FONDATION POUR LES ÉTUDES ET RECHERCHES SUR LE DÉVELOPPEMENT INTERNATIONAL

Working Paper 104
May 2014
Development Policies

Climate Variability and Migration: Evidence from Tanzania

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Abstract

We analyze whether Tanzanian households engage in internal migration as a response to weather-related shocks. Our findings confirm that climate shocks lead to a higher probability of migration by reducing agricultural yields, which in turn induces households to send their members away in order to spatially diversify their income. This effect is, however, low, since a 1% reduction in agricultural income induced by weather shock increases the probability of migration by 3% for an average household. What is more, such mechanism is valid only for households whose income is highly dependent on agriculture, but is not significant for diversified livelihoods.

JEL classification : O13, Q54, R23

Keywords : migration, adaptation, climate variability, risk, agricultural productivity

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CETTE PUBLICATION A BÉNÉFICIÉ D'UNE AIDE DE L'ÉTAT FRANCAIS GÉRÉE PAR L'ANR AU TITRE DU PROGRAMME «INVESTISSEMENTS D'AVENIR»
PORTANT LA RÉFÉRENCE «ANR-10-LABX-14-01».

1. Introduction

There is a substantial evidence that climate has been changing in recent decades, both in terms of its means and extremes, and this trend will not only persist, but will also intensify in near future (IPCC, 2007). According to recent estimates, this unprecedented climate variability will first occur in the tropics and among low-income countries, where the projected mean climate may continuously move outside the bounds of historical variability already in 2034, about 17 years earlier than the global average (Mora et al., 2013). Through their implications for agricultural production, these changes will exert additional pressure on the populations in developing countries, both because majority of the poor rely on rain-fed agriculture and also because the share of food in the budget of the poor may amount to two-thirds (Cranfield at al., 2003). Therefore, climate change and climate variability should be perceived as an important source of risk for rural households in developing countries.

The link between climate and agricultural productivity has been thoroughly analyzed. Despite calibration caveats or data limitations, both Crop Growth Simulation Models and statistical studies reveal that whereas some yield gains are possible under global warming in temperate regions, the lowest income countries will experience the sharpest losses (Deryng et al., 2011). In particular, cereals, the staple food in most of developing world, show the greatest potential to be adversely affected by climate change (Schlenker and Roberts, 2008) and according to Schlenker and Lobell (2010), yields will decline by about 10% by 2050 in nearly all countries in Sub-Saharan Africa. Schlenker and Roberts (2008) identified a clear threshold at 30˚C for maize, after which additional increments to temperature result in sharp reduction in yields. This type of non-linearity can therefore have important consequences should the climate change lead to an increase in the intensity and frequency of extreme heat events (Easterling et al., 2000).

The implications of increased climate anomalies may have a much broader range than just distortions of plant phenology. Other consequences include spread of crop pests and livestock diseases, and reduction in pastures (Swai et al., 2012), land degradation and soil erosion (Morton, 2007), spread of human diseases such as malaria, cholera and typhoid (Kudamatsu et al., 2012) or conflict over water and other environmental resources (Harari and LaFerrara, 2012). In this study, however, our aim is to analyze the direct impact of changing weather conditions on rural households whose livelihood depend on farm activities, therefore we focus our attention solely on climate variability as a risk factor for the agriculture. In particular, we investigate the extent to which rural households engage in internal migration to ensure against agricultural risk due to weather-related shocks.

The literature suggests a range of mechanisms that households living in risky environments have developed to shield their consumption from risk, including income smoothing, self-insurance, and social insurance arrangements, particularly important in the absence of formal insurance or credit markets. Much emphasis has been put on households depleting their productive assets (Kazianga and Udry, 2004; Fafchamps, Udry, and Czukas, 1998), making low-risk, low-return investment

(Rosenzweig and Binswanger, 1993), diversifying their income sources (Dercon, 1996) or diversifying landholdings into various spatially separated plots and into various crops (Townsend 1994). Even though these strategies prove efficient to some extent, they do not lead to a level of consumption smoothing required by the permanent income hypothesis or to Pareto efficient allocation of risk within local communities (Kazianga and Udry, 2004).

Indeed, the effectiveness of these risk-bearing institutions is hindered by the fact that weather risk is spatially covariant. This applies particularly to formal and informal credit which, as useful as it can be in case of idiosyncratic risk, proves unworkable when the whole village experiences the same climatic stress (Rosenzweig and Stark, 1989). Similarly, the limited use of livestock as a buffer stock may be partly explained by the price dynamics at play when a nonidiosyncratic shock, such as drought, affects the whole region. In this context, spatial diversification of income through migration may be considered as a valid option in order to reduce vulnerability of smallholder farmers to weather risk. Since interhousehold family transfers are an important source of income insurance in low-income countries, a household, as long as it can afford the cost of migration, may decide to relocate one or more of its members within a country in order to reduce the correlation between origin and destination income shocks, adjusting the distance travelled by migrants accordingly (Rosenzweig and Stark, 1989). Therefore, a better understanding of the effectiveness and limitations of migration as a risk management strategy may inform us about households' ability to adapt to weather-related risk, and, potentially, inform the design of policy in the context of increasing climatic stress on the smallholder farmers in developing countries.

A growing literature investigates the use of migration as a response to climate change or climate variability. Starting with Rosenzweig and Stark's (1989) seminal paper on India, some evidence of environmentally induced migration has been found for low income countries (Burkina Faso (Henry et al., 2004), Ethiopia (Ezra and Kiros, 2001; Meze-Hausken, 2004), Mali (Findley, 1994)), but also for high income countries, for example the US, both in historical (McLeman and Smit, 2006) and modern perspective (Feng et al., 2012). Even though the prevailing strand of literature focuses on internal migration, international migration flows have also been modeled as a response to climatic stress (Marchiori et al., 2012; Feng et al., 2010; Munshi, 2003; Halliday, 2006).

However, the environmentally induced migration is a highly contextual phenomenon, depending on particular agroecological conditions or cultural norms, as in case of female migration (Curran and Rivero-Fuentes, 2003), and therefore different studies produce different, sometimes conflicting, results. For example, a study on Ecuador emphasizes the importance of international migration as a response to agricultural shocks (Gray and Bilsborrow, 2010), whereas Findley (1994) and Henry et al. (2004) suggest that in west Africa, migrants choose short-distance destinations. Both papers show that mobility takes place primarily within rural zones. On the other hand, Marchiori et al. (2012) propose a model where environmental factors lead to international migration through urbanization. Other inconsistencies occur with respect to the role of female migration (Findley, 1994; Gray and Mueller, 2011), or the impact of natural disasters versus slow-onset climatic changes (Halliday, 2006; Gray and Mueller, 2012; Gray et al., 2009). The most striking is the example of Mexico in which case two papers on migration to the US found a positive relationship between climate change, crop yields, and migration (Munshi, 2003; Feng et al., 2010), whereas an alternative analysis suggests the reverse relationship, showing that Mexican migration to the US decreases as rainfall declines (Kniveton et al., 2008). Therefore, the hybrid narrative of environmental migration requires further investigation.

What is more, a closer examination of the literature suggests that important data issues may be at stake. First, an important number of studies are based on household surveys covering a very limited number of individuals, households, and communities, which restrains the diversity of observed climatic conditions. Second, climatic data itself is not always available nor reliable, and covers a limited time span in case of majority of developing countries, forcing researchers to base their estimations on a merely a decade of observations, or on a highly extrapolated data. Finally, a lot of studies use rainfall data only, while temperature might be much more detrimental to agriculture according to recent research (Ahmed et al., 2011).

In this paper, we attempt to address these challenges in a number of ways. Our contribution to the existing literature is threefold. First of all, we base our estimations on high-quality household survey data on Tanzania, covering a large and representative sample of households from the whole country (more than 16,000 individuals). We merge these data with a high-resolution[1] climate data from Climatic Research Unit of the University of East Anglia (Harris et al., 2013), which enables us to test different climate measures, and we use both temperature and rainfall as our main explanatory variables. Secondly, the unquestionable advantage of Tanzanian setting to which we apply our estimations is its diversity of agroclimatic conditions and ecological zones, including different types of both semiarid and sub-humid environments, which proves to be essential for analyzing the impact of climate on livelihoods. Finally, not only do we examine whether there is any impact of climate on migration, but we also propose a mechanism through which adverse weather conditions induce human mobility.

2. Background

Tanzania appears to be a pertinent case study for the analysis of the link between climate variability, agricultural yields and human mobility. Although Tanzania is not considered to be a drought-prone area to the same extent as Ethiopia or Sudan, the country registered two important drought events in the last decade, leading to severe losses in some regions. At the same time, other parts of the country are subject to recurrent flooding. Indeed, the diversity of agroecological zones in Tanzania ranges from arid or semiarid zones, sub-humid highlands, plateaux, to alluvial plains and coastal zones (DePauw, 1984).

An empirical analysis of rainfall and temperature suggests a trend of decreasing rainfall between 1922 and 2007, whereas temperature mean and temperature extremes increased by 1.9 and 0.2˚C respectively (Mary and Majule, 2009). Several future projections using General Circulation Model

[1] 0.5x0.5 degree

indicate that the interior of the country will experience a 20% decrease in rainfall in June – August season, shortening the rainy season and increasing the risk of drought, whereas precipitations are expected to increase by up to 50% in eastern Tanzania and the regions around Lake Victoria (Hulme et al., 2001). Temperatures are projected to increase by up to 2.2˚C by 2100 (Agrawala et al., 2003). Climate change should therefore be considered as an important challenge Tanzanian households will be about to face, all the more so because of the importance of agriculture for the poor.

Agriculture accounts for about half of gross production, and employs about 80 % of the labor force (Thurlow and Wobst, 2003). Agriculture in Tanzania is also primarily rain-fed, with only 2 % of arable land having irrigation facilities (FAO, 2009), which makes it particularly susceptible to adverse weather patterns. In a recent study, Rowhani et al. (2011) predict that by 2050, the projected seasonal temperature increases by 2˚C in Tanzania will reduce average maize, sorghum, and rice yields by 13%, 8.8%, and 7.6% respectively. Ahmed et al. (2011), using CGE model, predict that this decrease in crop yields will have a spillover effect on other sectors, and , especially, on food prices, leading to an increase in poverty headcount.

3. Data

We base our analysis on a high quality household survey data. We use the Tanzania National Panel Survey (TZNPS) collected by the National Bureau of Tanzania as part of nationally representative living standard survey (WB's LSMS-ISA). The extensive focus of the survey on agriculture offers a wealth of data. TZNPS include a range of data on 16,709 individuals from 3,265 households. We take households baseline characteristics and agricultural production data from the first 2008/2009 wave. Since individuals from the first wave were followed in 2010/ 2011, with very low attrition level (93% of individual or 97% of households were tracked), we use the second wave survey in order to construct migration variable.

For the purpose of our study, a migrant is any household member who moved to another village between the two waves of survey. We adopt the New Economics of Migration approach (Stark and Levhari, 1982; Lucas and Stark, 1985; Stark and Bloom, 1985; Katz and Stark, 1986) where migration is a collective and not an individual decision. Therefore, our unit of observation is a household, and our principal dependent variable is a dummy variable for household with at least one migrant. Alternatively, we also use a dummy for household having at least one migrant in working age. TZNPS provides a range of household characteristics which we use in our estimations (table 1): household size, highest level of education in the household, assets (total livestock units[2]), and also a detailed data on crop production we use in agricultural income equation: land area in ha, soil quality (elevation, slope). We use the data on distance to major road, or the distance to the district capital as a proxy of connectedness or cost of migration. The data on 2008/2009 income (total income and agricultural income) or value of crop and livestock production (all aggregates in

[2] Based on conversion factors from Chilonda and Otte (2006)

Tanzanian shillings) come from the FAO Rural Income Generating Activities database. These data were computed based on the TZNPS. On average, agricultural activities combined (crop, livestock, and agricultural wage labor) amount to 70% of total income in our sample (Covarrubias et al., 2012). Importantly, TZNPS covers the entire country and thus represents all types of agro-ecological conditions.

Since the TZNPS provides the GPS coordinates of the sample households[3], we are able to assign the climatic data, aggregated at the village level, to each household. The climate data come from a high-resolution (0.5x0.5 degree) gridded dataset by the Climate Research Unit of the University of East Anglia (Harris et al., 2013). In this analysis, we focus on slow-onset climate changes rather than natural disasters. We test different available measures, but in principle our estimations are based on monthly mean temperature and precipitation data. Our preferred climatic variable is temperature and precipitation shock in 2008, one year prior to migration. We define a shock as a number of standard deviations above / below the 15-year mean. We apply this measure to seasonal data since on the premise of plant phenology it is more relevant for estimating the impact of climate variability on crop yields than annual data. Since Tanzania is characterised by both unimodal and bimodal rainfall patterns, we averaged seasonal patterns for both regimes, and following Ahmed et al. (2011) we take the data for January – June growing season. For sake of consistency, we also check the results using the data for long *masika* season (March – May), more pertinent for bimodal rainfalls.

Because of extrapolation issues, we do not have climatic data for three enumeration areas. Similarly, lack of GPS coordinates for some villages in TZNPS made it impossible to match their climatic data. Finally, since we focus on households that are involved in any agricultural activity, our final sample consists of 2202 households.

[3] For confidentiality reason, these are the averages of household GPS coordinates in each enumeration area, to which a random offset within a specified range has been applied. Spatial queries using medium or low resolution datasets should be minimally affected by the offsets.

Table 1. Variable definitions and statistics

	Variable	Definition	Mean	Std. Dev.
migration	migr	Migration, dummy (1=hh with at least one migrant)	0.125	0.331
	migr15	Migration, dummy (1=hh with at least one migrant aged >14 & <65)	0.118	0.323
	migr_fem	Migration, dummy (1=hh with at least one female migrant)	0.096	0.294
climate	tmp2008	Mean temperature in 2008 rainy season, degree C	23.378	2.384
	tmpshock	Temperature shock in 2008 rainy season, no of sd over 15 year mean	0.819	0.439
	pre2008	Mean precipitation in 2008 rainy season, mm	108.064	28.992
	preshock	Precipitation shock in 2008 rainy season, no of sd over 15 year mean	0.464	0.334
income	totincome	Total income (TZ shillings)	1078993.000	1839698.000
	cropinc	Crop income (TZ shillings)	193856.600	287228.900
	offinc	Off-agricultural income (TZ shillings)	700103.000	1684272.000
hh characteristics	hhsize	Household size	5.317	2.890
	femhead	Female head, dummy (1=female)	0.243	0.429
	educhigh	Highest education level (years)	6.390	3.463
	credit	Acces to credit	0.057	0.232
	saccos	SACCOS membership	0.052	0.222
	distroad	Distance to road (km)	20.919	23.923
	distdistrict	Distance to district capital (km)	31.216	45.414
	migrexp	Previous migration experience in hh	0.472	0.499
	totarea	Total area owned (ha)	5.513	16.739
	TLU_cattle	Total livestock unit: cattle	1.459	4.705
	TLU_total	Total livestock unit: all	1.784	5.050
	fhh	Farm specializer, dummy	0.459	0.498
	fshh	Subsistence agriculture, dummy	0.359	0.480
	divhh	Income diversification, dummy	0.307	0.461

N = 2202

12.5% of households have at least one migrant, and in 94% of cases migrants are in working age. Migration appears to be mainly a female phenomenon, since about 60% of migrants are females. Even though female migration is often related to marriage, Rosenzweig and Stark (1989) showed that such context does not exclude the importance of environmental factors in migration decision. Interestingly, rural – urban migration and, particularly, migration out-of-agriculture, constitute a small proportion of moves (30% and 14% of migrants respectively), in line with findings by Findley (1994) and Henry (2004). In our dataset, we observe internal migration only. It should be noted, however, that this picture may be blurred by attrition between the two survey waves, since it is possible that there are international migrants among attritors. Finally, the distance travelled ranges from 5.2 km to 1065 km, with median 41.8 km and mean 123.7 km. In our baseline specification, we consider a migrant anybody who moved out of the village, however, we check our results by defining a migrant as an individual who moved a distance bigger than the median, in order to account for the objective of spatial diversification in terms of climatic conditions.

Table 2. Characteristics of households with migrants

		hh without migrants	hh with migrants	difference
	tmpshock	0.826	0.774	0.0521
climate	preshock	0.455	0.522	-0.0663*
	totincome	1027921	1433718	-405796.9***
	cropinc	188669.2	229886	-41216.7**
	offinc	656505.3	1002917.9	-346412.6*
income	totcons	2188758.2	2935106.9	-746348.7***
	hhsize	5.18	6.275	-1.096***
	femhead	0.238	0.275	-0.0375
	educhigh	6.263	7.264	-1.001***
	credit	0.054	0.0797	-0.0257
	saccos	0.0483	0.0761	-0.0278
	distroad	20.89	21.08	-0.187
	distdistrict	31.55	28.99	2.56
	migrexp	0.458	0.569	-0.111***
	totarea	5.474	5.78	-0.306
	TLU_total	1.316	2.446	-1.129***
	TLU_cattle	1.64	2.788	-1.148***
	fhh	0.463	0.428	0.0357
	fshh	0.369	0.293	0.0753**
hh characteristics	divhh	0.307	0.312	-0.00486
	N = 2202			

* significant at 10% level ** significant at 5% level *** significant at 1% level

Some important differences can be observed between households with and without migrants (table 2). In particular, households with migrants experienced a more pronounced precipitations shock in 2008. They are wealthier and have twice as much livestock units, which not only is a good wealth indicator, but also constitutes an important productive asset in Sub – Saharan Africa, and their consumption and income (total income, but also income from agriculture and off – agriculture) are higher on average. Similarly, households who have sent migrants are less financially constraint, since they have better access to credit and are more involved in informal assistance groups (SACCOS), even though these differences are not statistically significant. Also, the percentage of households involved in subsistence farming is smaller among migrant – sending ones. These differences may suggest that migration is costly, and that poor households cannot afford it. Finally, households that have sent their members away differ significantly along the lines of traditional migration drives: they are bigger, have lower dependency ratio, are better educated, and have more migration experience.

4. Estimation and Results

Our specification is motivated by the literature on the New Economics of Migration (Stark and Levhari, 1982; Lucas and Stark, 1985; Stark and Bloom, 1985; Katz and Stark, 1986). A central tenet of this approach is that families evolve economic strategies not only to maximize household earnings, as in the Harris Todaro model, but also to minimize risk. Our specification is employed in order to analyze how households respond agriculture income negative shock induced by a climatic shock. The main idea behind our model is that climate does not impact migration decision directly, for example through its amenity value or through household's preferences for a given climatic setting; this is why climate variables do not appear directly in the migration equation. Instead, we propose that climate affects household's members mobility through its impact on agricultural yields, i.e. temperature or precipitation shock decreases yields and as a consequence household's income, which in turn induces household to send its member away. Therefore, we apply an IV probit model, where eq. (1) estimates the determinants of the household *i* in a village *j* sending at least one migrant *M* between 2008 and 2010:

$$M_{ij} = f\left(Y_{farm,ij}, X_{ij}, C_j\right) + \epsilon_{1ij} \qquad (1)$$

where $Y_{farm,ij}$ is the logarithm of crop production one year prior to migration, and the vector *X* refers to pre-migration household characteristics at the baseline (2008/2009), such as household size, gender of household head, the highest level of education, livestock assets, and landholdings. We include these variables to reflect initial endowments that influence the decision to send migrants and are uncorrelated with climate fluctuations. C_j denotes cost of migration, proxied by the distance from the village to a main road, or to a district capital. In order to account for the main mechanism in our model, but also to take into account the endogeneity in eq. (1), we instrument crop production with temperature and precipitation shock and other determinants of crop production as in eq. (2):

$$Y_{farm,ij} = f\left(N_{ij}, L_{ij}, LS_{ij}, S_{ij}, Shock_j\right) + \epsilon_{2ij} \qquad (2)$$

where household's agricultural income is determined as a function of climatic shock in a village *j*, and as a function of household *i*'s number of laborers N_{ij}, land units L_{ij}, livestock units LS_{ij}, and soil type S_{ij}.

Table 3. Crop production regression

	OLS	OLS	OLS	cluster	moulton
	(1)	(2)	(3)	(4)	(5)
totcropprod_lg					
hhlabor	0.104***	0.110***	0.111***	0.111***	0.111***
	-5.94	-6.24	-6.31	-5.21	-5.88
totarea	0.00554***	0.00579***	0.00561***	0.00561	0.00561*
	-3.47	-3.61	-3.53	-1.65	-3.15
TLU_cattle	0.0231***	0.0284***	0.0238***	0.0238***	0.0238***
	-3.94	-4.88	-4.05	-4.04	-3.82
slope	0.0288***	0.0281***	0.0255***	0.0255***	0.0255***
	-6.27	-6	-5.44	-3.83	-3.82
tmp_shock	-0.276***		-0.418***	-0.418***	-0.418***
	(-4.39)		(-5.48)	(-3.66)	(-3.63)
pre_shock		-0.0378	-0.340***	-0.340**	-0.340**
		(-0.46)	(-3.43)	(-2.27)	(-2.27)
_cons	12.37***	12.14***	12.65***	12.65***	12.65***
	-154.68	-177.08	-111.72	-77.37	-73.38
N	1890	1890	1890	1890	1890

t statistics in parentheses

* significant at 10% level ** significant at 5% level *** significant at 1% level

First, we estimate the impact of climatic shock on crop production in order to confirm the feasibility of the IV probit model. We draw on previous studies that use climate variability (Fafchamps et al., 1993; Rose, 2001; Rosenzweig and Stark, 1989; Rowhani et al., 2011). The results in table 3 suggest that a temperature shock decreases crop production, and this result is highly significant in statistical terms. On the other hand, the precipitation shock tested alone turns out insignificant. This may result from two issues. First of all, as explained by Rowhani et al. (2011), the CRU dataset overestimates rainfall in comparison to data obtained from meteorological stations by the Tanzanian Meteorological Agency, while temperature measures seem much more consistent. Also, rainfall patterns show much greater spatial heterogeneity than temperature, and such heterogeneity is not fully captured by the extrapolated data. Second, some recent works suggest that temperature variability is much more important factor for plant growth than precipitations (Schlenker, Hanneman, and Fischer, 2006).

On the other hand, both temperature and precipitation shocks appears to be highly significant in statistical as well as in economic terms when tested together. This may suggest that some important interdependencies exist between the two types of shocks. Indeed, it seems that the effectiveness of rainfall depends on temperature, for example through evapotranspiration or the capacity of soil to retain water (Vicente – Serrano et al., 2011). In order to account for the fact that climatic data we use is aggregated at the village level, while our estimation is done at the household level, we test these results by correcting standard errors with cluster and Moulton correction options, but the estimates remain highly significant. Therefore, in our preferred specification, we use both temperature and precipitation shocks as main explanatory variables.

Table 4. IVprobit coefficients

	(6)
migr	
totcropprod_lg	-0.294**
	(-2.11)
hhlabor	0.155***
	-6.67
educhigh	0.0276**
	-2.29
femhead	0.186
	-1.89
TLU_cattle	0.0182**
	-2.55
migrexp	0.211**
	-2.89
_cons	1.884
	-1.02
totcropprod_lg	
hhlabor	0.0982***
	-5.21
educhigh	0.00000446
	0
femhead	-0.216***
	(-3.33)
TLU_cattle	-0.216***
	(-3.33)
migrexp	0.056
	-1.01
slope	0.056
	-1.01
totarea	0.00574***
	-3.71
tmp_shock	-0.403***
	(-5.22)
pre_shock	-0.363***
	(-3.77)
_cons	12.70***
	-105.07
athrho	
_cons	0.394**
	-2.08
lnsigma	
_cons	0.150***
	-9.19
N	1889
Instrumented:	totcropprod_lg
Instruments:	hhlabor educhigh femhead TLU_cattle migrexp slope landown tmpshock2008
Wald test of exogeneity (/athrho = 0): chi2(1) =	4.32 Prob > chi2 = 0.0376

* significant at 10% level ** significant at 5% level *** significant at 1% level

We present our main results in tables 4 and 5. Table 4 shows the coefficient of IV probit estimates which confirm the viability of the instrument. Table 5, instead, presents the marginal effects at means. Indeed, for the average household, a 1% decrease in crop production induced by a climatic shock increase the probability of migration by almost 3%. While this is an important effect in statistical terms, its magnitude is rather low, which can be explained by a culturally based reluctance toward migration in Tanzanian society, well described by Dercon et al. (2004) and Majule et al. (2011).

Table 5. IVprobit marginal effects

	(7)
migr	
totcropprod_lg	-0.294**
	(-2.11)
hhlabor	0.155***
	(-6.67)
educhigh	0.0276**
	(-2.29)
femhead	0.186
	(-1.89)
TLU_cattle	0.0182**
	(-2.55)
migrexp	0.211**
	(-2.89)
N	1889

* significant at 10% level ** significant at 5% level *** significant at 1% level

The estimates in table 5 also confirm the importance of traditional migration drivers: bigger and better educated households, but also those households with previous migration experience are more prone to send their members away. The number of livestock units is an important determinant of migration, too. In particular, cattle is considered to be a wealth indicator in Tanzanian culture, therefore, these results suggest that richer households have a higher probability of migration.

Finally, in order to test the validity of the main mechanism in our model, we estimate eq. (1) separately for household specialized in agriculture, i.e. for whom at least 70% of income is derived from agricultural activities, and those who have diversified income sources. The results in table 6 confirm that such mechanism indeed works only for households dependent on agriculture, and therefore those which are highly vulnerable to weather shocks, while climatic shock does not seem to have any impact on diversified households.

Table 6. IVprobit marginal effects: farm specialisers

	farm specilizers	diversified
	(8)	(9)
migr		
totcropprod_lg	-0.472*	-0.109
	(-1.95)	(-0.53)
hhlabor	0.0739***	0.117**
	(-4.13)	-3.29
educhigh	0.0286	0.0464**
	-1.73	-2.75
femhead	0.133	0.301*
	-1.07	-2.14
TLU_cattle	0.0194*	0.00455
	-2.57	-0.3
migrexp	0.224*	0.217*
	-2.26	-2.02
N	965	924

* significant at 10% level ** significant at 5% level *** significant at 1% level

5. Robustness

As a robustness check, we employ a set of estimations using alternative measures of dependent variable. In table 7, we present our estimates for eq. (1) with a dummy migration equal to one for households that have at least one migrant in working age (between 15 and 64 year old), in order to account for economic drivers of migration (such as employment opportunities). Our previous results are confirmed also for this narrower definition of migrants.

Table 7. IVprobit marginal effects: migrants >14 & < 65

	(10)
migr15	
totcropprod_lg	-0.316**
	(-2.25)
hhlabor	0.164***
	-7.06
educhigh	0.0229
	-1.88
femhead	0.156
	-1.57
TLU_cattle	0.0197**
	-2.78
migrexp	0.216**
	-2.91
N	1889

* significant at 10% level ** significant at 5% level *** significant at 1% level

Also, we check these results for migrants who moved above the median distance (41 km), and our results remain stable also for this group of movers (results not reported here).

Finally, we proceed in a similar manner with respect to main explanatory variable, i.e. we redefine our seasonal variables in two ways: first, we compute the temperature and precipitation shock over a longer 30 year mean; second, we compute the shock only for *masika* rainy season (March to May).

Table 8. IVprobit marginal effects: different climate variables

	shock over 30 yr avg	shock masika
	(11)	(12)
migr		
totcropprod_lg	-0.298*	-0.394**
	(-1.81)	(-2.98)
hhlabor	0.155***	0.159***
	-6.59	-7.24
educhigh	0.0279**	0.0255**
	-2.29	-2.16
femhead	0.186	0.151
	-1.82	-1.55
TLU_cattle	0.0184**	0.0206**
	-2.48	-3.01
migrexp	0.210*	0.204**
	-2.87	-2.86
N	1889	1889

* significant at 10% level ** significant at 5% level *** significant at 1% level

Results reported in table 8 remain significant. In particular, marginal effect of a decrease in crop production induced by a climatic shock seems to be very pronounced for long rainy season (column 12). This may suggest that some differences exist between unimodal and bimodal rainfall areas, or between different agroecological zones, which is an issue to be explored in more detail in future.

6. Conlcusion

We investigate whether Tanzanian households respond to weather risk. We test an IV probit model where migration decision is determined by agricultural income instrumented with temperature and precipitation shocks. Our results suggest that climatic shocks have a significant negative impact on crop production. As a consequence, a 1% reduction in agricultural income induced by weather shock increases the probability of migration by 3% for an average household. This number may be considered rather low in economic terms. What is more, such mechanism where climate variability affects household's migration decision only through agricultural channel, is valid only for households whose income is highly dependent on agriculture, while the results are not significant for diversified livelihoods.

Finally, whereas the impact of temperature shock is significant in any specification, the precipitation shock alone does not seem to be a significant determinant of crop production and consecutive human mobility. This may result from data issues, but may also be in line with recent literature on plant phenology suggesting that temperature variability is more important determinant of plant growth than precipitation. On the other hand, our results indicate that, when estimated together, both temperature and precipitation shocks exert strong pressure on households whose livelihoods are dependent on agriculture.

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