)
=1 HH Owns Bicycle	0.008	-0.001	0.015*	0.000	0.016	0.006
	(0.007)	(0.002)	(0.009)	(0.004)	(0.010)	(0.004)
=1 HH Used Animal Traction	0.001	-0.006	0.004	-0.011	0.006	0.001
	(0.011)	(0.005)	(0.013)	(0.018)	(0.015)	(0.007)
=1 HH Received Extension Service	0.006	-0.004	0.030***	0.006	-0.01	-0.001
	(0.008)	(0.003)	(0.011)	(0.006)	(0.011)	(0.004)
=1 HH is Farmers' Assoc. Member	0.01	0.008	-0.017	0.006	0.017	0.008
	(0.012)	(0.005)	(0.016)	(0.011)	(0.018)	(0.005)
=1 Village has Electricity	0.000	-0.001	0.026	0.001	0.023	0.006
	(0.013)	(0.003)	(0.022)	(0.007)	(0.020)	(0.004)
Constant	0.022	-0.003	-0.091***	-0.129***	0.081***	-0.005
	(0.017)	(0.007)	(0.028)	(0.027)	(0.025)	(0.008)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.007	0.008	0.024	0.017	0.01	0.007
# of villages	396	396	396	396	396	396
N	5626	5626	5626	5626	5626	5626

Notes: This table provides estimates from correlated random effects (linear) regressions of locational differences in households' *ex ante* labor adaptation through migration to water balance risk. Coefficient estimates for mean of the time-varying variables is not reported here but can be available upon request. Standard errors are clustered at the village level and reported in parenthesis. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. FE=fixed effects, N=Number of observations, M=Adaptation by migrating outside the village, D=Domestically , and I= Internationally.

Table 7:Labor adaptation to drought shock

	(1)	(2)	(3)	(4)
	WE_Ag	WE_NAg	SE_NFB	SE_FFF
Drought	-0.026	0.062***	0.002	-0.230***
	(0.027)	(0.021)	(0.032)	(0.045)
=1 Male Head	0.058*	0.056*	-0.054	0.035
	(0.035)	(0.030)	(0.050)	(0.037)
Head Age	-0.001	-0.003*	-0.003	-0.002
	(0.001)	(0.002)	(0.002)	(0.002)
Head Education	0.001	0.026***	0.007	-0.004
	(0.007)	(0.006)	(0.008)	(0.007)
Household Size	0.005	0.037***	0.020**	0.005
	(0.007)	(0.007)	(0.010)	(0.007)
Young Dependents	-0.003	-0.026***	-0.002	0.01
	(0.010)	(0.009)	(0.013)	(0.009)
Elderly Dependents	-0.006	0.021***	0.003	0.035***
	(0.008)	(0.008)	(0.010)	(0.009)
Land Size	0.001	-0.004**	0.009**	-0.003
	(0.001)	(0.002)	(0.004)	(0.002)
Asset Index	-0.051*	0.02	0.06	0.005
	(0.027)	(0.023)	(0.037)	(0.029)
=1 HH Owns Bicycle	0.011	0.032**	0.102***	0.039**
	(0.016)	(0.012)	(0.020)	(0.017)
=1 HH Used Animal Traction	0.043*	0.011	0.071**	0.015
	(0.024)	(0.022)	(0.034)	(0.039)
=1 HH Received Extension Service	0.034*	0.023	0.040*	-0.003
	(0.018)	(0.014)	(0.023)	(0.019)
=1 HH is Farmers' Association Member	-0.006	0.024	0.070**	0.026
	(0.026)	(0.025)	(0.034)	(0.027)
=1 Village has Electricity	-0.014	-0.014	-0.034	0.052
	(0.032)	(0.025)	(0.042)	(0.037)
Constant	0.067	-0.048	0.249***	1.029***
	(0.070)	(0.074)	(0.091)	(0.073)
Year FE	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
R-squared	0.062	0.05	0.073	0.151
# of villages	396	396	396	396
N	5626	5626	5626	5626

Notes: This table provides estimates from fixed effects (linear probability model) regressions of households' *ex post* labor adaptation to water deficit (drought) shock. WE_Ag=Wage employment in agricultural activities, WE_NAg=Wage employment in non-agricultural activities, SE_NFB=Self-employment in non-farm businesses, and SE_FFF=Self-employment in forestry, fishery and fauna activities. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. Standard errors are reported in parenthesis. Standard errors are clustered at the village level. FE=fixed effects, HH=Household, N=Number of observations

Table 8:Locational differences in households' *ex post* labor adaptation to drought shock

	WE_Ag		WE_NAg		SE_NFB	
	L	M	L	M	L	M
Drought	-0.021	-0.007	0.011	0.056***	0.008	-0.007
	(0.026)	(0.011)	(0.015)	(0.015)	(0.031)	(0.014)
=1 Male Head	0.04	0.017	-0.006	0.061**	-0.066	0.016
	(0.031)	(0.019)	(0.017)	(0.028)	(0.050)	(0.026)
Head Age	0.000	-0.001	0.000	-0.003*	-0.002	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Head Education	0.002	0.000	0.010**	0.018***	0.013	-0.004
	(0.006)	(0.004)	(0.005)	(0.006)	(0.008)	(0.005)
Household Size	0.001	0.005	0.017***	0.024***	0.015	0.013*
	(0.007)	(0.003)	(0.005)	(0.007)	(0.009)	(0.007)
Young Dependents	0.001	-0.003	-0.014**	-0.017**	0.001	-0.004
	(0.009)	(0.004)	(0.006)	(0.008)	(0.012)	(0.008)
Elderly Dependents	-0.007	0.002	0.004	0.020***	0.007	0.001
	(0.008)	(0.003)	(0.006)	(0.007)	(0.011)	(0.007)
Land Size	0.001	0.000	0.000	-0.004**	0.008**	0.002*
	(0.001)	(0.001)	(0.002)	(0.002)	(0.004)	(0.001)
Asset Index	-0.056**	0.004	-0.013	0.033*	0.034	0.029
	(0.026)	(0.013)	(0.017)	(0.019)	(0.038)	(0.019)
=1 HH Owns Bicycle	0.004	0.008	0.022**	0.011	0.096***	0.023**
	(0.014)	(0.007)	(0.009)	(0.010)	(0.020)	(0.011)
=1 HH Used Animal Traction	0.047**	-0.005	0.023	-0.003	0.077**	0.005
	(0.022)	(0.013)	(0.015)	(0.020)	(0.032)	(0.016)
=1 HH Received Extension Service	0.033**	0.003	-0.011	0.034***	0.059***	-0.011
	(0.016)	(0.009)	(0.010)	(0.012)	(0.022)	(0.011)
=1 HH is Farmers' Assoc. Member	-0.022	0.019	0.051***	-0.017	0.058*	0.021
	(0.025)	(0.012)	(0.018)	(0.019)	(0.033)	(0.019)
=1 Village has Electricity	-0.018	-0.001	-0.039*	0.031	-0.05	0.028
	(0.033)	(0.014)	(0.021)	(0.022)	(0.044)	(0.020)
Constant	0.049	0.014	-0.047	-0.024	0.186**	0.035
	(0.059)	(0.040)	(0.045)	(0.068)	(0.085)	(0.057)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.062	0.006	0.023	0.038	0.075	0.012
# of villages	396	396	396	396	396	396
N	5626	5626	5626	5626	5626	5626

Notes: This table provides estimates from fixed effects (linear probability model) regressions of locational differences in households' *ex post* labor adaptation to drought (water deficit) shock. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. Standard errors are reported in parenthesis. Standard errors are clustered at the village level. FE=fixed effects, HH=Household, N=Number of observations, L=Local adaptation, M=Adaptation by migrating outside the village.

Table 9:Locational differences in households' *ex post* labor adaptation through migration

	WE_Ag_M		WE_NAg_M		SE_NFB	
	D	I	D	I	D	I
Drought	-0.011	0.003	0.035**	0.023***	-0.011	0.004
	(0.012)	(0.003)	(0.014)	(0.008)	(0.013)	(0.004)
=1 Male Head	0.006	0.011	0.032	0.032*	0.007	0.009
	(0.017)	(0.009)	(0.023)	(0.019)	(0.025)	(0.007)
Head Age	-0.001	0.000	-0.001	-0.001	-0.001	-0.000**
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
Head Education	0.002	-0.002	0.011**	0.008**	0.001	-0.005**
	(0.003)	(0.001)	(0.005)	(0.004)	(0.005)	(0.002)
Household Size	0.005*	0.000	0.019***	0.007*	0.01	0.004
	(0.003)	(0.002)	(0.005)	(0.004)	(0.006)	(0.003)
Young Dependents	-0.005	0.002	-0.017***	-0.002	-0.001	-0.003
	(0.004)	(0.002)	(0.007)	(0.004)	(0.007)	(0.003)
Elderly Dependents	0.003	-0.001	0.015**	0.008	0.001	0.000
	(0.003)	(0.002)	(0.006)	(0.005)	(0.006)	(0.004)
Land Size	0.000	-0.001	-0.003**	-0.001	0.002*	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Asset Index	-0.001	0.005	0.025*	0.005	0.028	0.000
	(0.012)	(0.004)	(0.015)	(0.013)	(0.018)	(0.009)
=1 HH Owns Bicycle	0.009	-0.001	0.013	-0.001	0.017*	0.005
	(0.007)	(0.002)	(0.009)	(0.004)	(0.010)	(0.004)
=1 HH Used Animal Traction	0.001	-0.006	0.005	-0.01	0.006	0.001
	(0.011)	(0.005)	(0.013)	(0.018)	(0.015)	(0.007)
=1 HH Received Extension Service	0.006	-0.004	0.029***	0.006	-0.009	-0.001
	(0.008)	(0.003)	(0.011)	(0.006)	(0.011)	(0.004)
=1 HH is Farmers' Assoc. Member	0.01	0.008	-0.017	0.006	0.017	0.008
	(0.012)	(0.005)	(0.016)	(0.011)	(0.018)	(0.005)
=1 Village has Electricity	-0.001	0.000	0.028	0.002	0.022	0.007*
	(0.013)	(0.003)	(0.022)	(0.007)	(0.020)	(0.004)
Constant	0.023	-0.009	-0.026	-0.012	0.032	0.005
	(0.038)	(0.011)	(0.056)	(0.042)	(0.055)	(0.014)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.007	0.008	0.026	0.019	0.009	0.008
# of villages	396	396	396	396	396	396
N	5626	5626	5626	5626	5626	5626

Notes: This table provides estimates from fixed effects (linear probability model) regressions of locational differences in households' *ex post* labor adaptation through migration to drought shock. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. Standard errors are reported in parenthesis. Standard errors are clustered at the village level. FE=fixed effects, , N=Number of observations, M=Adaptation by migrating outside the village, D=Domestically , and I= Internationally.

Table 10: *Ex post* labor adaptation to medium term drought shocks

	(1)	(2)	(3)	(4)
	WE_Ag	WE_NAg	SE_NFB	SE_FFF
Drought (t)	-0.048	0.063***	0.032	-0.271***
	(0.030)	(0.023)	(0.035)	(0.052)
Drought (t-1)	-0.006	0.003	-0.004	-0.119***
	(0.024)	(0.021)	(0.031)	(0.035)
Drought (t-2)	-0.053***	0.002	0.084***	-0.034
	(0.016)	(0.012)	(0.021)	(0.023)
Constant	0.098	-0.049	0.198**	1.040***
	(0.071)	(0.074)	(0.091)	(0.071)
Other Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
R-squared	0.066	0.05	0.079	0.162
# of villages	396	396	396	396
N	5626	5626	5626	5626

Notes: This table provides estimates from fixed effect (linear probability model) regressions of households' *ex post* labor adaptation to medium term water deficit shocks controlling for contemporaneous drought shock. WE_Ag=Wage employment in agricultural activities, WE_NAg=Wage employment in non-agricultural activities, SE_NFB=Self-employment in non-farm businesses, and SE_FFF=Self-employment in forestry, fishery and fauna activities. The coefficient estimates for other control variables is not reported here, but can be available upon request. Standard errors are clustered at the village level and reported in parenthesis. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. FE=fixed effects, and N=Number of observations.

Table 11: Locational differences in *ex post* labor adaptation to medium term drought shocks

	WE_Ag		WE_NAg		SE_NFB	
	L	M	L	M	L	M
Drought (t)	-0.041	-0.008	0.016	0.054***	0.036	-0.002
	(0.029)	(0.012)	(0.017)	(0.017)	(0.034)	(0.015)
Drought (t-1)	-0.007	0.003	0.025*	-0.018	-0.01	0.004
	(0.024)	(0.010)	(0.014)	(0.016)	(0.029)	(0.017)
Drought (t-2)	-0.048***	-0.003	-0.004	0.005	0.078***	0.011
	(0.016)	(0.006)	(0.008)	(0.010)	(0.020)	(0.011)
Constant	0.077	0.016	-0.043	-0.029	0.138	0.029
	(0.059)	(0.040)	(0.045)	(0.068)	(0.084)	(0.057)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.066	0.006	0.025	0.039	0.081	0.013
# of villages	396	396	396	396	396	396
N	5626	5626	5626	5626	5626	5626

Notes: This table provides fixed effect (linear probability model) regression estimates of locational differences in households' *ex post* labor adaptation to medium term drought shocks controlling for contemporaneous drought shock. The coefficient estimates for other control variables is not reported here, but can be available upon request. Standard errors are clustered at the village level and reported in parenthesis. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively FE=fixed effects, N=Number of observations, L=Local adaptation, and M=Adaptation by migrating outside the village.

Table 12:Locational differences in households' *ex post* labor adaptation through migration

	WE_Ag_M		WE_NAg_M		SE_NFB	
	D	I	D	I	D	I
Drought (t)	-0.012	0.004	0.037**	0.018*	-0.004	0.003
	(0.014)	(0.004)	(0.015)	(0.009)	(0.014)	(0.005)
Drought (t-1)	-0.001	0.004	0.002	-0.026	0.013	-0.007
	(0.011)	(0.005)	(0.013)	(0.016)	(0.015)	(0.008)
Drought (t-2)	-0.003	0	0.003	0.004	0.01	0.002
	(0.006)	(0.002)	(0.008)	(0.006)	(0.010)	(0.004)
Constant	0.024	-0.009	-0.028	-0.017	0.027	0.004
	(0.038)	(0.011)	(0.056)	(0.043)	(0.055)	(0.014)
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.007	0.009	0.026	0.023	0.01	0.008
# of villages	396	396	396	396	396	396
N	5626	5626	5626	5626	5626	5626

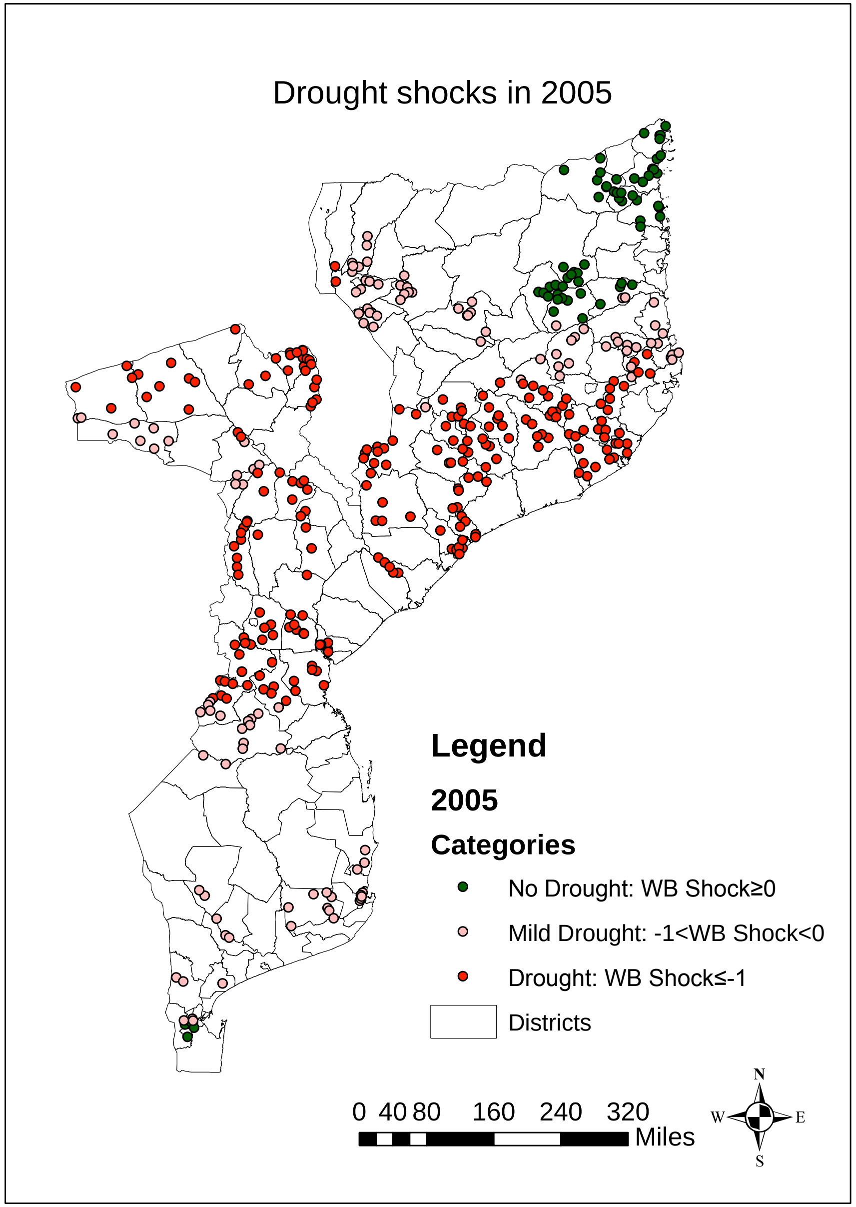
Notes: This table provides fixed effects (linear probability model) regression estimates of locational differences in households' *ex post* labor adaptation through migration to medium term drought shocks controlling for contemporaneous drought shock. The coefficient estimates for other control variables is not reported here, but can be available upon request. Standard errors are clustered at the village level and reported in parenthesis. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. FE=fixed effects, , N=Number of observations, M=Adaptation by migrating outside the village, D=Domestically , and I= Internationally.

Table 13:Households' labor adaptation in local salaried agricultural activities

	WE_Ag_L		
	Unskilled	Unskilled	Skilled
	HH farms	Commercial Farms	
Drought (t)	-0.032	0.000	-0.009
	(0.026)	(0.009)	(0.006)
Drought (t-1)	0.007	-0.008	-0.006
	(0.022)	(0.007)	(0.005)
Drought (t-2)	-0.043***	-0.003	0.000
	(0.015)	(0.003)	(0.003)
Constant	0.086*	-0.017	0.002
	(0.050)	(0.018)	(0.025)
Other Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Household FE	Yes	Yes	Yes
R-squared	0.065	0.006	0.007
Mean of Y	0.088	0.008	0.005
# of villages	396	396	396
N	5626	5626	5626

Notes: This table provides fixed effects (linear probability model) estimates of households' *ex post* labor adaptation in local salaried agricultural activities to medium term drought shocks, controlling for contemporaneous drought shock, disaggregated based on the type of labor and employment. Skilled labor refers to labor employed by the government, NGOs, factories, etc. The coefficient estimates for other control variables is not reported here, but can be available upon request. Standard errors are clustered at the village level and reported in parenthesis. Asterisks: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels, respectively. FE=fixed effects, L=local adaptation, and N=Number of observations.

Figure 1: Distribution of drought shocks across survey villages in different years


Drought shocks in 2005
Legend
2005
Categories
No Drought: WB Shock≥0
Mild Drought: -1<WB Shock<0
Drought: WB Shock≤-1
Districts
0 40 80 160 240 320
Miles
N
W
E
S

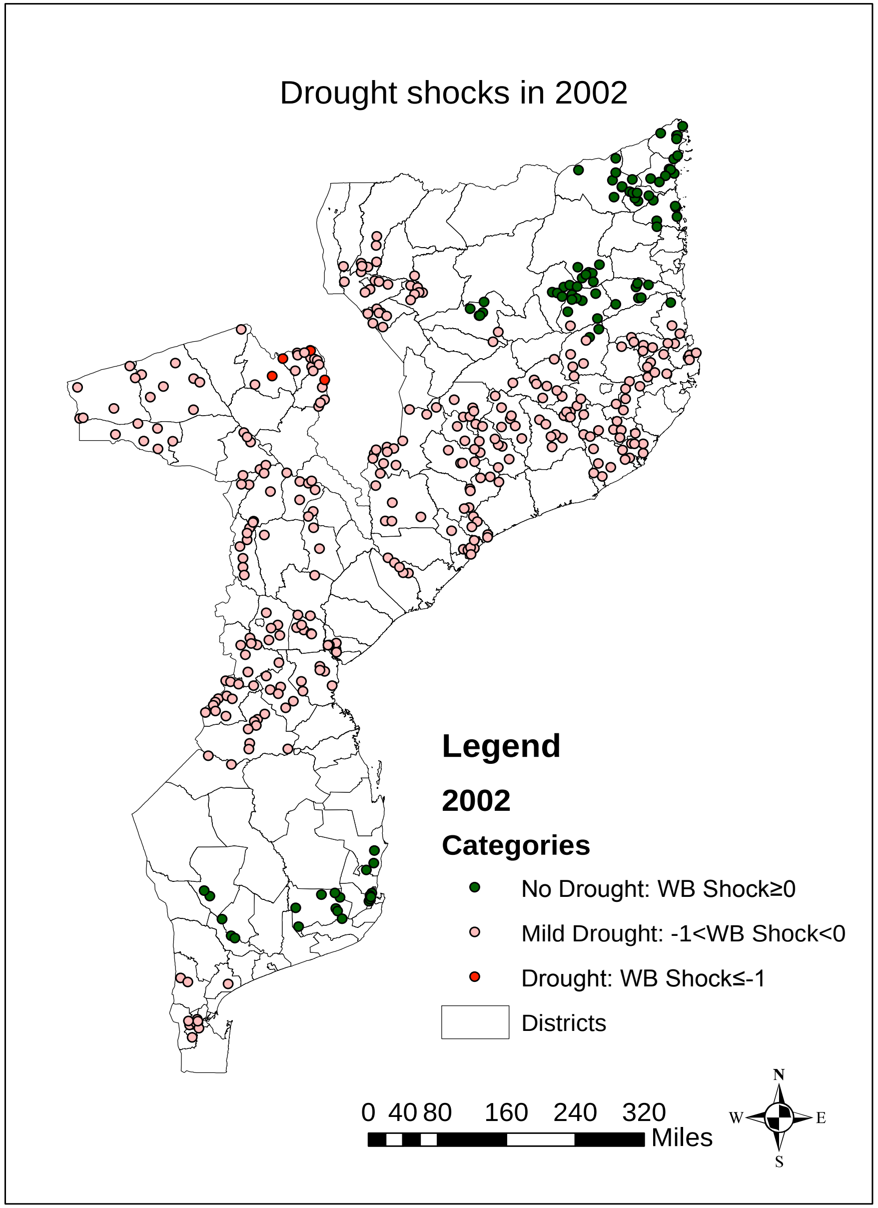

Drought shocks in 2002
Legend
2002
Categories
No Drought: WB Shock≥0
Mild Drought: -1<WB Shock<0
Drought: WB Shock≤-1
Districts
0 40 80 160 240 320
Miles
N
W
E
S

Figure 2: Distribution of Coefficient of Variation of Water Balance across villages

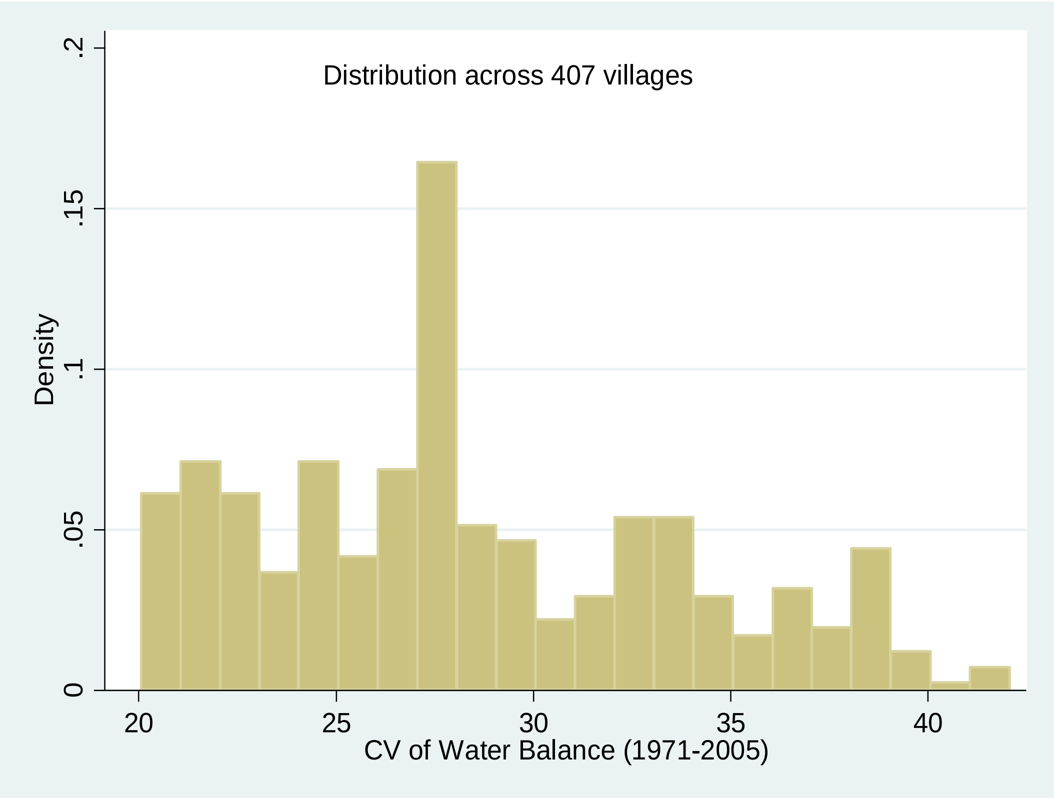
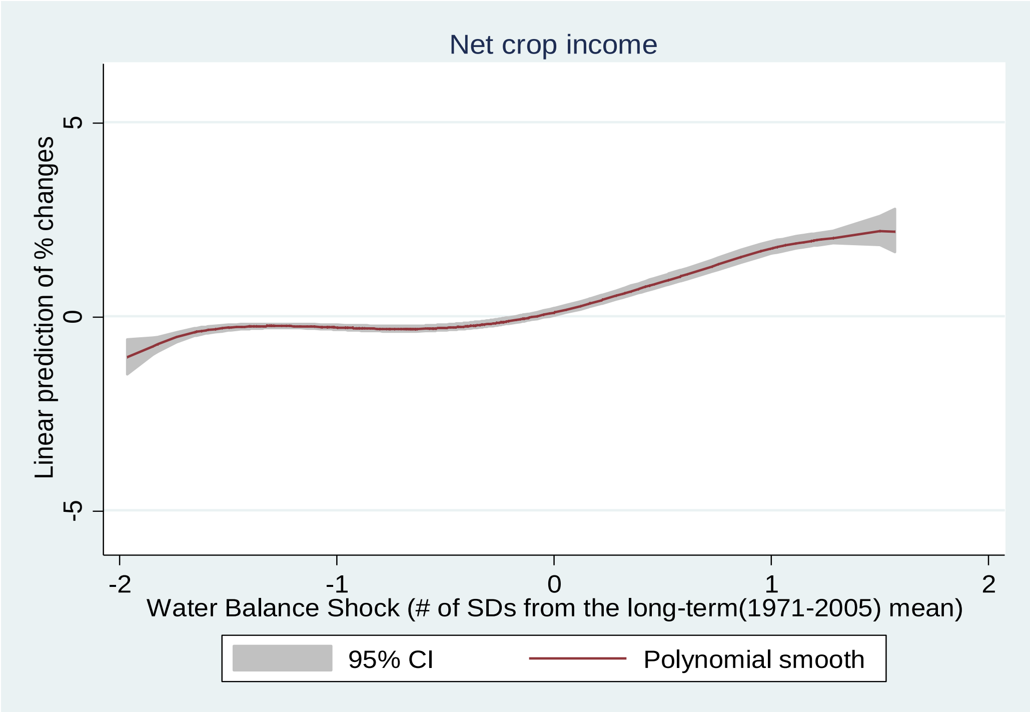
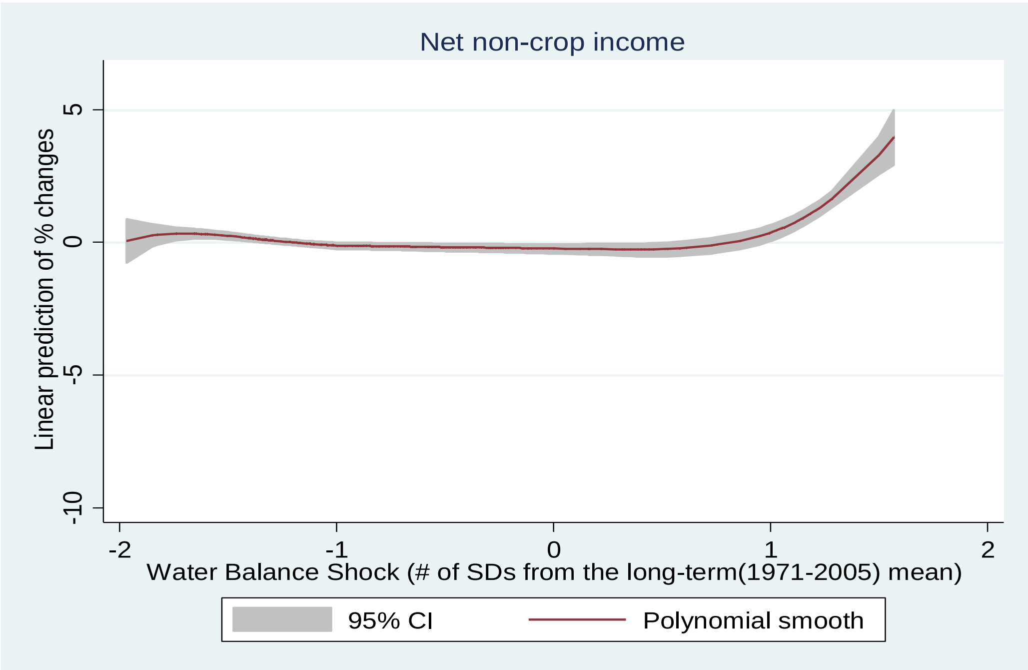


Figure 3: Distribution of impacts of water balance shocks on household incomes





Notes: Semiparametric fixed effect regression results of the impact of water balance shock on (log of) household incomes expressed (in real terms) in 2005 *Meticais da Nova Familia* (MTN). Water balance shock is the only non-parametrical variable. Other controls include male head, head age, head education, household size, young dependents, elderly dependents, land holding in hectares, asset index, dummy variables for bike ownership, usage of animal traction, receipt of extension service over the last 12 months, membership in farmers' association, and village access to electricity.