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Weather and Welfare in Ethiopia

Jeremy Foltz

*University of Wisconsin - Madison
Email for correspondence: jdfoltz@wisc.edu*

Jared Gars

University of Wisconsin - Madison

Mutlu Özdo an

University of Wisconsin - Madison

Belay Simane

Addis Ababa University

and

Ben Zaitchik

Johns Hopkins University

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WEATHER AND WELFARE IN ETHIOPIA

Jeremy Foltz, Jared Gars, Mutlu Özdoğan, Belay Simane, Ben Zaitchik

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Abstract

Long term increases in rural incomes and productivity in Ethiopia are threatened by weather fluctuations. Changes in weather variability and the number of extreme weather events (specifically droughts) has the capacity to undermine development efforts if it translates into decreased food availability and incomes. This study integrates downscaled daily weather data with household surveys to study the impact of weather and temperature on rural household welfare in Ethiopia. Our panel data econometric approach is one of the first to measure the impacts of weather on household consumption directly. Generally, we find that food and non-food consumption are a function of weather in Ethiopia, and that this link is lessening over time but more pronounced for poor households. Evidence from these survey villages suggests that being in a vulnerable area may not actually result in being worse off relative to being poor in a non vulnerable area. These findings have implications for focusing climate mitigation strategies on the poor regardless of location rather than just the poorest regions.

Recent World Bank reports indicate that 22.2 percent of the world live on less than 1.25 dollars per day, down from 52 percent in 1981. This decline has been less pronounced in Sub-Saharan Africa, due in part to rapid increases in population (Bank, 2012). The rate of those living on less than \$ 1.25 in the region decreased by nearly 5 percent from 2005 to 2008, but the absolute numbers of those under the \$2 per day poverty line has been attributed to 'the vulnerabilities still faced by a great many people in the world'(Skoufias, 2012).

Agriculture has been a large source of growth in rural Ethiopia over the past decade. In Ethiopia, the poverty headcount ratio fell from 39 percent to 29.6 percent from 2004 to 2011 alongside a substantial increase in agricultural output. Total agricultural output grew at an annual growth rate of 9.3 percent between 2004 and 2009, due primarily to expansion in grain production. Most of this growth has been the result of increasing yields which grew at 5.9 percent over the same period. However, cereal yields remain low relative to international standards indicating the potential for growth through improved seeds, irrigation, and fertilizer. Ethiopia is particularly susceptible to drought and floods which are predicted to become more severe under most climate change scenarios. These disastrous weather events compound the vulnerability of rural households, leading to long term negative effects for development efforts through health impacts, lost human capital, infrastructure damage, and loss of assets.

Weather in Ethiopia presents a large threat to agricultural production, exposing households to a high degree of risk and potential misfortune. The IPCC predicts that Sub-Saharan Africa will experience an increase in extreme weather events including drought and floods which will have devastating effects as a result of the changing hydrologic balance. From 1900 - 2009, Ethiopia suffered 12 extreme droughts and 47 major floods, killing 402,000 and 1,957 people, and causing damages of 93 million and 16.5 million, respectively. The country faced three severe droughts in the 1990s as well as the 2000s, resulting in massive harvest failure and production below subsistence level for many households. In addition to precipitation, future climate predictions suggest that temperatures will increase, which induces an a 2-3 percent increase in evapotranspiration for each degree Celsius (You and Ringler, 2010). Thus, drier areas will be more sensitive to the impact of climate change.

This study integrates downscaled daily weather data with household surveys to study the impact of weather and temperature on rural household welfare in Ethiopia. Our econometric approach is similar to previous research on the weather-yield relationship and the role of climate change on economic

growth but is one of the first to measure the impacts on household consumption directly. The use of household level fixed effects allows us to control for local variation in soil quality and management capacity that cannot be controlled at the district or country level. Using these estimates, we can identify those households that are most vulnerable to climate change.

Despite short term growth, long term increases in rural incomes and productivity in Ethiopia are threatened by weather fluctuations. Changes in weather variability and the number of extreme weather events (specifically droughts) has the capacity to undermine development efforts if it translates into decreased food availability and incomes. You and Ringler (2010) note that Ethiopia is particularly susceptible to extreme hydrological variability that has retarded economic growth through decreased crop production and the destruction of roads and bridges from flooding. This phenomenon takes on a regional focus in Ethiopia, where some areas may be experiencing extended periods of desertification and drought, while others may enjoy more favorable weather conditions under current climate predictions. Under most climate change scenarios drought, flooding, and intensity in weather variability will increase exposing agricultural producers to greater risk and threatening growth, food security, and poverty reduction efforts. The difficulty then includes mitigating loss in productivity in dryer areas and creating viable transportation and marketing networks to link these contrasting agroecological zones. Due to the centrality of agriculture to Ethiopian welfare, it is essential to understand the role of climate change and the impact of household adaptation strategies and targeted policy interventions that can limit the negative impacts of erratic weather.

Using hydrological modeling projections integrated with economics indicators, You and Ringler (2010) find that the negative impact on GDP growth actually stems from hydrological variability rather than water supply constraints. Their results are driven by flood damage when the effects of all climate factors are evaluated together. Both extreme low and high levels of rainfall can have severe impacts on local farmers. Droughts stunt agricultural output hence driving subsistence farmers into poverty traps. On the other hand, too much rainfall can cause flooding. Flooding has much more long-term impacts on agriculture and has a direct negative impact to GDP since it may: damage crops, causing a direct impact to farmers' productivity and income; destroy infrastructure important to farmers such as roads, further aggravating the lack of adequate transport infrastructure and worsening farmers' links to markets.

While the majority of the literature points to increasing rainfall and temperature averages and

volatility, there has been significant heterogeneity in these magnitudes and impacts both across and within countries. Skoufias et al. (2011) outline previous efforts to estimate the impact of climate change on growth and poverty, emphasizing the difference between economy wide growth models and sector specific analysis such as agricultural productivity. From the aggregate perspective, Dell et al. (2009) find that a degree Celsius increase in temperature results in a reduction of 8.9 percent of GDP per capita. The same relationship was found within countries as well as across 134 countries. Andersen et al. (2010) estimate the output-climate elasticity for 5 Latin American countries, assuming that poverty is decreasing in per capita income. Their elasticities suggest an increase in poverty under climate change relative to no climate change in 2058 for Peru, Chile, and Brazil, with a decrease in poverty for Bolivia and Mexico. Thus, the impacts of climate change on welfare from the aggregate perspective are generally seen to be negative but there is heterogeneity at the country level.

More direct microeconomic studies of climate change on welfare and poverty are limited. Deschenes and Greenstone (2007) estimate the impacts of precipitation and weather fluctuations on agricultural profits in the US and find that there will be no significant effects on yields for most crops, contrary to popular perceptions. Many other microeconomic studies utilize the incidence of extreme weather events to estimate a variety of impacts on welfare, finding that extreme events tend to decrease agricultural incomes. Skoufias et al. (2011) note that these studies rely primarily on self reported weather events but do not use actual temperature and precipitation data.

Rural households may be faced with substantially different adaptation and coping strategies depending on location, wealth level, etc. In a study of family farm businesses in rural Indonesia, Skoufias et al. (2011) find that areas that receive low rainfall have 14 percent lower per capita household expenditure. Nonfood expenditure is more sensitive to weather fluctuations, including health and education expenditures. These reductions underscore the potential for long term development effects as they translate into lower levels of human capital in children. The results in their study also highlight the important role that public works projects and access to credit play in household adaptation strategies.

In a similar study in rural Mexico, Skoufias and Vinha (2012) find that rainfall and temperature deviations from their long run mean translated into changes in average well-being of households in rural Mexico. The authors used a nationally representative survey, the Mexican Family Life Survey (MxFLS) which was carried out in 2002 and 2005/07, and integrated weather measurements including rainfall and growing degree days provided by the Mexican Water Technology Institute (IMTA). Their analysis

utilized interpolated daily values for the geographic centroid of each municipality in Mexico. The authors construct both positive and negative temperature and rainfall shocks as standard deviations from the long term average and analyze the effects on various expenditure measures across specifications that differentiate climate zones and accessibility. Their results show that household consumption is sensitive to negative shocks and that expenditure increases in periods of higher productivity. The magnitude of these effects were a function of the timing of the shocks with respect to the annual growing cycle. Unlike Skoufias et al. (2011) and Skoufias and Quisumbing (2005), household expenditure on food items was not protected relative to nonfood expenditure. The authors note that the capacity for households to smooth consumption is limited in arid climates resulting in lower expenditures following weather shocks.

In rural Ethiopia, previous research has shown that droughts, the primary covariate shock in Ethiopia, can limit peoples' welfare for many years following the drought (Dercon, 2004). Rainfall shocks decreased growth rates 5 years following the lower rainfall by a one percentage point. On aggregate, this translated into 16 percent lower growth in the 1990's for those that experienced a substantial shock relative to a moderate shock. The anticipated effect of these shocks resulted in preventative measures meant to limit their impact while lowering average returns over time, or what have been called risk induced poverty traps. In an attempt to distinguish the limited adoption of fertilizer in Ethiopia as a result of seasonal credit constraints or constraints to smooth consumption over time, the authors find that downside risk significantly lowers fertilizer adoption and application rates. Poor households limit their use of profitable modern inputs as protection against downside risk, resulting in persistence of poverty for those caught in this trap (Dercon and Christiaensen, 2011).

In a study of the effects of self reported shocks on consumption in Ethiopia, Dercon et al. (2005) find that drought and illness present the greatest threat to household consumption after controlling for household and village characteristics. Self reported drought in the previous 5 years resulted in 20 percent lower per capita consumption, while illness accounted for another 9 percent decrease. The impact of drought was most pronounced for female headed, less educated, and low land holding households and they had a longer impact (28 percent) between 1999 and 2004.

For this study we consider the impact of drought, rainfall, and temperature on welfare outcomes using measures common to the agronomic and climate change literature. One benefit of this approach is integrating the existing climate change methodology with household data. Previous studies use

some measure of rainfall, and occasionally temperature, to construct shocks based off deviations from a long term average Skoufias and Vinha (2012); Dercon (2004). The use of continuous measures, in addition to binary classifications, allows for continuity across disciplines and is more appropriate when considering predictions based on climate change prediction models.

Data and Context

Household survey data

Our survey data comes from the Ethiopia Rural Household Survey (ERHS), a longitudinal household data set covering households in 15 areas of rural Ethiopia. The survey was undertaken by the Department of Economics of Addis Ababa University (AAU) in collaboration with IFPRI and the Center for the Study of African Economies (CSAE) of Oxford University. The survey focuses on 15 geographically diverse peasant associations, or collections of villages, that were specifically chosen to represent the diversity which is apparent in Ethiopia's farming systems. The 15 PAs are representative of Ethiopia's diverse religious, ethnic, ecological and agricultural nature. Village sample sizes were picked to approximate a self-weighting sample regarding the farming system; approximately each individual is representative of an equal number of individuals found in the main farming systems as of 1994. Yet, results can not be completely regarded as nationally representative of Ethiopia's population since it does not include any pastoral households or urban areas.

After the initial random sampling of 1,477 households over 15 PAs in 1994, these same households and villages were resampled in late 1994, 1995, 1997, 1999, 2004 and 2009. Our sample excludes the 1994 survey, covering from 1995 - 2009. The survey is administered From March to August depending on the survey year, so our harvest data comes from the output from the previous year's agricultural season. All of the waves contain detailed household information on demographics, agricultural production, consumption, land, and health. Other data includes network participation and village level questions on infrastructure, prices, and public goods. The data benefits from a low attrition rate, with only 12.4%, or 1.3% per year, of the sample was lost in the 15 year sampling period.

Weather in Ethiopia

Weather data was collected from a 1-degree resolution Princeton surface meteorology reanalysis using the MicroMet topographic correction routines to account for steep topographic contrasts in Ethiopia (Liston & Elder 2006). The daily weather variables were determined according to the geographic centroid of the woreda (administrative unit similar to a U.S. county) The main harvest period for the *meher* season ranges from October to December for the 17 study woredas. The survey collection periods ranged from March to July so that the reported harvest in survey year 1997 was from the 1996 growing season. Woreda level weather variables are calculated for the year or season prior to the survey year, accounting for local *meher* season variation, and then matched to the household level variables for each survey instrument. Thus, for the 1997 survey the weather variables of interest are calculated using the 1996 interpolated daily values from January 1996 to December 1996 or using only the months of the growing season from May 1996 to November 1996. Using surveys 1995, 1997, 1999, 2004, and 2009 results in 85 weather-year pairs.

We use daily weather measurements for the 17 study woredas to construct summary statistics by year and main growing season (*meher*). Since Ethiopian agriculture is primarily rainfed, with the prevalence of irrigation in our sample at just one percent, crop yields should be highly responsive to rainfall and temperature variation. The measures of weather used in this study include total rainfall in millimeters (annual and growing season), the length of the longest dry spell over the rainy season, and the growing degree days (GDD). The total rainfall measure captures the degree of total precipitation over the period and reflects the degree of annual moisture available, conditional on local soil conditions. The length of the longest dry spell provides a statistic meant to capture the severity of drought for the season. This was calculated by summing over the number of days included in the longest consecutive spell of daily rainfall that was less than .2 mm.

Our measure of temperature is growing degree days (GDD), a cumulative measure of temperature over the growing season that relates daily temperature to crop maturation. The required cumulative heat for maturation (GDD) varies by crop and variety, as well as environmental factors. Maize varieties range in GDD from 2,450 to 3,000 while wheat varieties can range from 1,800 to 2,000 GDD. The definition of GDD is determined by the base and ceiling temperatures of crop growth, with the base being the minimum temperature required while the ceiling is the maximum. The cumulative measure is constructed by summing average daily temperature over the season after converting temperature

through a predefined function. The bounds in this study are those used in Schlenker and Roberts (2009) and are calculated according to:

$$D(T) = \begin{cases} 0 & \text{if } T \leq 8^{\circ}C \\ T - 8 & \text{if } 8^{\circ}C < T \leq 32^{\circ}C \\ 24 & \text{if } T > 32^{\circ}C \end{cases}$$

Summary statistics for household consumption and weather variables are provided in Table 1. Poverty in the sample is slightly above 40 percent with a high degree of variation across years and regions. Our poverty status indicator is based on the consumption based poverty line outlined in Dercon and Krishnan (1998). Average rainfall for the *meher* season is 922 millimeters, though some areas can receive in excess of 1,500 mm while others receive less than 600. Finally, the length of the longest dry spell averages just under a week. The weather variables were created for the 15 study village in the sample and reflect the averages across these observations.

Table 1: Summary Statistics 1995-2004

Variable	Mean	Std. Dev.
Log of Food	5.62	0.85
Log of Consumption	4.11	0.81
Poor = 1	0.40	0.49
Rainfall/100 (mm)	9.22	2.93
Degreedays/100	19.95	6.19
Longest Dry (days)	6.72	3.03
n	5101	

Figure 1 presents average yearly rainfall for the seventeen woredas in the study from 1979 to 2009. From the figure, total rainfall has increased by 12 percent over the period while the variance and severity of deviations has increased since the 1980s. The large troughs are periods of droughts in the years 1991, 1999-2000, and 2002. From Figure 2, there has been a concurrent growth in average temperature which exacerbates the impact of droughts and increases the prevalence of disease. The past two decades have seen average temperatures increase by one half of a degree Celsius, which has promoted the growth of crops in some areas and limited the growth of crops in others.

Figure 1: Annual Average Rainfall (mm)

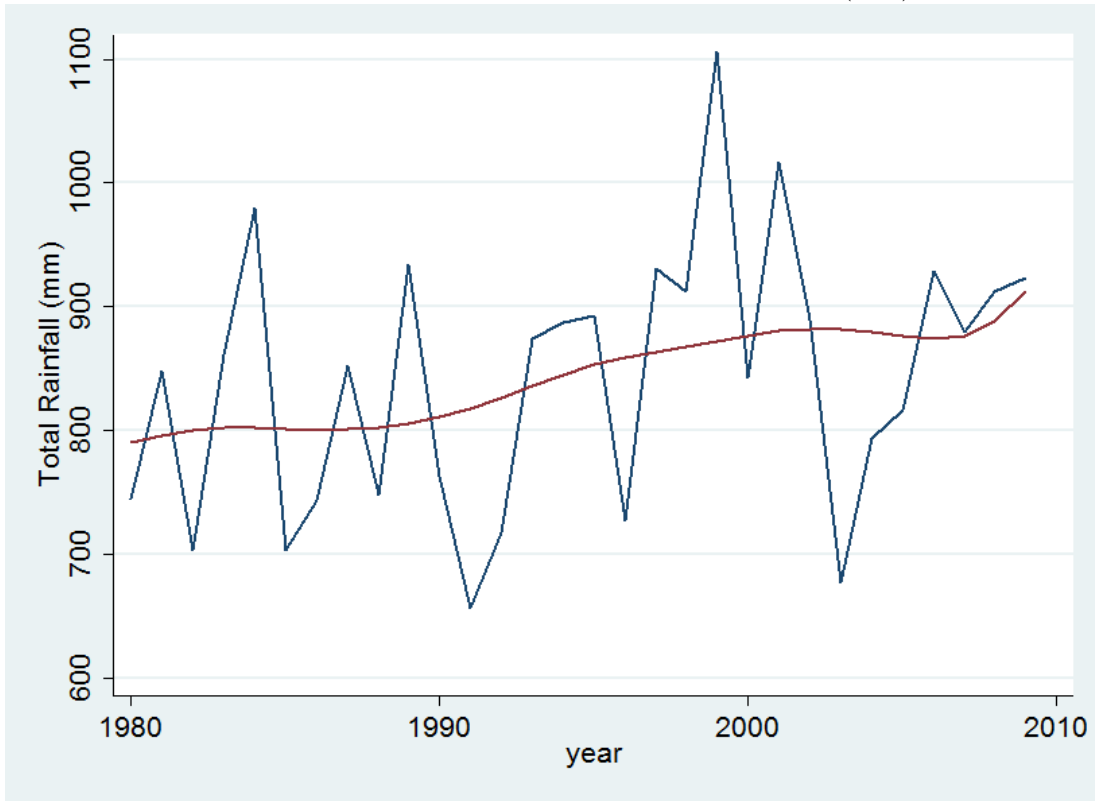
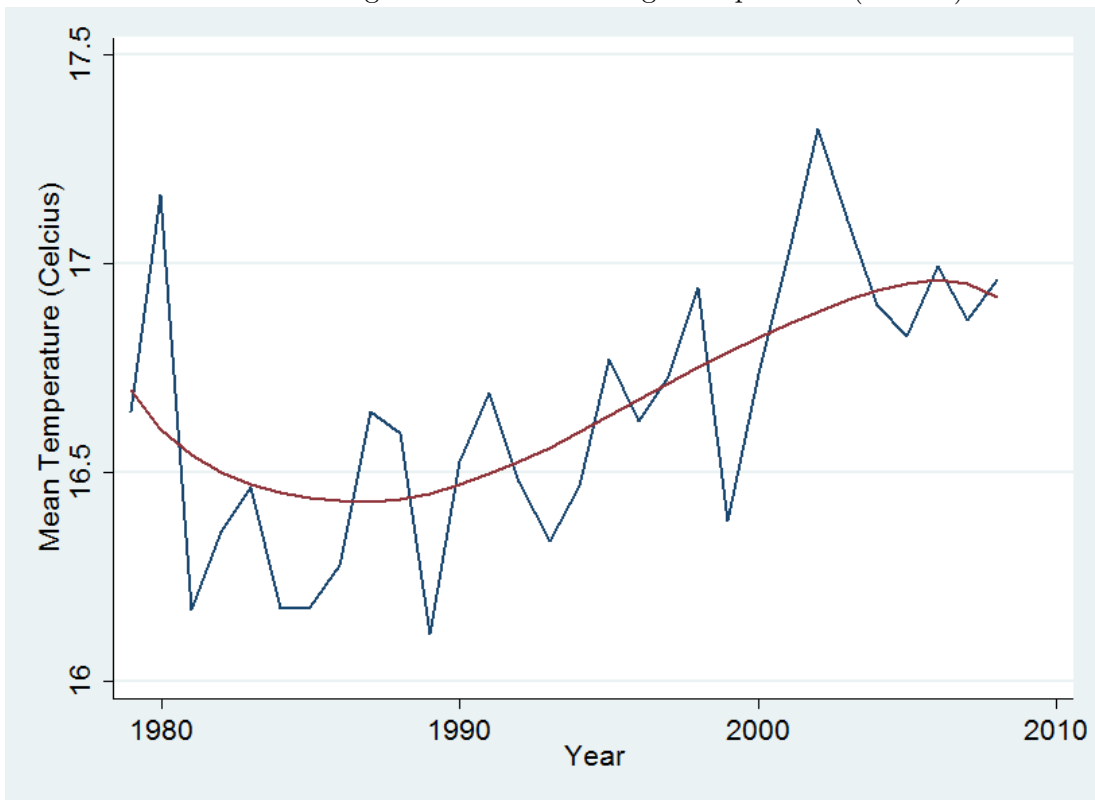


Figure 2: Annual Average Temperature (Celcius)



Methodology

The empirical strategy follows the panel data estimation method similar to Deschenes and Greenstone (2007); Guiteras (2009) to estimate the impact of annual changes in weather patterns on welfare outcomes. Our methodology converges from there as we are able to use individual observations of consumption, with woreda level observations for temperature and rainfall. The estimating equation given by:

$$\log C_{wht} = \beta_i \cdot \mathbf{f}_i(\mathbf{W}_{wt}) + \mathbf{t} + \mu_h + \epsilon_{wht} \quad (1)$$

where C_{wht} is a measure of household consumption, \mathbf{W}_{wt} is a vector of woreda level weather measures, t is a country level time trend, and μ_h is a household fixed effect.

The primary consumption measure of interest is a household size adjusted (adult equivalent units) measure of real consumption. The consumption aggregate includes all food consumption in the previous week, scaled to a month, including all purchased, gifts, and own stock food. Non-food items are restricted to consumables (clothes, soap, linen) but do not include school and health expenditures, taxes, and extraordinary contributions. This excludes rare or lumpy expenditures such as ceremonial expenses and contributions to local savings groups. In addition to total consumption, we include a measure of just food consumption to test the sensitivity of food consumption to weather variation.

The vector of weather variables, \mathbf{W}_{wt} , includes the amount of total rain over the year (mm), the amount of total rain during the growing season (mm), the length of the longest dry spell in days, and the growing degree days over the growing season described in the previous section. One alternative specification includes a measure of the distribution of rainfall in a woreda year, the shape parameter of a fitted gamma distribution of the rainfall for the rainy season. The shape parameter is a measure of the skewness of the distribution, which has been previously shown to affect the yield outcomes for a variety of crops (Fishman, 2011).

We include a series of interaction terms between the weather variables and measures of household welfare in previous periods. The interaction terms capture heterogeneity in impacts of weather events on households based on a measure of poverty status. We include estimations using both current poverty status and the household poverty status in the prior survey year. Households may be limited in their capacity to manage weather shocks based on their level of wealth and resources available to them. Given the results found in Dercon (2004) that weather shocks exhibit long term persistence in

consumption, we include a measure of the poverty status of the household in the first year of the survey (1994). The poverty indicator is meant to capture this effect, but in separate estimations we include a measure of asset wealth in the previous survey to determine whether access to liquid assets protects allows households to smooth consumption, or if there are ancillary aspects that constrain relatively poorer households that are not captured by an asset index.

We include a time trend to account for growth in consumption over the period that is not explained by changes in weather. The time trend may reflect changes in off farm work opportunities, migration, or economic growth that provides food or consumption. The time trend is interacted with the weather variables to allow for changes in total factor productivity over time, or may reflect the capacity of household to shield consumption from adverse weather effects, that may or may not be correlated to weather patterns or rainfall. The error term allows for arbitrary correlation across time and within regions, and is clustered at the village year level.

Results

Baseline results from the household fixed effects regression from equation 1 are presented in Table 2 with the log of total consumption and the log of food consumption as dependent variables in columns 1 and 2. The coefficient on total rainfall represents a percent change in real consumption per capita from a 100 millimeter increase in total rainfall. The coefficient can be interpreted as a semi-elasticity such that a one standard deviation increase in rainfall (293 mm) translates into a 2.6 percent increase in total consumption. Similarly, a day longer without rain decreases consumption by 2.3 percent. While the mean dry spell is 6 days, some areas experience regular dry spells between 9 to 12 days which decrease consumption by 6 to 12 percent relative to the mean. Additionally, it is worth noting that even controlling for village year fixed effects, consumption is increasing over 6 percent annually in the sample. Food consumption exhibits similar decreases as a result of dry spells, as we might expect. Food consumption, however, responds positively to increased temperature, indicating that the base crops grown in these areas (maize, wheat, teff, barley) benefit from increased exposure to heat, especially in the highlands. The fact that more heat does not translate into increased consumption of nonfood items, but does respond to drought stress is indicative of possible general equilibrium effects associated with droughts.

Tables 3 and 4 include interaction terms between weather variables and time for consumption and

food consumption, respectively. Total consumption has become more sensitive to total rainfall in later periods, while degree days has an increasingly positive effect over time and the effects of drought become more negative. These results suggest that households may lack available mechanisms for shielding consumption from weather shocks. The results for food consumption reflect similar patterns though the effects are more dramatic as food consumption is more sensitive to weather changes.

Table 2: Baseline Weather on Nonfood and Food Consumption (Ln)

Variables	(1) Ln(Cons)	(2) Ln(Food)
Totalrain	0.0264 (0.0174)	-0.0129 (0.0193)
Degreedays	0.0184 (0.0950)	0.272*** (0.0907)
Longdryspell	-0.0230*** (0.00861)	-0.0296*** (0.00968)
t	0.0637*** (0.0224)	-0.00259 (0.0227)
Constant	3.249* (1.777)	0.391 (1.687)
Observations	5,101	5,098
R-squared	0.231	0.196
Number of idhh	1,406	1,406

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5 provides estimates with the log of consumption as the dependent variable, including heterogeneity in weather effects across household poverty status in the previous survey year. Columns 2-4 contain the estimates with interactions between the weather variables and whether the household was poor in the previous survey year. In general, the results from these columns show that poorer households' consumption is more sensitive to weather patterns than non-poor households so that they are less able to shield their consumption from weather shocks. This includes both food and non-food consumption such that poor households may purchase less consumer durables following a year of poor rains, or may be consuming less food. Poor households are relatively worse off from lower rainfall and lower degree days but actually are less hurt by drought. In contrast, columns 5-7 include heterogeneity across whether a household is located in a poor or vulnerable zone. Households in these zones are not more sensitive to rainfall, drought, and temperature relative to non vulnerable areas.

Table 6 contains the same specifications with the log of food consumption as the dependent variable. The results are qualitatively equivalent to using log of consumption, though the magnitudes are slightly higher. This suggests that food consumption is sensitive to weather changes, or that households are consuming more in periods of higher yields and less from periods of lower yields.

Table 3: Impacts of weather on NonFood Consumption (Ln) over time

Variables	(1) Ln(cons)	(2) Ln(cons)	(3) Ln(cons)	(4) Ln(cons)
Totalrain	0.0264 (0.0174)	0.103*** (0.0183)	0.0346* (0.0193)	0.0515*** (0.0186)
Degreedays	0.0184 (0.0950)	-0.00870 (0.100)	0.0562 (0.0918)	0.0884 (0.116)
Longdryspell	-0.0230*** (0.00861)	0.109*** (0.0102)	-0.0203* (0.0106)	-0.0121 (0.0176)
t*Totalrain		-0.0246*** (0.00241)		
t*DegDays			0.00575*** (0.000908)	
t*Longdryspell				-0.00581** (0.00262)
t	0.0637*** (0.0224)	0.241*** (0.0268)	-0.0821*** (0.0293)	0.0851*** (0.0223)
Constant	3.263* (1.774)	2.212 (1.858)	2.480 (1.733)	1.593 (2.199)
Observations	5,101	5,101	5,101	5,101
R-squared	0.231	0.231	0.231	0.231
Number of HH	1,406	1,406	1,406	1,406

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Impacts of weather on Food Consumption (Ln) over time

Variables	(1) Ln(food)	(2) Ln(food)	(3) Ln(food)	(4) Ln(food)
Totalrain	-0.0129 (0.0193)	0.0360* (0.0204)	-0.00861 (0.0210)	0.0261 (0.0198)
Degreedays	0.272*** (0.0907)	0.191 (0.120)	0.241*** (0.0868)	0.294*** (0.113)
Longdryspell	-0.0296*** (0.00968)	0.0706*** (0.0111)	-0.0357*** (0.0111)	-0.0365** (0.0178)
t*Totalrain		-0.0205*** (0.00266)		
t*DegDays			0.00445*** (0.000958)	
t*Longdryspell				-0.00364 (0.00263)
t	-0.00259 (0.0227)	0.182*** (0.0324)	-0.0937*** (0.0296)	0.000325 (0.0214)
Constant	0.375 (1.690)	0.776 (2.207)	1.006 (1.642)	-0.166 (2.145)
Observations	5,098	5,098	5,098	5,098
R-squared	0.196	0.196	0.196	0.196
Number of HH	1,406	1,406	1,406	1,406

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Conclusions

Ethiopia remains vulnerable to weather fluctuations that damage household production and expose farmers to risk. Current climate change predictions find that Subsaharan Africa will experience an increase in extreme weather events including drought and floods which will have devastating effects as a result of the changing hydrologic balance. We investigate the impact of rainfall, temperature, and length of dry spells on household consumption using survey data and seasonal weather observations from 1995 to 2004. Generally, we find that food and non food consumption are a function of weather in Ethiopia, and that this link is lessening over time but the effects are more pronounced for poor households. This decoupling of agriculture and consumption may be the result of economic growth or non weather related earnings, as well as improved agricultural technologies that are less sensitive to weather variation. Temperature increases have a positive impact on food consumption, with the

Table 5: Heterogeneity across poor and vulnerable on Nonfood consumption (Ln)

Variables	(1) Ln(cons)	(2) Ln(cons)	(3) Ln(cons)	(4) Ln(cons)	(5) Ln(cons)	(6) Ln(cons)	(7) Ln(cons)
Totalrain	0.0264 (0.0174)	0.0104 (0.0182)	-0.0442*** (0.0161)	-0.0468*** (0.0161)	-0.0228 (0.0205)	0.0284 (0.0365)	0.0202 (0.0183)
Longdryspell	-0.0230*** (0.00861)	-0.00897 (0.0106)	0.00401 (0.0110)	0.0175* (0.0104)	-0.0156 (0.0106)	-0.00756 (0.0558)	-0.00875 (0.0105)
Degreedays	0.0184 (0.0950)	0.0874 (0.0632)	0.0685 (0.0964)	0.0737 (0.0955)	-0.0600 (0.0932)	-0.0582 (0.108)	0.0873 (0.0669)
Totalrain*poor		0.0164*** (0.00253)			0.0164*** (0.00253)		
Dryspell*poor			0.0183*** (0.00336)			0.0183*** (0.00336)	
Degreedays*poor				0.00723*** (0.00123)			0.00722*** (0.00123)
Totalrain*vuln					0.00509 (0.0306)		
Dryspell*vuln						0.0143 (0.0598)	
Degreedays*vuln							0.00607 (0.0192)
t	0.0637*** (0.0224)	0.0443*** (0.0156)	0.101*** (0.0242)	0.100*** (0.0240)	0.118*** (0.0259)	0.0576*** (0.0220)	0.0430*** (0.0155)
Constant	3.249* (1.777)	1.848 (1.167)	2.255 (1.800)	1.988 (1.788)	4.556*** (1.740)	4.564** (1.982)	1.850 (1.212)
Observations	5,101	4,933	4,933	4,933	4,933	4,933	4,933
R-squared	0.231	0.241	0.239	0.240	0.241	0.239	0.240
Number of idhh	1,406	1,366	1,366	1,366	1,366	1,366	1,366

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Heterogeneity across poor and vulnerable on Food consumption (Ln)

Variables	(1) Ln(food)	(2) Ln(food)	(3) Ln(food)	(4) Ln(food)	(5) Ln(food)	(6) Ln(food)	(7) Ln(food)
Totalrain	-0.0129 (0.0193)	-0.0302 (0.0200)	-0.0820*** (0.0176)	-0.0857*** (0.0175)	-0.0607*** (0.0219)	0.00297 (0.0460)	-0.0173 (0.0205)
Longdryspell	-0.0296*** (0.00968)	-0.0336*** (0.0117)	-0.00838 (0.0120)	0.0104 (0.0114)	-0.0293*** (0.0111)	-0.0698 (0.0725)	-0.0330*** (0.0116)
Degreedays	0.272*** (0.0907)	0.236*** (0.0686)	0.332*** (0.0913)	0.340*** (0.0903)	0.165* (0.0893)	0.141 (0.129)	0.230*** (0.0745)
Totalrain*poor		0.0210*** (0.00271)			0.0210*** (0.00271)		
Dryspell*poor			0.0251*** (0.00354)			0.0251*** (0.00353)	
Degreedays*poor				0.00960*** (0.00131)			0.00959*** (0.00131)
Totalrain*vuln					0.0101 (0.0409)		
Dryspell*vuln						0.0441 (0.0780)	
Degreedays*vuln							0.0131 (0.0260)
t	-0.00259 (0.0227)	0.0130 (0.0190)	0.0323 (0.0245)	0.0309 (0.0243)	0.0590** (0.0263)	0.0264 (0.0274)	0.0117 (0.0188)
Constant	0.391 (1.687)	1.093 (1.268)	-0.788 (1.710)	-0.996 (1.698)	2.401 (1.668)	2.855 (2.394)	1.054 (1.341)
Observations	5,098	4,930	4,930	4,930	4,930	4,930	4,930
R-squared	0.196	0.207	0.205	0.206	0.207	0.206	0.207
Number of idhh	1,406	1,366	1,366	1,366	1,366	1,366	1,366

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

effects increasing over time, which is promising given predicted increases in temperature over the next several decades.

Our results are consistent with previous findings that poorer households are more vulnerable to shocks or weather fluctuations. However, evidence from these survey villages suggests that being in a vulnerable area may not actually result in being worse off relative to being poor in a non vulnerable area. These findings have implications for climate mitigation strategies, which should be focused on the poor regardless of location rather than just the poorest regions. In contrast, currently many aid agencies in Ethiopia focus their aid programs and resources on hungry Ethiopia which may not be the best strategy when developing climate mitigation strategies.

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