Gender, weather shocks and welfare: evidence from Malawi

Article (Accepted Version)

Gender, Weather Shocks and Welfare: Evidence from Malawi

Abstract

This paper explores the gender-differentiated effects of weather shocks on households' welfare in Malawi using panel data aligned with climatic records. Results show that temperature shocks severely affect household welfare, reducing consumption, food consumption and daily caloric intake. The negative welfare effects are more severe for households where land is solely managed by women, a finding that sheds light on the gender-unequal impact of temperature shocks. Our evidence also suggests that women's vulnerability to temperature shocks is linked to women's land tenure security, as temperature shocks impact significantly women's welfare only in patrilineal districts, where statistics show that investment in agricultural technologies is lower.

JEL Classification: *E2, J16, O44, O47, Q54*

Key words: *Climate change, welfare, rainfall shocks, impact, gender, Malawi.*

1. Introduction

This paper explores the interconnections between weather vulnerability, gender and cultural empowerment in Malawi. The World Bank (2010) ranks Malawi as the twelfth most exposed country to the effects of climate change and this vulnerability is likely explained by two elements. First, the country's historical climate distribution is characterised by frequent environmental shocks such as droughts and floods (Chinsinga, 2012). Second, structural economic conditions exacerbate its vulnerability: for example, Malawi's agricultural sector contributes nearly 37 per cent of the country's GDP with subsistence smallholders producing 75 per cent of Malawi's total agricultural output, using a production system that is predominantly rain-fed with limited irrigation. These features widely explain why Malawian household's welfare might be highly elastic to extreme events in weather (Chirwa and Quinion, 2005).

In addition, Malawi is characterized by a complex system of gendered land institutions that have developed across its history, providing a unique context for the study of gender in agriculture. As emphasized in the ground breaking book by Agarwal (1994), a prominent determinant of women's disadvantaged economic condition across developing countries is the gender-gap in command over productive resources such as land. In Malawi, women's empowerment in agriculture varies according to the customary principles that regulate land holding in their community of residence (Peters, 2010; Mueller, Quisumbing, Lee, & Droppelmann*,* 2014). The Malawian system of land tenure is geographically heterogeneous and is defined by two systems of norms: the matrilineal and the patrilineal system of property inheritance. In Matrilineal-uxorilocal societies, women usually inherit land therefore men move to their wives' villages to cultivate land, as men do not have access to land belonging to their own matrilineage. Within these communities, women have a recognized influence on land decisions, agriculture and community management.

According to Berge, Kambewa, Munthali, and Wiig (2014), nearly 80 per cent of the population follows a matrilineal land inheritance system in Malawi, including Chewa and Lomwe people, two of the largest ethnic groups in the country. Principles regulating the Patrilineal-virilocal communities are diametrically opposed to their matrilineal counterparts (Peter, 2010). Both in patrilineal and matrilineal communities, following the death of the official owner, the wife/husband loses the right to retain the property rights and the risk of expropriation by the deceased's relatives is high. Recent studies underscore how insecurity in land tenure often correlates with low investment in agricultural technologies, as farmers tend to prefer a low return from agricultural production to the risk of immediate loss of the investment through expropriation (Lovo, 2016). Other works on Malawi discuss the presence of a productivity gap between women and men, due to differences in endowments, lower cultivation of high value crops and a lower ratio of adult male labourers, and to other structural factors, such as higher child dependency-ratio and lower effects from the usage of inorganic fertilizer (Kilic, Palacios-Lopez, & Goldstein, 2015).

In this paper, we use the gender of the land-manager within the household to investigate the impact of weather shocks on a household's welfare. Anecdotal evidence suggests that extreme events in weather might disproportionally affect the poorest part of the population, and the social groups that have less access to resources to cope with these shocks (Dankelman, 2008; Denton 2002; Nelson & Stathers, 2009). There is also a small growing literature investigating how gender differences could be correlated with a differentiated impact of weather shocks in the context of smallholder agriculture (Akampumunza and Matsuda, 2016; Akter, Krupnik, Rossi, & Khanam, 2016).[1]

This article adds evidence to the discussion on gender and weather shocks by employing georeferenced panel household-level data combined with climate data. The growing availability of high quality georeferenced data on weather allows for the measurement and inclusion of a significant and exogenous component of risk in the empirical model. Although weather represents only one of the several exogenous factors affecting income and consumption of rural households, it is among the few that are spatially covariant. This covariance has a crucial role for income variability, which is likely to influence welfare, especially for farm households relying on a rainfed production system. We estimate the causal impact of weather shocks on welfare using a fixed effects (FE) strategy to address the individual response to shocks while accounting for unobserved heterogeneity. First we assess the mean impact of weather shocks on the national representative household sample, including agricultural and non-agricultural households. Then our work investigates the existence of a gender-differentiated impact of weather shocks, where the gender of the household is defined by the decision maker of the household's plots.[2] We further test the hypothesis that local cultural norms that determine women's property and inheritance rights may narrow/enlarge differences in welfare between women and men in some areas. On this purpose, the effects of weather shocks are tested by disaggregating between households where land is managed by women/men/jointly managed in matrilineal districts and in patrilineal ones. This exercise shows how customary rules enforced in the geographical location could propagate the impact of weather shocks on the welfare of given groups (such as female-dominated or female-managed groups). We suggest that when women's land tenure is embedded within customary norms, women may be incentivised to invest more in climate-resilient technologies and this could decrease their vulnerability to extreme events in weather.

There are three key findings in our work. First, occurrence of high temperature shocks during the agricultural season disrupts household's consumption, food consumption, and caloric intake. Second, temperature shocks lead to severe decreases in the above welfare measures, but also in non-food consumption, when plots in the household are solely managed by women. In contrast, when men are the exclusive managers of the plots, or when the plots are jointly managed, our findings suggest that households' consumption is more resilient to extreme events. We derive that the gendered nature of the household influences household's vulnerability. As a third contribution, we show that the vulnerability to shocks of gendered households disappears when they live in districts nested in matrilineal social norms, whereas gender differences remain consistent in patrilineal districts, even if this last result needs to be interpreted with caution due to the small sample size. This finding suggests that the insecurity of land tenure associated to social norms governing women's property rights might affect the vulnerability of households where women are primary land managers as well as their incentive to invest in climate resilient technologies.

The remainder of the paper proceeds as follows. Section 2 outlines Malawi's background on climate change, livelihood and gender. Section 3 reviews extant literature to develop hypotheses within our conceptual framework. Section 4 reports data construction and variables used; section 5 presents the empirical strategy. Econometric results are discussed in sections 6 and Section 7 concludes.

2. Climate variability, welfare and gender in Malawi

In Malawi agriculture represents a key component of the economy as it employs 85 per cent of the labour force, accounts for about 39 per cent of Gross Domestic Product (GDP), and provides 83 per cent of foreign exchange earnings (Chirwa and Quinion, 2005; Chinsinga 2012). The agricultural sector is composed of estates and smallholder farmers and these two groups diverge substantially in terms of characteristics and performance. Smallholders are 90 per cent of total farmers and they own 78 per cent of total cultivated land, characteristics that make Malawi's economy extremely dependent on the performance of the smallholder subsector (Chirwa and Quinion, 2005; Tchale, 2009). Average farm size is about 1.12 hectares (ha), but more than 72 per cent of smallholder farms are less than one ha. This makes Malawi the third most densely populated country in terms of land owned in Sub-Saharan Africa (at 2.3 rural people per ha of agricultural land) after Rwanda (3.8 people per ha) and Burundi (2.7 people per ha) (Benin, Thurlow, Diao, McCool, & Simtowe, 2008). There is a single growing season lasting between November and May, and a dry season that spans between June and October. During the dry season, few farmers are able to make use of residual moisture in valley floors (*dambos*) to continue cultivation during the dry season.

The constitution of Malawi enshrines principles of equality both in terms of gender equality (section 13) and in promoting women's empowerment (section 24), prohibiting any type of discrimination based on gender. Despite this legal framework, national governments failed to deliver concrete policies allowing the achievement of gender equal development until 2011,[3] when the National Gender Policy was implemented to address the legislative gap in gender-based violence, environmental degradation and gendered dimensions of poverty. Although the policy allows for the identification of areas of intervention for eradicating gender biases, such as occupational segregation, promotion of tertiary education among women and the facilitation of women's access to resources, the policy does not provide tools for the effective implementation of gender mainstreaming (FAO, 2011). The lack of policy implementation targeting gender has determined the persistence of gender inequalities in certain zones of the country.

Despite the absence of subnational statistics at gender level, some authors and institutions have started to investigate the gender gap in Malawi. Ngwira (2010) highlights how female headed households, representing 30 per cent of all households, have a lower income and less access to policy programs to move out of poverty. African Gender and Development Index for Malawi shows that in smallholder agriculture, women earn only 71% of money that men earn, despite the fact that labour force participation is nearly equal (Government of Malawi, 2010). Women represent 70% of the labour force employed for the production of cash crops (ONAR, 2005). The literacy rate is lower for women (44%) than for men (72%). Average land size owned by women (0.8 ha) is lower than national average and the productivity of women farmers is lower, due to their restricted access to adult male labour and other productive inputs (Ngwira, 2010).

3. Conceptual and theoretical framework

It is widely recognized that high climate variability may be harmful for individual welfare, especially when individuals are unable to ensure against covariate shocks are unlikely to adapt and pursue a diversified adaptation strategy. An extensive amount of work explores the linkage between climate and the welfare of individuals employed in the agricultural sector of a developing country (e.g. Dell, Jones, & Olken*,* 2014; Dercon, 2004; Dercon, Hoddinott, & Woldehanna, 2005; Fafchamps, Udry, & Czukas, 1998; Kazianga and Udry, 2006; Skoufias and Vinha, 2013). Households, generally, have a higher capacity to cope with idiosyncratic shocks than with covariate shocks, such as climatic ones. Weather has the potential to disrupt entire communities neutralising the effectiveness of social protection instruments devolved to the poorest part of the population (formal and informal), such as loans and other forms of credit aiding households' consumption smoothing (Harrower and Hoddinott, 2005). Experiencing a drought or flood during the agricultural season has been shown to correlate with large decreases in both food and non-food consumption, but the impact varies depending on the climatic zone of the household and whether the event occurred before, during, or after the growing season (Skoufias and Vinha, 2013). In Ethiopia, for example, droughts have a long lasting effect and studies highlight how households are subjected to losses for several years after the drought (Dercon *et al.,* 2005). Evidence suggests that the occurrence of an extreme event may also modify both the distribution of resources within the household and its optimal consumption path (Skoufias and Vinha, 2013). Part of these studies find that countries more reliant on the agricultural sector are more exposed to negative economic impact when experiencing weather shocks (Dell, Jones, & Olken 2012). Extreme weather events significantly decrease crop yield, reducing total agricultural production. This consequently reduces consumption in other welfare measures (Fischer, Shah M, van Velthuizen, 2002; Auffhammer and Schlenker, 2014). Occurrence of shocks on production are also likely to indirectly harm the consumption of non-agricultural households through their impact on prices (Fischer *et al.*, 2002).

Hypothesis 1: weather shocks occurring during the agricultural season decrease household welfare.

Differences across social groups, especially across gender, persist since each group presents differences in labour supply, in access to available resources and to technologies and other forms of sustainable agricultural practices (Dankelman, 2008; Denton, 2002; Futoshi, Yohannes, & Quisumbing, 2009). Women make essential contributions to agricultural and rural economies, nonetheless they constitute one of the poorest and most disadvantaged groups in the society (Blackden and Wodon, 2006; CGAP, 2004; Doss & SOFA 2011; World Bank FAO & IFAD, 2009). In many countries men and women have differential access to physical, social, and financial resources (such as land, networks, and credit), and access to instruments which mitigate the impact of climate change (Nelson, 2011). Some studies find that female-dominated groups/households are associated with more climate sensitive resources and technologies, which is also influenced by the gendered nature of resource entitlements, such as access to land or to the credit market (Dankelman, 2008; Huynh and Resurreccion 2014; Nelson and Stathers, 2009, Nelson 2011). However, this evidence is not generalizable as the social norms in which gender is embedded may determine an advantaged or disadvantaged condition.[4] Lamboru and Piana (2006) discuss how specific mechanisms contribute to the gender gap, as the differentiated access to the agricultural information, which includes information on risk-coping techniques. Absence of access to agricultural information could prevent women from adopting effective techniques to respond to agricultural risk. Unfortunately, there is a lack of empirical literature addressing whether the effect of covariate shocks is heterogeneous across the gendered nature of the household (Cohen and Young, 2007; Goh, 2012; Sabarwal, Sinha, Buvinic., 2010). This in part is due to the absence of detailed gender data, as well as to the complexity behind the construction of a long-term panel of climatic observations (Arora-Jonsson, 2011). We find a remarkable exception in Quisumbing, Kumar & Behrman (2012), who use a self-reported assessment on weather events and tests the claim of gender differences in response to shocks in Uganda and Bangladesh. Whilst in Bangladesh the effects of weather shocks on men's and women's assets depend on their involvement in agriculture, in Uganda weather shocks do not demonstrate a gendered effect on assets. Lamboru and Piana (2006) identify gender biases in access to services delivered by formal institutions. They argue that institutions are male-centric, as they assume that farmers are exclusively men and therefore promote and create agricultural extension services and technologies rarely accessible to women farmers.

Hypothesis 2: Weather shocks have a gender differentiated impact on household welfare.

However, social and cultural norms occasionally interact with weather events, resulting in unexpected gendered spillovers. For example, Turner (1999) describes how droughts in Niger strengthened women's control over livestock, as they were able to invoke a norm that entitled men as responsible for the provision of food to the household. As a result, men were obliged to sell their livestock in the market before women and, through this mechanism, women acquired a predominant position in the livestock market. In northern Mali, Brockhaus and Djoudi (2008) examine how women diversified their labour activities to cope with vulnerability to climate change (e.g. by starting charcoal production).

In Malawi, land entitlement is customary and lineage-based and more than 80 per cent of the population practice a matrilineal-matrilocal land-tenure system (Berge *et al.*, 2014). Matrilineal communities reside in the centre and southern areas of the country, while patrilineal ones are mostly located in the northern region. Death of the land owner, and consequently land inheritance, represents the main reason behind the transfer of land ownership, as a land market is absent and a rental market is newly emerging (Lovo, 2016). This allows for the consideration of land ownership as exogenous to agricultural decision, as land is not marketed and land owners are mainly determined by land inheritance (Berge *et al.* 2014). In matrilineal communities women's authority is effectively enforced. Peters (2010) describes how matrilineal culture shapes the bond between siblings (brother and sister), which can be stronger than a marriage's bond. Even if village chiefs are usually men, in matrilineal societies brothers consult sisters during important community's decisions, such as the treatment of illness and disputes (Peters, 2010). Outside these cultural domains, Malawi remains a state profoundly based on male authority. Agricultural services, institutions, and religious groups are all dominated by males, evidencing the persistence of gender inequalities (Peters 2010, Bhaumik, Dimova, & Gang 2016). In addition, recent evidence in the literature points out that farmers experiencing insecurity in land tenure are less willing to invest in agricultural technologies, soil conservation practices and climate-resilient technologies (Lovo, 2016).

Hypothesis 3: Welfare in female-managed households is differently impacted by weather shocks in patrilineal districts than in matrilineal ones.

To the best of our knowledge, our work is the first contribution on the gender-differentiated impact of weather shocks employing a national representative survey aligned with historical weather records measured at enumerator area-level.

4. Data, variables construction and summary statistics

4.1 Data

We use three main data sources: 1) socio-economic panel household and community data from the Malawi Integrated Household Panel Survey (IHPS); 2) plot management and ownership data; 3) historical data on rainfall and temperature from the National Oceanic and Atmospheric Administration (NOAA) and the European Centre for Medium Range Weather Forecasts (ECMWF).

The primary source of socioeconomic indicators is the household level data from the Integrated Household Panel Survey (IHPS), which is part of a series of the Integrated Household Survey (IHS) realized by the Government of Malawi and supported by the World Bank Living Standards Measurement Study. According to the survey guidelines, enumerators have administered to every household a multi-topic questionnaire, asking information on household characteristics, health, wage, consumption, food security, agricultural assets and production. The final panel sample (IHPS) originally comprised 3,246 households, interviewed during the rainy season 2009/2010 and designed to be tracked for a second wave during 2012/2013.[5] Interviewers have been able to track back for a second interview only 3,104 households from the original panel subsample. Attrition rate at household level is relatively low (3.78%). Panel data allow to control for unobserved heterogeneity, which is an unusual advantage for a study on climate variability and livelihood in Sub-Saharan countries. The final national representative sample, including agricultural and non-agricultural households, counts 6,208 observations (two observations per household). Figure 1 displays the geographical allocation of households by waves, showing high mobility of households between the two interviews.[6]

<INSERT FIGURE 1 HERE>

Our main dependent variables are four indicators of welfare: natural log of the consumption per capita, food consumption per capita, non-food consumption per capita, and caloric intake. From the Household questionnaire, the study integrates information on household demographics, such as the urban/rural status of the household, age of the head of the household, dependency ratio, religious identity, size of the household, average years of education, area owned and distance of the household from original location (measured in km). From the Agricultural and Household questionnaires, we build an indicator on the sex of the land's manager (decision maker) within the household. Total land managed by gender is therefore computed at household level. This allows to distinguish between 1) households where only women manage land, defining them as female-managed households (FMH); 2) households where only men take decisions on the land, as male-managed households (MMH); 3) and households where both men and women are entitled to manage land as joint-managed households (JMH).[7] While we prefer to focus on effective and exclusive management of the land to have a clearer indication of the gender effect, which otherwise could be co-founded by the management of land by men or by some form of collaboration within the household, we are also aware of recent findings on literature on gender and collective action. These findings suggest that looking at exclusive management rather than joint management could miss some important aspects of gender dynamics (Doss and Meinzen-Dick 2015), especially when households with jointly-managed plots account for the majority of the sample (see table A1 and table A2 in Appendix).[8]

To study the effect of cultural and social norms on the vulnerability of the household, we make use of the districts' lineage classification available in Berge *et al.* (2014) and generate a matrilineal dummy assuming value one for households residing in district where matrilineal system prevails, and zero otherwise. Using the agricultural questionnaire, a wealth index on agricultural goods is added to the specification for controlling for the wealth level of the household. Construction of the wealth index involves the principal component analysis on the ownership of a set of agricultural tools.[9] Household questionnaire provides information on the total safety net or credit received by the household, and on the participation of the household in the farm input subsidy programme (FISP). To minimize endogeneity of these policy variables, we average their value at community level.

The IHPS and community survey collects an extensive set of information on the presence of policy interventions at EA-level, as well as on the access to infrastructure (including market and roads in addition to irrigation schemes and migration flows). Using the community questionnaire, variables on the implementation of the Malawi Social Action Fund (MASAF)[10] programme, irrigation schemes, and agricultural collective actions are added to the specification. Again, to minimize endogeneity, we average these community-level covariates at district level. Finally, using the Community module we add to our dataset variables measuring the population in the EA, and the prevalence of migration into or out of the EAs.

We construct two weather shock variables adopting the following methodology. Firstly, for each EA we calculate the historical (1983-2008)[11] average rainfall/maximum temperature during agricultural seasons (November – March). We then take the differences between actual observation (of rainfall or maximum temperature) and their historical averages. Through this process we obtain the residual of actual precipitations/maximum temperature in the current agricultural rainy season. Then we calculate the average and the standard deviation of the residual during the historical period (1985-2008) and we identify as shocks the deviation from a positive confidence band, computed by adding the historical average of the residual to two times its standard deviation.[12] Rainfall records are extracted from the Africa Rainfall Climatology version 2 (ARC2), which is a project developed by the National Oceanic and Atmospheric Administration's Climate Prediction Centre (NOAA-CPP). This platform delivers elaborated data on a 10 day interval, from January 1983 to July 2015[13] with a spatial resolution of 0.1 degrees. Surface maximum, minimum, and average temperature data are provided on a 10 day interval by the European Centre for Medium Range Weather Forecast (ECMWF) and they are delivered at a spatial resolution of 0.25 degrees. The sources of temperature data are both the operational database (1989-2010) and the interim database (2011-2013). The main difference between the two databases is on the model applied to elaborate the data. The operational database uses the forecast output by ECMWF's current model in forecasting, while the interim database employs diverse forecast models and data assimilation systems to analyse archived observations. For the usage of both sources we assume that the sample is affected uniformly by the change in the measurement between the two databases.[14] Since the IHPS data reports latitude and longitude coordinates of the household, using global positioning system (GPS) we have merged socio-economic data with climatic data. Weather data are matched with the EA's centroid available in the socioeconomic panel and this allows to compute the value of weather realizations at EA level.

4.2 Summary statistics

Table 1 reports summary statistics both for dependent and independent variables. All welfare indicators are stable across the waves. Consumption (expressed in natural log) shifts from 11.61 during 2010/2011 to 11.64 during 2012/2013, increasing on average by 3 per cent. Food consumption registers an increase of about 5 per cent, whilst non-food consumption decreases by 1 per cent and caloric intake grows, on average, by 3 per cent. Mean temperature shocks increase from 0.04 °C during 2010/2011 to 0.41 °C during 2012/2013. Positive rainfall shocks raise from 5.23 mm to 30.01 mm in the second wave. Seasonal average temperature and total seasonal rainfall do not vary significantly across waves. Low volatility of the other climatic controls is likely due by their construction at annual level, differently from the shock indicators which are measured on a 10 day interval. A wide subset of the socio-demographic covariates do not vary substantially, such as urban share, dependency ratio, percentage of protestant households, years of education and area owned. Average age of the head of the household grows coherently with the time span between the waves. The size of the household slightly increases over the two waves. The mean level of population increases steadily, as well as the proportion of communities experiencing outmigration. However, the share of the communities characterized by immigration declines, as well as the agricultural wealth index. In terms of access to policy, mean safety net and mean credit received at EA level follows a positive trend, as do the proportion of households accessing extension services or MASAF programmes; while the percentage of fertilizer coupon recipients' decreases, as well as the share of households accessing irrigation schemes and agricultural collective actions.

<INSERT TABLE 1 ABOUT HERE>

The panel dataset enables the capture of inter-wave variability of weather shocks, affecting different shares of the sample across the two waves. Figure 2 presents the percentage distribution of households affected by temperature and rainfall shocks during the first wave. More than 73 per cent of the households did not experience any temperature shocks during the first wave, but this percentage dropped to less than 9 per cent during the second wave, suggesting that the rainy season 2012/2013 was exceptionally warmer. According to this evidence, for example, during 2013 a large proportion of the sample experienced a temperature shock between 0.4 and 0.5 degree Celsius. Figure 3 highlights a similar pattern for the shocks on rainfall. Finally, we identify 418 panel households where women are the only members entitled to manage the land (FMH), 387 panel households where men are the exclusive managers of the household's plots (MMH), 1,076 households were women and men joint-manage household's plot (JMH).[15] In terms of lineage, the majority of FMH (69.3 per cent) and less than half of MMH (48 per cent) resides in matrilineal districts.

< FIGURE 2-3 ABOUT HERE>

5. Empirical strategy

We model the statistical relationship through an OLS Fixed Effect (FE) model. Inclusion of household fixed effects accounts for unobserved time-invariant characteristics correlated with household-level observables whereas year fixed effects capture idiosyncratic shifts in welfare outcomes. A household's ability to receive information, skills and technological knowledge are all unobserved determinants of welfare and might affect resilience to weather shocks. Is is usually impossible or highly demanding to observe these parameters with available data, therefore we adopt FE for dealing with the standard selection problem and to obtain non-biased estimates of the coefficients. We are aware that Fixed effects in short panels could determine a bias in the estimation of the standard errors. In similar cases some authors adopt corrected random effect models (see Chamberlain, 1982; Mundlak, 1978). These methods add the mean values of time-varying variables to relax the assumption of no-correlation between the unobserved characteristics and other regressors (Mundlak, 1978). Despite the suitability of a Mundlak-RE, we rely on a FE model as it is able to account for the whole unobserved heterogeneity, which could be more correlated with individual vulnerability.[16] The OLS-FE empirical strategy takes the following form:

$$Ln(c_{hit}) = \beta_0 + \beta X_{hit} + \theta_1 rainshock_{it} + \theta_2 tempshock_{it} + \rho clim_{it} + \Upsilon_1 \mathbf{P}_{it} + \alpha_h + \gamma_t + \varepsilon_{it} \quad (1)$$

Where $Ln(c_{hit})$ is the natural logarithm of the dependent variable (consumption, food consumption, non-food consumption, caloric intake) of household *h* residing in EA *i* at time *t*; β_0 is the intercept; β is a vector of coefficients belonging to the matrix of household- and EA-level controls $X_{h,i,t}$; $clim_{it}$ is a matrix of climatic controls (seasonal temperature and precipitation) with the associated vector of coefficients ρ. Vector $\mathbf{P}_{it}$ entails a set of policy variables averaged at EA or district level.[17] Finally, α_h and γ_t are households and year fixed effects and, ε_{it} represents the heteroskedastic error term clustered at EA-level.

6. Econometric results

6.1 Impact on welfare measures

Table 2 reports the set of coefficients linked to the four dimensions of welfare. Results in columns 1, 2, and 4 corroborate hypothesis 1 suggesting that an increase in temperature that exceeds the upper confidence interval by 1 °C has a detrimental effect on consumption, food consumption and caloric intake. The shift in maximum temperature leads to a substantial decrease in consumption (-17.9%) and food consumption (-29.8%). A similar reduction is registered for caloric intake (–22.2%). As the table shows, no significant result is obtained for non-food consumption. This finding indicates that climate change is likely to hit, specifically, food related consumption and can be explained by channels such as agricultural production and food prices. The occurrence of a rainfall shock does not lead to any significant decrease in consumption. Given that this variable is measuring rainfall above the historical trend in an area that is drought-prone, it is reasonable to believe that these shocks do not have any impact on consumption. As for the other climate controls, estimates reveal that an increase in seasonal average temperature induces a drop in overall consumption, food- and non-food consumption, providing further evidence on the negative relationship between welfare and temperature. Seasonal rain does not consistently correlate with any of the welfare specifications.

<INSERT TABLE 2 ABOUT HERE>

Table 2 also presents coefficients linked to the remaining controls that exhibit expected signs and magnitudes.[18] Urban households experience higher growth in welfare, with the only exception of food consumption. Ageing of the head of the household leads to a drop in consumption and food consumption. A similar result is observed for the dependency ratio, for which an increase is negatively correlated with changes in non-food consumption. An expansion of the household size has a negative effect across all specifications. Agricultural wealth is positively correlated with consumption growth. Among the policy variables, safety net and extension service show positive correlation with welfare outcomes.

6.2 Gender-differentiated impact

In this subsection, we examine the gender-differentiated impact of extreme weather events. To investigate whether gender could correlates with household vulnerability to weather we pursue the following strategy. We first identify three household clusters, according to whether land is managed exclusively by women, men or jointly managed (FMH; MMH; JMH). Then we run the main specification on each of these subsample, as these variables do not change over time and the correspondent dummies would be collinear to the Fixed Effect specification. We maintain constant the set of controls, while the number of observations drop to 2268 observations as we focus only on agricultural households.

Table 3 presents findings from the three subsamples. We observe that an increase in temperature shocks has a steady negative effect on total consumption *only* in the FMH subsample. Consumption per capita drops by 46 per cent when women are the exclusive managers of the land, while it does not vary considerably when the land is managed by men or jointly managed. Food consumption appears affected in all cases, but the coefficient has a higher magnitude for FMH. Findings on non-food consumption again support the evidence of a gender-differentiated impact. Indeed, the impact of the shocks is negative and significant only for the FMH subsample (-36.8%). Finally, daily caloric intake is more vulnerable to temperature shocks within households where women manage land (-69.4%) than in the case of MMH (-50.3%), while JMH are unexpectedly unaffected by these shocks. For rainfall shocks, we do not find any differentiated impact coherently with the previous estimation, except for the caloric intake of FMH, where the correlation is positive and significant.

<INSERT TABLE 3 ABOUT HERE>

We test the robustness of our findings using the share of land managed by women and the share of land co-managed. We therefore replicate all the estimates in Table 2-3 by adding the interaction between this new gender indicator with the shock variables.[19] The results are reported in the Appendix (Table A1 and A2). Findings are particularly consistent for the coefficient of the interaction between temperature shock and the share of land managed by women (share of female-managed area). This coefficient is negative and significant for consumption (-26.8% per one degree of temperature shock), food consumption (-28.8% per degree of temperature shock), and caloric intake (-31.2% per degree of temperature shock). These results indicate that the same shock will have a more destructive impact in households with larger shares of female-managed area.[20] All these findings support the crucial role that new forms of gender data could have for understanding household welfare dynamics during covariate shocks.

6.3 *Type of lineage and shocks*

In this section, we test whether women's traditional inheritance rights in matrilineal or patrilineal societies correlates with the level of their vulnerability to weather shocks. We identify a household as patrilineal or matrilineal depending on the classification available in Berge *et al.* (2014) for the district of residence.[21] Then, we replicate the above analysis by dividing the sample according to the lineage of their district of residence and estimating the main specification on the three subsamples.[22] As Table 4 shows, in matrilineal districts (column 1-2-3) the impact of weather shocks on the three types of household is homogeneous and non-significant. In contrast, when running the model on the patrilineal subsample (column 4-5-6), we find that temperature shocks severely affect consumption of FMH in patrilineal districts (column 5). However, consumption in MMH and JMH is not influenced by the occurrence of shocks on temperature (column 4 and column 6), underscoring the lower level of vulnerability of MMH in patrilineal districts. This result provides support for hypothesis 3 and suggests that differences in vulnerability between the three subsamples (FMH, MMH, JMH) are linked to women's land tenure security in matrilineal districts. A similar mechanism is observable for the other dimensions of welfare (column 7-24). FMH's food consumption, non-food consumption, and caloric intake are negatively affected by the occurrence of temperature shocks in patrilineal districts. In contrast, we do not find a significant impact of temperature shocks on FMH residing in matrilineal districts and the (null) impact is similar to the one reported by MMH. What is driving the difference between FMH in patrilineal and matrilineal districts? The geographically clustered nature of cultural norms linked to the tenure system would compel one to argue that the magnitude of temperature shocks might differ across the two sets of districts. According to this interpretation, FMH within patrilineal districts might have been affected by sharper temperature shocks than their matrilineal counterparts. Alternatively, a second explanation might rely on the argument that the security of women's property right in different inheritance or lineage systems could play a role in propagating the effect of the shocks, thus affecting their vulnerability. As Lovo (2016) suggests, insecurity in land tenure might be often associated with low levels of investment in soil conservation technologies. The probability of investing in these technologies decreases considerably because of the instability and the risk of land requisition by others relatives (Lovo, 2016; Place, 2009; Goldstein 2011).

Table 5 presents summaries and test statistics on the level of temperature shocks and on the adoption of three technologies/techniques for the patrilineal and matrilineal FMH subsamples. We focus on legume intercropping, hybrid seeds adoption and soil and water conservation systems. The first two technologies are associated with positive spillovers in yield and higher resistance to temperature, while the third one is particularly important during shocks on temperature because it avoids soil erosion and water runoff from the root zone (Araya and Stroosnijder, 2010; Qaim and Zilberman, 2003; Rusinamhodzi, Corbeels, Nyamangara, & Giller 2012). As shown in table 5, during the period of analysis temperature shocks have been significantly more intense in the matrilineal district. This result does not support the argument that differences in shocks' magnitude are driving the vulnerability of FMH in patrilineal districts. In terms of technology adoption, the percentage of FMH using legume intercropping is 11 per cent higher in matrilineal than in patrilineal districts. Hybrid seed is also 9 per cent higher in matrilineal districts, and the difference is significant at 1 per cent level. Finally, also soil and water conservation systems are 3 per cent higher amongst FMH residing in matrilineal districts, but the difference is not statistically significant. These statistics suggest that security of women's land rights work as a mitigation/propagation channel for the vulnerability of gendered households by reducing/increasing propensity of adopting climate resilient technologies. In summary, the results indicate that social conditions, inclusion and empowerment play a key role in determining the vulnerability of women to temperature shocks. Their exposure is higher in districts where women's land tenure security and resource control are weak.

<INSERT TABLES 4-5 ABOUT HERE>

7 Conclusions and policy implications

This paper explores the causal effects of weather shocks on the welfare of Malawian households, addressing whether a gendered approach reveals new insights into the dynamics behind vulnerability of households in developing countries. We use georeferenced household level panel data from IHPS, which is a national representative study implemented by the Government of Malawi designed to track agricultural and non-agricultural households. By merging these data with a long panel on climatic realization at enumerator area level allows us to control for past and actual weather events. We develop a new identification strategy for extreme events in weather, based on the deviation of the actual observation from its long-term average. The empirical model entails four different measures of welfare growth as dependent variables: overall consumption, food consumption, non-food consumption, and caloric intake absorption.

Our findings reveal that consumption, food consumption and caloric intake deviate significantly from their growth path only in the case of shocks on temperature, whereas rainfall shocks do not exhibit any consistent impact. In the second part, we disentangle the impact of extreme events at gender-level, relying on different theoretical foundations from the literature on gender and agriculture (Quisumbing *et al.*, 2014; Doss and Meinzen-Dick, 2015). We first identify households where women or men solely manage land, or where land is jointly managed. Then, we test whether the impact of weather shocks diverges across gender. The results point towards the hypothesis of a gender-differentiated impact of temperature shocks, which leads to a negative and consistent deviation of welfare for the households managed by women. We finally show that in districts where women traditionally have more secure property rights (i.e. matrilineal districts), they are also less vulnerable to shocks. This suggests that women's property rights play a key role in mitigating their vulnerability. These results point to the need for an improvement in policy actions tackling increasing climate variability, with much more effort to ensure the welfare of women, especially in regions where customary norms relegate women to an unequal social and economic position. This study stresses that policy-makers should prioritize the development of insurance mechanisms to protect less advantaged social groups from weather shocks, such as households whose land is solely managed by women.

Acknowledgements

We would like to thank the editor Richard Palmer-Jones and two anonymous referees for their useful indications. We are also grateful to Alessandro Carraro, Leslie Lipper, James Moody, Federico Belotti, Andrea Piano Mortari, Aslihan Arslan for their useful comments at different stages. Data for replication of the results will be available upon request. All errors remain ours.

Notes

---

[1] To describe gender dynamics in agriculture, it is not sufficient to compare male- and female-headed households, rather, the heterogeneous system of household behaviour embedded in the agricultural economy (Asfaw and Maggio

2015; Haddad, Hoddinott, & Alderman 1997; Quisumbing, Kumar, Behrman, 2012). Analysis, therefore, should also account for the different conditions of women in male- and female-headed households in terms of their access and control of productive resources, services, employment opportunities and land; especially when dealing with smallholder farmers in developing countries (Quisumbing *et al.*, 2014).

[2] In the robustness section we also test for the gender of plot's owner.

[3] During 1998, government promoted the study Vision 2020 on the perspectives of gender development, labelled as gender blind by many observers, due to its inability of targeting and supporting women in agriculture and in other core sectors of the economy. Also the implementation of the Malawi growth and development strategy (MGDS) during 2006 has been considered as another missed opportunity for the promotion of gender integration. The strategy identified ten areas of intervention for poverty reduction and acceleration of economic growth, but unexpectedly it overlooked gender (Ngwira, 2014).

[4] For an extensive review on gender and sustainability refers to Meinzen-Dick, Kovarik, & Quisumbing (2014).

[5] The first wave of the panel-subsample was implemented from March to November 2010 and the second one between April and December 2013.

[6] For this reason, we include among the controls the distance between the two locations.

[7] For determining the gendered impact mechanism at work, this article bases its gender definition on the decision-maker of the land and focuses on the difference between FMH, MMH, JMH.

[8] Findings obtained using the share of land managed by women (table A1 and A2) are generally consistent with the main results.

[9] The household agricultural-implement-access index is computed using principal components analysis and covers a range of dummy variables on the ownership of hand hoe, slasher, axe, sprayer, panga knife, sickle, treadle pump, watering can, ox cart, ox plough, tractor, tractor plough, ridger, cultivator, generator, motorized pump, grain mail, chicken house, livestock kraal, poultry kraal, storage house, granary, barn, and pig sty.

[10] The Malawi Social Action Fund (MASAF) is a social programme that provides liquidity for District governments and communities to invest in public infrastructure such as roads, hospital, schools, and income-earning activities.

[11] We do not include 2009 within the historical period to minimize the likelihood of serial correlation between this agricultural season and the agricultural season of reference.

[12] For the sake of brevity, the entire methodology on the computation of the shocks can be found in the supplementary material file.

[13] These data are uploaded on daily basis, thus this period refers to the time of writing.

[14] For more information about the two weather databases please refer to http://spirits.jrc.ec.europa.eu/?page_id=2869.

[15] We have been able to define management of the plot for 1881 households, remaining households are non-agricultural as they do not hold land.

[16] We conducted a robustness test running a Mundlak specification and main results remain consistent (available upon request).

[17] Specifically, the policy variables are: i) mean credit and mean safety net; ii) rate of access extension service; iii) rate of participation in a MASAF programme; iv) share of EAs participating to an irrigation scheme; v) proportion of EAs involved in a collective action.

[18] We do not include the FMH/MMH/JMH dummies in this specification as they are collinear with the household fixed effects and their effect is capture by the latter.

[19] Note that the observations in table A1 are fewer than the ones in table 2 since the inclusion of the share of land managed by women/co-managed in the baseline specification determines the drop of the non-agricultural households.

[20] We further test the robustness of the findings in table 3 focusing on the gender of the land owner instead of management. We therefore replicate all the estimates in table 3-4 on three subgroups: FMH/MMH/JMH. Results on table 3 are particularly consistent when looking at the impact of temperature shocks on consumption and food-consumption FOH. Results on table 4 are also consistent, as the test shows negative and significant coefficient associated only to FOH and JOH in matrilineal districts. For the sake of brevity, results are available upon request.

[21] We are aware that following an administrative-level classification for the lineage could ignore the existence of households following a different lineage system from the mainstream lineage of their district of residence. Unfortunately, absence of information on lineage at household level within LSMS makes impossible to have more detailed information. Also, we are unable to uniquely identify the lineage for five MMH, five FMH, and five JMH who fall out from the analysis here.

[22] We split the datasets in more subsamples for analysing the gender effects instead of generating a set of gender and lineage dummies because these would be collinear to the household fixed effects. We are aware that this method might reduce statistical power, however because of the nature of the data this method remains the more appropriate.

Results should be taken into account considering the usual caveats on sample size and statistical power (Wooldridge, 2010).

References

Agarwal, B. (1994). *A field of one's own: Gender and land rights in South Asia*. Cambridge University Press.

Akampumuza, P., & Matsuda, H. (2016). Weather Shocks and Urban Livelihood Strategies: The Gender Dimension of Household Vulnerability in the Kumi District Of Uganda. *The Journal of Development Studies*, 1-18. doi: http://dx.doi.org/10.1080/00220388.2016.1214723

Akter, S., Krupnik, T. J., Rossi, F., & Khanam, F. (2016). The influence of gender and product design on farmers' preferences for weather-indexed crop insurance. *Global Environmental Change*, *38*, 217-229. doi: http://dx.doi.org/10.1016/j.gloenvcha.2016.03.010

Arora-Jonsson, S. (2011). Virtue and vulnerability: Discourses on women, gender and climate change. *Global Environmental Change*, *21*(2), 744-751 doi: http://dx.doi.org/10.1016/j.gloenvcha.2011.01.005

Araya, A., & Stroosnijder, L. (2010). Effects of tied ridges and mulch on barley (Hordeum vulgare) rainwater use efficiency and production in Northern Ethiopia. *Agricultural water management*, 97(6), 841-847. doi: http://dx.doi.org/10.1016/j.agwat.2010.01.012

Asfaw, S., & Maggio, G. (2015). Gender integration in Climate Smart Agriculture (CSA): tools for data collection and analysis for policy and research, *FAO EPIC technical report*. Retrieved from: http://www.fao.org/3/a-i5299e.pdf

Asfaw, S., McCarthy, N., Lipper, L., Arslan, A. and Cattaneo, A. (2016): What Determines Farmers' Adaptive Capacity? Empirical Evidence from Malawi. *Journal of Food Security* 8(3), 643-664. doi: 10.1007/s12571-016-0571-0

Auffhammer, M., & Schlenker, W. (2014). Empirical studies on agricultural impacts and adaptation. *Energy Economics*, *46*, 555-561. doi: http://dx.doi.org/10.1016/j.eneco.2014.09.010

Benin, S., Thurlow, J., Diao, X., McCool, C., & Simtowe, F. (2008). *Agricultural growth and investment options for poverty reduction in Malawi*. Intl Food Policy Res Inst.

Berge, E., Kambewa, D., Munthali, A., & Wiig, H. (2014). Lineage and land reforms in Malawi: Do matrilineal and patrilineal landholding systems represent a problem for land reforms in Malawi?. *Land Use Policy*, 41, 61-69. doi: http://dx.doi.org/10.1016/j.landusepol.2014.05.003

Bhaumik, S. K., Dimova, R., & Gang, I. N. (2016). Is Women's Ownership of Land a Panacea in Developing Countries? Evidence from Land-Owning Farm Households in Malawi. *The Journal of Development Studies*, 52(2), 242-253. doi: http://dx.doi.org/10.1080/00220388.2015.1060314

Blackden, C. M., & Wodon, Q. (Eds.). (2006). *Gender, time use, and poverty in sub-Saharan Africa* (Vol. 73). World Bank Publications. Washington, DC.

Brockhaus M & Djoudi H. (2008). Adaptation at the interface of forest ecosystem goods and services and livestock production systems in northern Mali. *Center for International Forestry Research (CIFOR) Information Brief.*

Chamberlain, G. (1982). Multivariate regression models for panel data. *Journal of econometrics*, *18*(1), 5-46. doi: doi:10.1016/0304-4076(82)90094-X

Chinsinga, B. (2012). The political economy of agricultural policy processes in Malawi: A case study of the fertilizer subsidy programme. *Future Agricultures Consortium Working Paper* 39.

Chirwa, P. and Quinion, A. (2005). Impact of soil fertility replenishment agroforestry technology adoption on the livelihoods and food security of smallholder farmers in central and southern Malawi. In: P. Sharma and V Abrol (eds). *Crop Production Technologies*. Rijeka, Croatia, InTech.

Cohen, M., & Young, P. (2007). Using microinsurance and financial education to protect and accumulate assets. In: Moser, C. O. (Ed.). (2008). *Reducing global poverty: The case for asset accumulation*. Brookings Institution Press.

CGAP (Consultative Group to Assist the Poor). (2004). Improving risk management for the poor. *Microinsurance*, No. 3. Washington, DC

Dankelman, I. E. M. (2008). Gender, climate change and human security: Lessons from Bangladesh, Ghana and Senegal. *Report.* Retrived from: *http://www. wedo. org/wp-content/uploads/hsn-study-finalmay-20-2008. pdf*

Dell, M., Jones, B. F., & Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics*, *4*(3), 66-95. doi: https://doi.org/10.1257/mac.4.3.66

Dell, M., Jones, B. F., & Olken, B. A. (2014). What Do We Learn from the Weather? The New Climate-Economy Literature. *Journal of Economic Literature*, 52(3), 740-98. doi: https://doi.org/10.1257/jel.52.3.740

Denton, F. (2002). Climate change vulnerability, impacts, and adaptation: why does gender matter?. *Gender & Development*, 10(2), 10-20. doi: http://dx.doi.org/10.1080/13552070215903

Dercon, S. (2004). Growth and Shocks: Evidence from Rural Ethiopia. *Journal of Development Economics* 74(2): 309-329. doi: http://dx.doi.org/10.1016/j.jdeveco.2004.01.001

Dercon, S., Hoddinott, J., & Woldehanna, T. (2005). Shocks and consumption in 15 Ethiopian villages, 1999-2004. *Journal of African Economies*. doi: *10.1093/jae/eji022*

Doss, C. and R. Meinzen-Dick. 2015. Collective Action within the Household: Insights from Natural Resource Management. *World Development*, 74, 171–183. doi: http://dx.doi.org/10.1016/j.worlddev.2015.05.001

Doss, C. & SOFA Team, (2011). The role of women in agriculture. *Rome: Agriculture Development Economics Division, Food and Agriculture Organization, ESA Working Paper*, (11-02).

ONAR. (2005) Malawi Multi-sector country gender profile, *African Development Fund.*

FAO. (2011). Gender Inequalities in Rural Employment in Malawi Policy Context.

Fafchamps, M., Udry, C., and Czukas, K. (1998). Drought and saving in West Africa: are livestock a buffer stock?. *Jounal of Development Economics* 55 (2): 273-305. doi: http://dx.doi.org/10.1016/S0304-3878(98)00037-6

Fischer G, Shah M, van Velthuizen H (2002) Climate Change and Agricultural Vulnerability. Special Report Prepared as a Contribution to the World Summit on Sustainable Development (International Institute for Applied Systems Analysis, Laxenburg, Austria). Retrieved from:http://pure.iiasa.ac.at/6670/

Futoshi, Y., Yisehac, Y., & Quisumbing, A. (2009). Risks, ex-ante actions and public assistance: Impacts of natural disasters on child schooling in Bangladesh, Ethiopia and Malawi. *World Bank Policy Research Working Paper Series*, 4909.

Government of Malawi. (2010). Gender and Development Index. Retrieved from: http://tbinternet.ohchr.org/Treaties/CEDAW/SharedDocuments/MWI/INT_CEDAW_ADR_MWI_19520_E.pdf

Goh, A. H. (2012). A literature review of the gender-differentiated impacts of climate change on women's and men's assets and well-being in developing countries. *International Food Policy Research Institute*, CAPRi Work.

Haddad, L., Hoddinott, J., & Alderman, H. (1997). *Intrahousehold resource allocation in developing countries: models, methods, and policy*. Johns Hopkins University Press.

Harrower, Sarah, and John Hoddinott (2005). Consumption smoothing in the Zone Lacustre, Mali. *Journal of African Economies*, 14(4), 489-519. doi: *10.1093/jae/eji007*

Huynh, P. T., & Resurreccion, B. P. (2014). Women's differentiated vulnerability and adaptations to climate-related agricultural water scarcity in rural Central Vietnam. *Climate and Development*, 6(3), 226-237. doi: http://dx.doi.org/10.1080/17565529.2014.886989

IPCC (2014), Climate change 2014: Impact, adaptation, and vulnerability. *Technical report, Intergovernamental Panel on Climate Change.*

Jentsch, A., Kreyling, J., & Beierkuhnlein, C. (2007). A new generation of climate-change experiments: events, not trends. *Frontiers in Ecology and the Environment*, 5(7), 365-374. doi: 10.1890/1540-9295(2007)5[365:ANGOCE]2.0.CO;2

Kazianga, H., & Udry, C. (2006). Consumption smoothing? Livestock, insurance and drought in rural Burkina Faso. *Journal of Development Economics*, *79*(2), 413-446. doi: http://dx.doi.org/10.1016/j.jdeveco.2006.01.011

Kieran, C., Sproule, K., Doss, C., Quisumbing, A., & Kim, S. M. (2015). Examining gender inequalities in land rights indicators in Asia. *Agricultural Economics*, 46(S1), 119-138. doi: 10.1111/agec.12202

Kilic, T., Palacios-Lopez, A., & Goldstein, M. (2015). Caught in a productivity trap: a distributional perspective on gender differences in Malawian agriculture. *World Development*, *70*, 416-463. doi: http://dx.doi.org/10.1016/j.worlddev.2014.06.017

Lambrou, Y., & Piana, G. (2006). *Energy and gender in rural sustainable development*. Fao, Rome. Retrived from: http://agris.fao.org/agris-search/search.do?recordID=XF2008435067

Lovo, S. (2016). Tenure insecurity and investment in soil conservation. Evidence from Malawi. *World Development*, 78, 219-229. doi: http://dx.doi.org/10.1016/j.worlddev.2015.10.023

Meinzen-Dick, R., Kovarik, C., & Quisumbing, A. R. (2014). Gender and sustainability. *Annual Review of Environment and Resources*, *39*(1), 29. doi: 10.1146/annurev-environ-101813-013240

Mueller, V., Quisumbing, A., Lee, H. L., & Droppelmann, K. (2014). Resettlement for Food Security's Sake: Insights from a Malawi Land Reform Project. *Land Economics*, 90(2), 222-236. doi: 10.3368/le.90.2.222

Mundlak, Y. (1978). On the pooling of time series and cross section data. *Econometrica: journal of the Econometric Society*, 46(1), 69-85. doi: 10.2307/1913646

Nelson, V. (2011). *Gender, Generations, Social Protection & Climate Change*.

Nelson, V. and Stathers, T. (2009). Resilience, power, culture and climate: a case study from semi-arid Tanzania and new research directions. *Oxfam Gender & Development*, 17(1), p81-94. doi: http://dx.doi.org/10.1080/13552070802696946

Nelson, G. C., Rosegrant, M. W., Koo, J., Robertson, R., Sulser, T., Zhu, T., & Lee, D. (2009). *Climate change: Impact on agriculture and costs of adaptation* (Vol. 21). Intl Food Policy Res Inst.

Ngwira, N. (2010). Gender and poverty reduction in Malawi. In United Nations Department of Economic and Social Affairs Expert Group meeting.

Ngwira, N. (2014). *Gender and poverty reduction in Malawi*. Mimo.

Peters, P. E. (2010). "Our daughters inherit our land, but our sons use their wives' fields": matrilineal-matrilocal land tenure and the New Land Policy in Malawi. *Journal of Eastern African Studies*, *4*(1), 179-199. doi: http://dx.doi.org/10.1080/17531050903556717

Qaim, M., & Zilberman, D. (2003). Yield effects of genetically modified crops in developing countries. *Science*, 299(5608), 900-902. doi: 10.1126/science.1080609

Quisumbing, A., Kumar, N., & Behrman, J. (2012). Do Shocks Affect Men's and Women's Assets Differently? A Review of Literature and New Evidence for Bangladesh and Uganda. International Food Policy Research Institute.

Quisumbing, A. R., Meinzen-Dick, R., Raney, T. L., Croppenstedt, A., Behrman, J. A., & Peterman, A. (2014). *Closing the knowledge gap on gender in agriculture. In Gender in Agriculture* (pp. 3-27). Springer, Netherlands.

Rusinamhodzi, L., Corbeels, M., Nyamangara, J., & Giller, K. E. (2012). Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field crops research*, 136, 12-22. doi: http://dx.doi.org/10.1016/j.fcr.2012.07.014

Sabarwal, S., Sinha, N., & Buvinic, M. (2010). *How Do Women Weather Economic Shocks. A Review of the Evidence*. World Bank Policy Research Working Paper, (5496). Retrieved from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1722009

Seo, S. N., Mendelsohn, R., Dinar, A., Hassan, R., & Kurukulasuriya, P. (2009). A Ricardian analysis of the distribution of climate change impacts on agriculture across agro-ecological zones in Africa. *Environmental and Resource Economics*, 43(3), 313-332. doi: 10.1007/s10640-009-9270-z

Skoufias, E. and Quisumbing, A.R. (2005). Consumption insurance and vulnerability to poverty: A synthesis of the evidence from Bangladesh, Ethiopia, Mali, Mexico and Russia. *The European Journal of Development Research*, 17(1), 24-58. Retrieved from: http://www.tandfonline.com/doi/abs/10.1080/09578810500066498

Skoufias, E., & Vinha, K. (2013). The impacts of climate variability on household welfare in rural Mexico. *Population and Environment*, *34*(3), 370-399. doi: 10.1007/s11111-012-0167-3

Sun Y, Mwangi E, Meinzen-Dick RS. 2011. Is gender an important factor influencing 205 user groups' property rights and forestry governance? Empirical analysis from East Africa and Latin America. *International Forestry Review* 13(2):205–20. doi: https://doi.org/10.1505/146554811797406598

Tchale, H. (2009). The efficiency of smallholder agriculture in Malawi. *African Journal of Agricultural and Resource Economics*, 3(2), 101-121. Retrieved from: http://purl.umn.edu/56909

Turner M. (1999). Merging local and regional analyses of land-use change: the case of livestock in the Sahel. *Annal of the Associations of Americans Geographers* 89(2):191–219. doi: http://dx.doi.org/10.1111/1467-8306.00142

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. Cambridge. MA: MIT press.

World Bank, FAO & IFAD (2009). *Gender in agriculture sourcebook*. Washington, DC, World Bank.

World Bank (2010). *Social dimensions of climate change: equity and vulnerability in a warming world.* Washington DC.

Table 1: Summary statistics of welfare, climate, and control variables in our panel

	2010/2011			2012/2013		
	N	**mean**	**sd**	**N**	**mean**	**sd**
Outcome variables						
Consumption per capita (ln)	3104	11.61	0.63	3104	11.64	0.59
Food consumption per capita (ln)	3104	11.05	0.64	3104	11.10	0.61
Non-food consumption per capita (ln)	3104	10.65	0.73	3104	10.64	0.71
Daily caloric intake per capita (ln)	3103	7.47	0.60	3103	7.50	0.59
Household- and EA-level controls						
Temperature shock during growing season (°C)	3104	0.04	0.09	3104	0.41	0.14
Rainfall shock during growing season (mm)	3104	5.23	15.65	3104	30.01	31.01
Seasonal average temperature during growing season (°C)	3104	22.96	1.51	3104	22.63	1.25
Total seasonal rain during growing season (mm)	3104	736.98	113.61	3104	793.84	75.15
Urban (1==yes)	3104	0.15	0.36	3104	0.16	0.36
Age of head of the hh (years)	3104	42.67	16.33	3104	44.81	15.87
Dependency ratio	3104	0.11	0.10	3104	0.12	0.10
hh is not of protestant religion	3104	0.78	0.41	3104	0.78	0.41
Distance from first wave's location (km)	3104	0.00	0.00	3104	7.98	37.67
Size of the hh	3104	4.74	2.20	3104	5.05	2.18
Population in the community (EA level)	3104	4105.21	4786.13	3104	7568.99	12110.01
Migration in the EA (1==yes)	3104	0.59	0.49	3104	0.55	0.50
Outmigration in the EA (1==yes)	3104	0.13	0.34	3104	0.18	0.38
Share of area owned by women	2530	0.28	0.44	2479	0.26	0.44
Share of area co-owned	2530	0.41	0.47	2479	0.57	0.49
Years education of the head of hh	3104	5.13	2.94	3104	5.13	2.79
Area owned (hectars)	3104	0.70	0.73	3104	0.69	0.67
Wealth index agricultural goods	3104	0.08	0.98	3104	-0.04	1.01
Total safety-net (EA average in MKW)	3104	91.67	286.57	3104	733.97	1275.83
Total credit (EA average in MKW)	3104	1500.66	2245.57	3104	3287.10	3876.86
Extension service access (district average)	3104	0.37	0.18	3104	0.59	0.21
Receive FISP coupon (district average)	3104	0.49	0.27	3104	0.42	0.22
MASAF program (district average)	3104	0.17	0.20	3104	0.65	0.24
Irrigation scheme (district average)	3104	0.14	0.15	3104	0.12	0.17
Agricultural collective action (district average)	3104	0.34	0.26	3104	0.24	0.20

Note: during 2011 the exchange rate was 1 USD ~ 153 Malawi Kwacha (MKW)

Table 2: Weather shocks on consumption, non-food consumption, daily caloric intake and the role of policies – selected coefficients

Variables	(1) Consumption	(2) Food cons	(3) Non-food cons	(4) Caloric intake
Temperature shock (C)	-0.179*	-0.298***	0.041	-0.222*
	(0.098)	(0.099)	(0.114)	(0.120)
Rainfall shock (mm)	-0.000	-0.000	-0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Seasonal average temperature (C)	-0.149**	-0.106*	-0.255***	0.002
	(0.059)	(0.062)	(0.066)	(0.079)
Total seasonal rain (mm)	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Urban (1==yes)	0.184***	0.122*	0.304***	0.168**
	(0.066)	(0.067)	(0.079)	(0.071)
Age of head of the hh	-0.003*	-0.003*	-0.003	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
dependency ratio	-0.394***	-0.342***	-0.433***	-0.162
	(0.112)	(0.129)	(0.117)	(0.151)
hh is not of protestant religion	-0.088**	-0.091**	-0.035	-0.026
	(0.037)	(0.039)	(0.045)	(0.043)
Distance from first wave's location	0.000	0.000	0.001*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Size of the hh	-0.095***	-0.088***	-0.102***	-0.089***
	(0.009)	(0.009)	(0.010)	(0.009)
population in the community	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Migration in the EA (1==yes)	0.026	0.022	0.028	0.015
	(0.026)	(0.027)	(0.030)	(0.028)
Outmigration in the EA (1==yes)	-0.012	-0.022	0.012	-0.057
	(0.042)	(0.043)	(0.043)	(0.044)
Years education of the head of hh	0.008	0.008	0.009	0.001
	(0.005)	(0.005)	(0.006)	(0.006)
Area owned	0.016	0.030	0.010	0.029
	(0.020)	(0.020)	(0.020)	(0.022)
wealth index agricultural goods	0.095***	0.094***	0.102***	0.052***
	(0.012)	(0.013)	(0.014)	(0.015)
Total safety-net (EA average)	0.000**	0.000**	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Total credit (EA average)	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Extension service(1==yes)	0.103*	0.131**	0.081	0.039
	(0.060)	(0.058)	(0.077)	(0.068)
Receive FISP coupon (district average)	-0.037	-0.067	0.053	0.062
	(0.086)	(0.082)	(0.105)	(0.121)
MASAF program (district average)	0.040	0.020	0.052	-0.069
	(0.066)	(0.067)	(0.071)	(0.074)
Irrigation scheme (district average)	0.046	-0.029	0.113	-0.190*
	(0.090)	(0.096)	(0.096)	(0.108)
Agricultural collective action (district average)	-0.094	-0.042	-0.163***	0.076
	(0.058)	(0.066)	(0.063)	(0.069)
Observations	6,208	6,208	6,208	6,204
R-squared	0.123	0.096	0.116	0.052
Households	3,104	3,104	3,104	3,102

Note: Robust standard errors are in parentheses, and levels of significance are *** p<0.01, ** p<0.05, * p<0.10. Errors are clustered at enumerator area level. The estimates are obtained by fitting an OLS model with Fixed Effects on households and time; all the specifications include controls on climate, demography, education, land owned, infrastructure, policies and agricultural wealth index.

Table 3: Gender differentiated impact of weather shocks – selected coefficients

	Consumption			Food consumption			Non-food consumption			Caloric intake		
	MMH	FMH	JMH	MMH	FMH	JMH	MMH	FMH	JMH	MMH	FMH	JMH
Temperature shock (C)	-0.185	-0.458**	-0.092	-0.307*	-0.471**	-0.291**	0.084	-0.368*	0.199	-0.474**	-0.694**	-0.126
	(0.183)	(0.207)	(0.138)	(0.180)	(0.233)	(0.136)	(0.216)	(0.223)	(0.177)	(0.240)	(0.301)	(0.162)
Rainfall shock (mm)	-0.001	0.001	-0.001	-0.001	0.001	-0.001	-0.001	0.002	-0.000	-0.001	0.004**	0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Households FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	774	836	2,152	774	836	2,152	774	836	2,152	774	834	2,152
R-square	0.184	0.195	0.126	0.184	0.150	0.098	0.150	0.191	0.117	0.096	0.095	0.047
Households	387	418	1,076	387	418	1,076	387	418	1,076	387	417	1,076

Note: Robust standard errors are in parentheses, and levels of significance are *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Errors are clustered at enumerator area level. The estimates are obtained by fitting an OLS model with Fixed Effects on households and time; all the specifications include controls on climate, demography, education, land owned, infrastructure, policies and agricultural wealth index. For the entire list of controls, please refer to table 1.
MMH = men-managed households; FMH= female-managed households; JMH= jointly-managed households.

Table 4: Gender differentiated impact of weather shocks across lineage of land tenure

Panel a	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Consumption						Food Consumption					
	Matrilineal			Patrilineal			Matrilineal			Patrilineal		
	MMH	FMH	JMH	MMH	FMH	JMH	MMH	FMH	JMH	MMH	FMH	JMH
Temperature shock (C)	0.142	-0.029	-0.300	-0.131	-0.981***	-0.092	0.414	0.203	-0.592	-0.394	-0.946***	-0.167
	(0.698)	(0.441)	(0.295)	(0.229)	(0.320)	(0.168)	(0.732)	(0.562)	(0.363)	(0.248)	(0.350)	(0.195)
Rainfall shock (mm)	-0.001	0.001	-0.002**	-0.002	0.001	0.000	-0.001	0.002	-0.001	-0.001	0.001	-0.000
	(0.003)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.003)	(0.003)	(0.001)	(0.001)	(0.002)	(0.001)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH & Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	362	570	1,456	402	256	676	362	570	1,456	402	256	676
R-squared	0.263	0.224	0.149	0.219	0.422	0.323	0.225	0.158	0.109	0.261	0.383	0.235
Households	181	285	728	201	128	338	181	285	728	201	128	338

Panel b	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
	Non-food consumption						Caloric intake					
	Matrilineal			Patrilineal			Matrilineal			Patrilineal		
	MMH	FMH	JMH	MMH	FMH	JMH	MMH	FMH	JMH	MMH	FMH	JMH
Temperature shock (C)	-0.146	0.203	0.105	0.248	-0.992***	0.131	0.267	-0.549	-0.669*	-0.223	-1.128**	0.169
	(0.748)	(0.562)	(0.339)	(0.308)	(0.351)	(0.215)	-0.681	-0.64	-0.393	(0.375)	(0.531)	(0.238)
Rainfall shock (mm)	-0.002	0.002	-0.004***	-0.001	0.002	0.001	0.002	0.002	0.003**	-0.003	0.007**	-0.002
	(0.003)	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)	-0.003	-0.003	-0.001	(0.002)	(0.003)	(0.001)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH & Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	362	570	1,456	402	256	676	362	568	1456	402	256	676
R-squared	0.249	0.158	0.148	0.194	0.397	0.273	0.243	0.118	0.058	0.158	0.201	0.108
Households	181	285	728	201	128	338	181	284	728	201	128	338

Note: Robust standard errors are in parentheses, and levels of significance are *** p<0.01, ** p<0.05, * p<0.10. The estimates are obtained by fitting an OLS model with Fixed Effects. MMH = men-managed households; FMH= female-managed households; JMH= jointly-managed households.

Table 5: Shocks and adoption by district

	FMH in Patrilineal districts			FMH in Matrilineal districts			T-test
	N	Mean	Sd	N	Mean	Sd	
Temperature shock (C)	261	0.16	0.21	575	0.24	0.2	***
Adoption of technologies by lineage type							
Legume intercropping	261	0.46	0.21	575	0.57	0.49	***
Hybrid seeds	261	0.61	0.49	575	0.7	0.46	***
Soil water conservation system	261	0.41	0.49	575	0.44	0.5	

Test statistics significance are *** p<0.01, ** p<0.05, * p<0.10

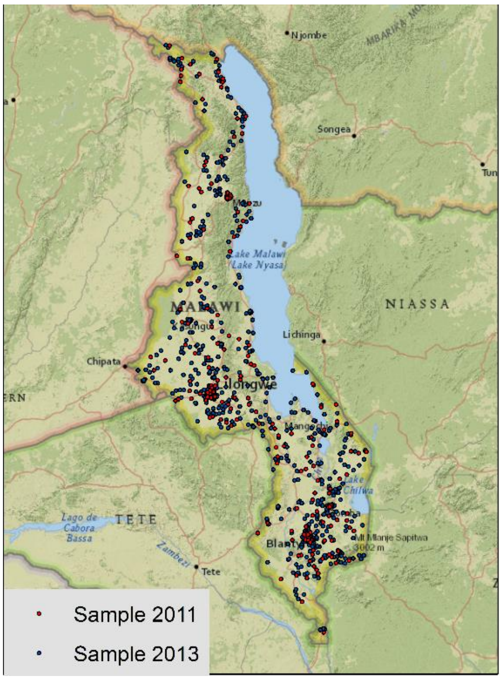

Figure 1: Geographical distribution of the sample

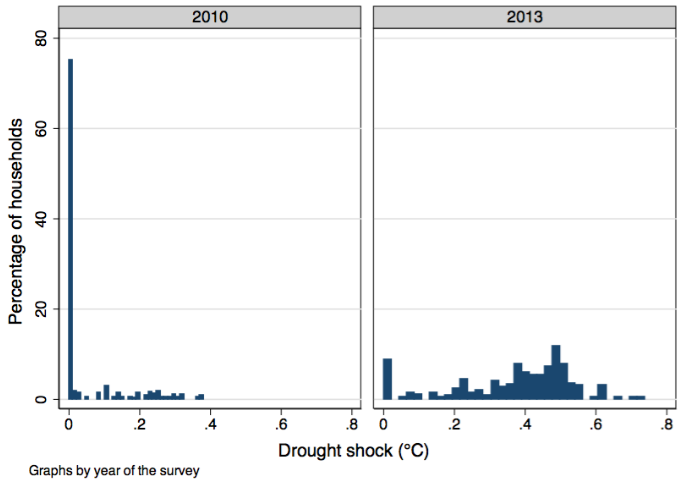

Figure 2: Percentage of households hit by temperature shock level and year

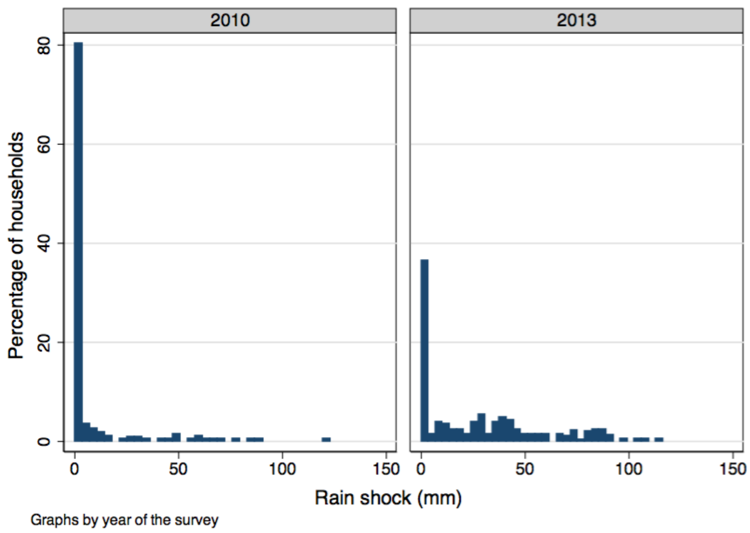

Figure 3: Percentage of households hit by positive rainfall shocks level and year