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# Leaving Home: Cumulative Climate Shocks and Migration in Sub-Saharan Africa

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## Abstract

We combine a multi-country household panel dataset with high-resolution gridded precipitation data to investigate how cumulative climatic shocks affects the decision to leave the households in five sub-Saharan African countries. We find that while the effect of recent adverse weather shocks is on average modest, the cumulative effect of a persistent exposure to droughts over several years leads to a significant increase in the probability for a household member to leave the household. We speculate that this pattern can be indicative of increased migratory flows due to increase in the frequency of extremes.

**Keywords** Climate shocks · Rural–urban migration · Economic development

**JEL Classification** O15 · O13 · Q54

## 1 Introduction

A fundamental aspect of the ongoing process of climate change is the increase of extreme weather events in sub-Saharan Africa. Higher frequency of droughts and floods exacerbate the economic fragility of rural populations thus undermining their development prospects (Barrios et al. 2006; Niang et al. 2014). While migrating from rural to urban areas is a key adaptive response to these economic shocks, the existing literature has provided so far mixed empirical evidence (Neumann et al. 2015; Cai et al. 2016; Cattaneo and Peri 2016; Carleton and Hsiang 2016; Mueller et al. 2020; Backhaus et al. 2015; Kaczan and Orgill-Meyer 2020). This paper aims to contribute to the literature by documenting the effects of *cumulative* adverse weather shocks on the decision to leave the household in five countries in sub-Saharan Africa. We combine panel household surveys from the existing waves of the World Bank Living Standards Measurement Survey (LSMS) for five different countries

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(Ethiopia, Malawi, Niger, Nigeria, and Uganda) with precipitation data by the Climatic Research Unit to construct a large rural household micro panel. We find that while a single drought has a relatively moderate effect, a series of severe shocks do have a much larger effect on the probability to leave the household. This result complements existing evidence from studies on natural disasters[1] in Mexico and South-East Asia (Bohra-Mishra et al. 2014; Sedova–Kalkuhl 2020; Saldana-Zorrilla–Sandberg 2009) and it can be considered as indicative of increasing migratory flows in response to increased frequency of extremes. Our study thus shows the importance of incorporating the impact of cumulative past weather shocks, rather than only recent single events, in the empirical investigation of important decision closely related to migration. These findings have important policy implications. In a context where a plethora of climatic models forecast an increase in the frequency of extreme events in Africa, our findings indicate that these events may have a persistent and long-lasting impact.

## 2 Data and Methodology

Our study draws on the Living Standards Measurement Survey—Integrated Surveys on Agriculture (LSMS-ISA), country-level household surveys carried out by the World Bank. We construct a multi-country panel dataset which covers the following sub-Saharan African countries: Ethiopia, Malawi, Niger, Nigeria, and Uganda.[2] Our sample focuses on rural households and includes 139,906 individual-time observations corresponding to 84,430 individuals. We exploit the reported information if a household member is still living with the rest of the household or not.[3] We use within household variation across time and exclude from the analysis members who are no longer there because they passed away. As we are interested in long-term patterns, we also exclude all individuals who we observe to return to their household the observed time period.[4] We also rely on the LSMS-ISA dataset

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[1] Berlemann and Steinhardt (2017) provides a review of empirical evidence between the connection of migration and natural disasters.

[2] The following waves and surveys are included: 1) Ethiopia: Rural Socioeconomic Survey 2011–12, Socio-economic Survey 2013–14, Socioeconomic Survey 2015–16, 2) Malawi: Integrated Household Long-term Panel Survey 2010–2013-2016, 3) Niger: Enquête Nationale sur les Conditions de Vie des Ménages et l'Agriculture de 2011, 2014, 4) Nigeria: 2010–2011, 2012–2013, and 2015–2016 GHS-Panel Surveys, 5) Uganda: the 2009–2010, 2010–2011, 2011–2012, 2013–14, and 2015–16 National Panel Surveys.

[3] The exact survey question is 'Is [x] still a member of the household?' The panel nature of the data allows to understand how household size and composition varies through time. Using the decision to leave the household as a proxy for migration has been used already in the literature. See for instance, Gray-Mueller (2012). It should be stressed that lack of precise migration data is a common issue in this research field. Detailed, long-term, migration data for Africa are rarely available. As result studies have often used different proxies to capture migration See for instance, Henderson et al. (2017), and Barrios et al. (2006) who rely on proportions of urban and rural populations to proxy rural–urban migration trends in a cross-country comparable way.

[4] Migration can take different forms depending on its destination (international migration, rural-rural or rural–urban migration) or by duration (seasonal, temporary, permanent). Based on the country-level datasets where data for the destination of migration are available (Ethiopia, Nigeria), we see that most of the reported migration is internal. It should be stressed that while we excluded from the analysis members that returned to the household during the observed period, we cannot do much for those who returned home after our panel ends.

to build a set of controls for individual and household-level covariates that influence the probability to migrate.

Using GPS coordinates, we merge our household-level panel dataset with high-resolution gridded precipitation data from the Climate Research Unit. This interpolated climate dataset covers all land areas of the world at a 0.5° resolution between 1901 and 2019 maximizing the amount of climate information included. As our sample focuses on rural households in sub-Saharan Africa, it is the shortage of rain in the growing season that can have the largest detrimental effect on agricultural yields (Naudé, 2010) and therefore on household income. Consequently, we construct two drought variables of different severity levels, capturing the non-linearity of the effect of rainfall shortages on migration (Cai et al 2016). We define severe drought and extreme drought as mutually exclusive events captured by indicator variables. We consider that a household has experienced a severe drought event if the quantity of rainfall in the previous growing season was more than 0.5, but less than 1.5 standard deviations lower than the long term mean growing season rainfall, and it experienced an extreme drought event if the quantity of rainfall was more than 1.5 standard deviations below the long term mean.[5] Both severe and extreme droughts are expected to substantially disrupt agricultural practices of the households, leading to substantial income losses. However, the households' migration responses to these adverse economic shocks can differ depending on the severity of the rainfall shortage.

Central to our study is the analysis of the prolonged or repeated exposure to droughts, which can seriously exacerbate the negative impacts of climate shocks on the households. We argue that even if households can successfully insure themselves against one negative weather shock (with food reserves or the sales of assets), repeated droughts seriously erode their capability to mitigate the adverse impacts on household income. To analyze this further, we define 2 year, 3 year, 4 year and 5 year cumulative severe and extreme drought variables, that refer to the number of occurrences of severe and extreme drought events that the household experienced in the past 2, 3, 4 or 5 years respectively. We examine for how long the effects of droughts persist, and how the significance and magnitude of these effects changes over 5 years. By construction, the mean of these variables increases with a larger cumulative time span, communities will have a larger probability to experience at least one severe or extreme drought during a longer period.

Figure 1 provides suggestive evidence for a relationship between rainfall shortages and an increased pace of urbanization in recent decades in four countries of our sample, Ethiopia, Malawi, Nigeria and Uganda.[6] As we can observe in the negative trend of standardized rainfall anomalies,[7] the quantity of growing season rainfall has been decreasing since the 1960s, reflecting an increasing frequency of droughts. On the other hand, we see a steady decline in the share of rural households in the total population, indicating an urbanization trend, particularly advanced in Nigeria (the only middle-income country in the sample), but observable from the 1980s in Uganda, and somewhat later in Ethiopia and Malawi. After the year of 2000 (marked by a vertical line), we see somewhat parallel trends between the

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[5] Comparing current-year rainfall to the long term mean and standard deviation has been previously used in the literature by e.g. Marchiori et al 2012.

[6] The fifth country of our sample, Niger is not included in the graph, as the trends in rainfall anomaly do not show a clear increasing or decreasing pattern.

[7] Rainfall anomaly is a standardized measure of extreme precipitation events calculated in the following way: the long term growing season mean rainfall is subtracted from the growing season rainfall in a particular year, and divided by long-term standard deviation of the rainfall.

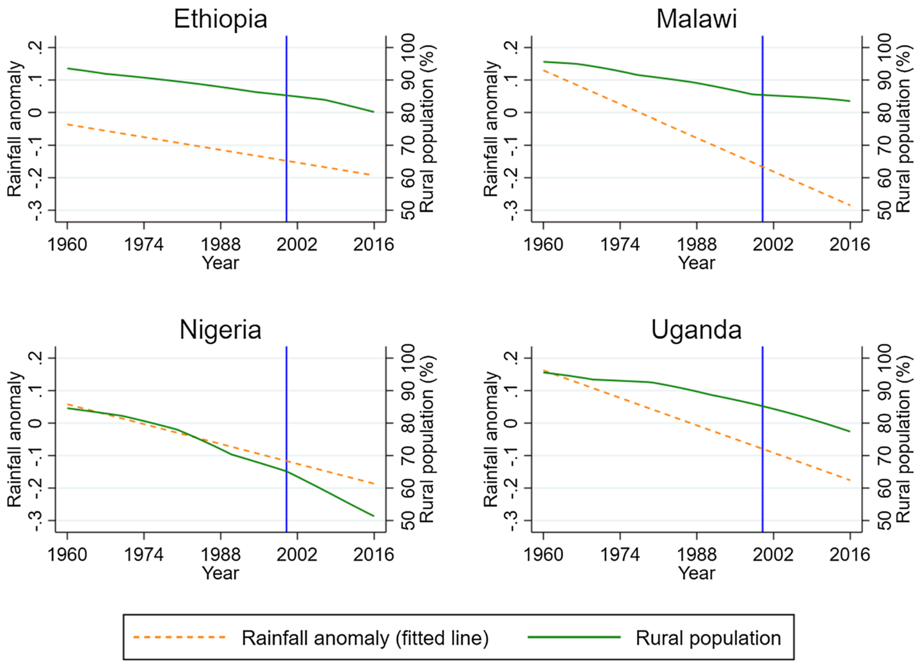

**Fig. 1** Negative rainfall anomalies (droughts) and urbanization. *Source*: Authors' calculations based on World Bank World Development Indicators (share of urban population) and CRU TS climate data. Note: Rural population as a share of total population of the country is included directly based on the data. Rainfall anomaly is a standardized measure of extreme precipitation events calculated in the following way: the long term growing season mean rainfall is subtracted from the growing season rainfall in a particular year, and divided by long-term standard deviation of the rainfall. Vertical line included at the year 2000

reduced quantity of rain, and the share of population living in rural areas, especially in Ethiopia and Uganda. Although there are differences in the pace of changes across countries, the similarity of the trends forecasts a potential relationship between extreme climatic events and rural–urban migration.

Table 1 shows the summary statistics for our main variables of interest, the migration and climate shock variables. Over the time period studied, from 2009 to 2016,[8] a total of 9464 individuals out-migrated from rural areas, i.e. about 11.2% of the individuals left their rural households for either other rural or urban areas in this time period, not considering migrants who returned to their households. This share underlines that long-term migration is a widespread phenomenon in rural communities, and the majority of households experience changes in their composition relatively often, either because of marriage-related or labor-related relocations.

In terms of climate shocks, rural communities are affected by droughts very often, in almost every second year (43%). The majority of these (26% of all observations) were severe droughts (rainfall more than half but less than 1.5 standard deviations lower than the local long term mean). In 17% of cases, households experienced extreme droughts,

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[8] There is some variation across countries in terms of time period covered.

**Table 1** Descriptive statistics *Source*: Authors' calculations based on WB LSMS household data, and CRU TS climate data

| | Number of observations | Mean | Standard deviation | Min | Max |
|---|---|---|---|---|---|
| Left the household | 139,906 | 0.07 | 0.25 | 0 | 1 |
| Severe drought | 139,906 | 0.26 | 0.44 | 0 | 1 |
| Cumulative severe drought, 2 years | 139,906 | 0.53 | 0.61 | 0 | 2 |
| Cumulative severe drought, 3 years | 139,906 | 0.73 | 0.73 | 0 | 3 |
| Cumulative severe drought, 4 years | 139,906 | 1.07 | 0.83 | 0 | 4 |
| Cumulative severe drought, 5 years | 139,906 | 1.19 | 0.89 | 0 | 4 |
| Extreme drought | 139,906 | 0.17 | 0.38 | 0 | 1 |
| Cumulative extreme drought, 2 years | 139,906 | 0.23 | 0.44 | 0 | 2 |
| Cumulative extreme drought, 3 years | 139,906 | 0.27 | 0.48 | 0 | 2 |
| Cumulative extreme drought, 4 years | 139,906 | 0.31 | 0.53 | 0 | 2 |
| Cumulative extreme drought, 5 years | 139,906 | 0.41 | 0.63 | 0 | 3 |

exceptionally severe climatic shocks, which can heavily damage plants in the growing season and substantially reduce agricultural yields (Naudé, 2010).

An important observation for our subsequent analysis is that droughts—especially severe droughts—are not isolated events, but happen relatively frequently. On average, communities experience around half severe drought in a two year period, and at least one severe drought every 4 years. Extreme droughts are less common events, with rural households experiencing on average 0.23 extreme rainfall shortages during a 2 year period and 0.41 extreme rainfall shortages over a 5 year long period.

It is also important to notice that the average number of droughts hides substantial heterogeneity in the frequency of experiencing droughts across rural communities. All climate shock variables, and especially extreme droughts and cumulative extreme droughts have a large standard deviation, often larger than the mean, suggesting that although a large share of households experience only infrequent droughts (zero or one every five years), a smaller share of them is highly vulnerable to droughts, and experiences them at a much higher frequency. The most intensely affected households might experience by up to four severely and/or three extremely dry growing seasons in a five-year period making it difficult to rely financially on agricultural production alone.

In the following estimation, we analyze how these random climate shocks of different severity and persistence affect the probability to leave the household. We estimate the following empirical model:

$$M_{i,t} = \alpha + \beta C_{m,t-1} + \gamma X_{i,t} + \xi Y_{h,t} + \zeta DN_{c,t} + \eta DO_{c,t} + \varphi_h + \varepsilon_{i,t} \quad (1)$$

where we rely on a linear probability model to estimate the likelihood of leaving the household and not return ($M_{i,t}$), (as an indication of migration), as a function of severe and extreme droughts, or cumulative severe and extreme droughts ($C_{m,t-1}$)[9] and include a set

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[9] Cumulative severe and extreme droughts are calculated as the sum of drought occurrences in t-5, t-4, t-3, t-2 and t-1 for the 5 year cumulative variables, t-4, t-3, t-2 and t-1 for the 4 year cumulative variable, and with a similar logic for the 2 and 3 year cumulative variables.

of household and individual-level determinants ($X_{i,t}$).[10] By accounting for all changes in non-agricultural household income, we separate the migratory impact of droughts via the agricultural yields channel from the migratory impact of other economic factors.

We additionally include covariates reflecting the effect of country-level shocks such as the number of people affected by natural ($DN_{c,t}$) and non-natural disasters ($DO_{c,t}$),[11] and introduce household ($\varphi_h$) fixed effects. As households do not move across countries in the panel, household fixed effects also control for national-level time-invariant unobservable factors in our analysis.

While variation in rainfall shocks should be largely random,[12] we conclude that the estimated parameters can have causal interpretation. Nevertheless, the specification could suffer from endogeneity due to measurement error, especially with the definition we use for migration, capturing changes in household size. As this measurement error shows up in our dependent variable, our estimates can still be considered unbiased albeit we are likely to have higher standard errors in our results.

Our baseline specification includes severe and extreme droughts that happened in the year preceding the migration as main explanatory variables, following the specification usually used in the climate literature. While this shows the immediate impact of climate shocks on household decisions, it hides possible long-term consequences. In our subsequent analysis, we estimate the effect of cumulative climate shocks on the probability of leaving the household in order to *compare* the size of the coefficients. This comparison emphasizes how the dynamics of migration decisions change when considering a 5-year climatic period preceding the migration.

## 3 Results

Results from our main specification (see Eq. 1 above) are presented in Table 2. We find that all rainfall shortages that are substantially lower than the average rainfall in the region, (i.e., at least half a standard deviation below the long-term mean) increase the probability of long-term migration. Conditional on individual and household level covariates as well as country-level natural and non-natural disasters, the likelihood of leaving the household, by 1.1% if there is a severe rainfall shortage, and by 2.8% if there is an extreme drought compared to the baseline case of a small rainfall shortage or a positive rainfall shock.

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[10] Following migration theory and the previous literature, we control for the main characteristics influencing migration. Controls include the following variables: gender, age, marital status, relationship to the household head, educational attainment, employment status (individual-level determinants), as well as indicators representing the vulnerability to agricultural shocks and household assets, such as household size, non-agricultural income and ownership of non-agricultural enterprises (household-level determinants).

[11] Number of people affected in natural and non-natural disasters are included from the EM-DAT CRED dataset.

[12] Importantly, human behavior can have an impact on the climate over a long period of time, as it is the case with anthropogenic climate change. However, this impact can only be large enough to influence observed weather patterns, when it is caused by actions of entire societies and not by those of individual farmers. From a farmer's perspective, it is impossible to affect next year's or season's weather in a predictable way. There could be a long-term anticipation of climate change, including an expectation of an overall global warming and an increased frequency of extreme events like droughts, which could in turn lead to adaptation in agricultural practices. However, short-term adjustments in anticipation of seasonal rainfall, especially in countries where farmers rarely have access to reliable sources of rainfall prognosis, are unrealistic.

**Table 2** Regression results with severe and extreme drought *Source*: Authors' calculations based on WB LSMS household data, CRU TS climate data and EM-DAT CRED disaster data. Notes: Regressions include the following controls: sex, age, marital status, relationship to the household head, education, employment status, household size, non-agricultural income and enterprises. Standard errors are clustered at the community level

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Variables | Left the HH | Left the HH | Left the HH | Left the HH | Left the HH |
| Severe drought | 0.011*** | | | | |
| | (0.004) | | | | |
| Extreme drought | 0.028*** | | | | |
| | (0.004) | | | | |
| Severe drought cumulative 2 years | | −0.003 | | | |
| | | (0.003) | | | |
| Extreme drought cumulative 2 years | | 0.010** | | | |
| | | (0.004) | | | |
| Severe drought cumulative 3 years | | | −0.003 | | |
| | | | (0.003) | | |
| Extreme drought cumulative 3 years | | | 0.005 | | |
| | | | (0.005) | | |
| Severe drought cumulative 4 years | | | | 0.008*** | |
| | | | | (0.003) | |
| Extreme drought cumulative 4 years | | | | 0.024*** | |
| | | | | (0.004) | |
| Severe drought cumulative 5 years | | | | | 0.007*** |
| | | | | | (0.002) |
| Extreme drought cumulative 5 years | | | | | 0.019*** |
| | | | | | (0.003) |
| Constant | 0.089*** | 0.101*** | 0.104*** | 0.094*** | 0.093*** |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) |
| Observations | 139,906 | 139,906 | 139,906 | 139,906 | 139,906 |
| R-squared | 0.255 | 0.254 | 0.254 | 0.255 | 0.255 |
| Country-household FE | Yes | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

The significantly larger migration-inducing effect of extreme droughts (2.8%) compared to severe droughts (1.1%) emphasizes that although methods of adaptation in agriculture can have some mitigating effect, these are relatively limited in the case of an extreme shock, and consequently migration likely becomes a more attractive income-diversification strategy.

Our results lead to the following interpretation: an additional year with a severe drought or an extreme drought that affected the entirety of our sample would lead to respectively 104 and 265 more potential migrants, compared to the baseline scenario featuring 9464 migrants. With a rural population of approximately 250 million people for the 5 countries combined,[13] the incidence of one more extreme drought in a 5 year period would translate into a marginal increase of approximately 98 thousand potential extra migrants from rural areas per year, in addition to 3.5 million people[14] who would not move even if there was no significant drought. Although we observe that both severe and extreme droughts significantly increase the likelihood of permanently leaving the household, this effect of a single drought is limited, for both severe and extreme droughts. This conclusion rests on the crucial assumption that droughts are a one-off event and have a non-persistent effect, i.e., if a bad year of severe or extreme drought can be offset by an agriculturally productive next season, there is no potential evidence of long-lasting effect on out-migration.

We therefore investigate whether the frequency of cumulative extreme events may play a role in the leaving decision. We expect that if rainfall shortages have an impact not only on decisions that happen the next year, but also on the migration decisions for years to follow, then our results in column 1 may seriously underestimate the cumulative long-term effect of exposure to climate shocks. We test this hypothesis by examining the effect of the sum of all occurrences of severe and extreme droughts in past 2 to 5 years on the present probability of leaving home and therefore migrating. These results are presented in columns 2 to 5 respectively.

We find that an additional episode of severe or extreme drought has a significant migration-inducing effect even if it happened 4 or 5 years before. If the community has experienced one more severe drought or extreme drought in the past 4 years, that can lead to respectively 0.8% or 2.4% more migration today. The much larger effect of extreme droughts that we show, i.e., approximately 3 times larger effect than the effect of severe droughts, validates the convention in the literature to use climate shock variables based on deviation from the localized long-term mean (for example rainfall anomaly) (e.g., Barrios et al. 2006). Our results confirm that larger deviations from the mean rainfall, i.e., more substantial droughts have a larger impact on relocation decisions.

Our key finding is that although we would expect that droughts that happened several years before the decision to leave the household would have a smaller—if any—impact on leaving the household decisions than the droughts that occurred one year before, i.e. that the coefficients in columns 2, 3, 4 and 5 should be smaller than the one in column 1, and in a descending order compared to each other, but this is not the case at all. Although the average effect of droughts in the past 2 or 3 years (column 2 and 3) are not significant, we find that the coefficients in columns 1, 4 and 5 are comparable in magnitude and significance, showing that the effect of droughts does not diminish over time, but persists for up to 4 and 5 years. For example, combining the results from column 1 and column 5, we observe that individuals from households that experienced a severe (extreme) drought last year have a 1.1% (2.8%) higher probability to leave, while if they experienced a severe (extreme) drought at any point in the past 5 years, the drought is expected to potentially increase this probability by 0.7% (1.9%), an effect very similar in magnitude. This proves that droughts have a significant migration-inducing effect for up to 5 years after they happen and potentially increase migration by on average 0.7% for severe and 1.9% for extreme droughts *in every single one of the 5 consecutive years*. This way, the full impact of a drought on migration is given by cumulating, summing up its effects in the next five years. In contrast to column 1, that suggests that a severe drought increases migration by 1.1%

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[13] Based on data about rural population from the World Bank (2019).

[14] Through the 8 years of our panel, 11.21% of the individuals left the sample. If we assume that the rate of out-migration was stable, we can expect 3.5 million migrants per year in a population of 250 million people.

and an extreme drought by 2.8% in the next year and has no potential effect on migration after that, the augmented model gives a better sense of the impact suggesting that the true cumulative impact will be 3.5% for severe and 9.5% for extreme droughts, felt through a period of 5 years after they occur.

To give a better sense of the magnitude and importance of these results, let us consider what the migration effect would be if the worst-case scenario that we observe in our sample for a certain community would affect all of the rural inhabitants of these five countries. In our sample, the community most severely hit by climate shocks suffers through 1 severe and 3 extreme droughts in 5 consecutive years. Calculated as the sum of the coefficients of 1 occurrence of severe and 3 occurrences of extreme droughts in column 5, the combined impact of these climate shocks will increase the probability to leave by 6.4% in the 6th year compared to the case where the community experienced neither severe, not extreme droughts in the past five years. For the entire rural population of five countries, this could range to approximately 224 thousand more possible migrants in that particular year. Additionally, as the effects of all 4 shocks last for 5 years after they happen, the combined cumulative impact over 9 years (from the first year after the first drought to the 5th year after the last one) would amount to five times the yearly impact, reaching altogether 1.1 million additional migrants.[15] This example shows how a small estimated effect of droughts on migration could become much larger if the effects accumulate over time because of their persistent impact on rural households. Migratory flows of this magnitude could lead to a significant pressure on the urban infrastructure.

These findings provide a contrast with the recent literature that uses similar multi-country individual-level datasets in sub-Saharan Africa to examine the effect of climate shocks on rural out-migration. Analyzing only short-term effects and including only two lags of rainfall anomalies, Gray and Wise (2016) find differing impacts by country; in the two countries overlapping with our sample, Nigeria, and Uganda, they show no consistent migration-inducing effect of droughts in the two years preceding the migration, while we find that rainfall shortages both in the previous year and two years before the migration decision have a significant increasing effect on rural out-migration. Mueller et al. (2020) observe that large rainfall anomalies, i.e. rainfall patterns with a large deviation from the local long term mean have no significant effect on the migration of rural populations in the short term (in the two years after the drought). They also test for higher order lags, but do not find any significant impact of earlier droughts on migration. On the other hand, our paper highlights that droughts that are at least half a standard deviation lower than the long-term mean have a significant impact on relocation decisions already in the short term. Our results further show that droughts can have a long-lasting and persistent impact, suggesting that households make migration-related decisions based on their cumulative exposure to severe and extreme droughts occurring over the past five years.

With a focus on the long-term out-migration of rural populations, our results emphasize the contribution of droughts to already occurring urbanization trends, especially in the case of repeated exposure to droughts over shorter periods. That is in line with the findings of macro-level cross-country studies (Backhaus et al 2015), e.g. Barrios et al (2006) who show using a long-term panel based on 5-year averages that rainfall shortages defined as standardized deviations from the long term mean rainfall accelerate urbanization

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[15] As the shocks happened in different years, these relocations do not happen in the same five years, but would extend over a longer period, on the other hand, their combined effect would be a fivefold multiplication of a yearly effect.

in sub-Saharan Africa. Similarly, Henderson et al (2017) find that droughts contribute to faster urban development in manufacturing center cities. As both these papers use longer-term data, Barrios et al (2006) 5 year averages and Henderson et al (2017) census data, they can better capture some of the sizable, lagged effect of droughts, which we have shown in this paper to exist. This could potentially account for some of the discrepancies between the results found in the literature based on individual-level datasets that find inconsistent or no effects of climate change on migration, as opposed to papers based on long-term country-or regional level datasets that often find a significant migration-inducing effect of climate change.

We find consistent results across different specifications: the effects are similar if we differently define migration (including migrants who return during our sample period) or drought variables (three linearly increasing drought variables),or include more covariates (interaction terms with household and individual characteristics). The most important result tables of these specifications are available in the Appendix.[16]

Individual and household characteristics such as age, marital status or household assets have been shown to have a large impact on decisions to leave the household by the migration literature (Hatton-Williamson 2003). In our estimations shown in Table A5 of the Appendix, we analyze whether there is significant heterogeneity in terms of migration responses to droughts depending on these household characteristics. It is plausible for example that individuals who have better skills will have more employment options outside the agricultural sector, which could lead to different migration decisions in response to weather shocks. To measure the variation in severe and extreme drought's effect on the probability of migration, we introduce interaction terms in our baseline regression, more specifically we interact the severe and extreme drought variables with marital status, household size, post-primary education and non-agricultural employment of the individuals. Our results are consistent with previous specifications in terms of the effects of severe and extreme droughts, severe droughts increase the probability of migration by 3.4%, while extreme droughts are associated with a larger, 4.7% increase. These effects are comparable in terms of sign and significance, but larger in magnitude (for severe drought around 3 times larger, while for extreme drought around 2 times larger) than the ones in the specification without interaction terms. This suggests that the effect of drought on migration varies substantially by individual characteristics.

We see a similarity in the impact of cumulative severe and extreme droughts as well. While coefficients for 2 year and 3 year cumulative droughts stay insignificant, we show that experiencing an additional drought at any point in the past 4 or 5 years increases the likelihood of individual migration. If the household's agricultural production was damaged by a severe drought in the past 4 (or 5) years, then migration will rise by 0.8%, a relatively small but significant impact. If the household experienced an extreme drought in the past 4 years (5 years), migration probability increases by 1.7% (1.3%). These results are in line with our baseline specification shown in Table 2, with slightly lower coefficients, but still showing that even droughts that happened years before can have a contribution to increasing migration probabilities.

As we turn our attention to the heterogeneity of these migration-inducing effects in different groups of individuals, we observe the following important facts. In all climate conditions, married individuals are more likely to leave the household than unmarried ones,

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[16] The rest of the robustness tables are available from the authors upon request.

with an additional migration-inducing effect of extreme droughts on married people. This result suggests that moving for marriage purposes is often postponed in times of extreme drought to adapt to the worsening income situation of the household. In a similar vein, extreme droughts have a larger migration-inducing effect on individuals with larger families. Both these patterns can potentially be explained by the fact that for individuals being married and having a larger family, extreme drought is an event where the household is under extreme financial strain, where even the larger cost of migrating with a family has to be accepted to counteract the adverse effects of the shock.

Individuals who have more than pre-primary education or are employed for a wage have more incentives to migrate, and will migrate more often, 3.6% more with more education and 1% more with wage employment than others within the same household. This is most likely thanks to their better chance of finding a job in a different area with their better skills. For wage employment, this advantage is even stronger if the household experiences a severe drought, as those employed for a wage are 2.2% more likely to react with increased migration than other members of the family. On the other hand, in case of extreme droughts, the difference in migration probability by employment status disappears within the household. This shows that if households experience extreme droughts, then migration is not only an attractive outside option, but a necessity, and that contributes to a larger increment in the migration probability of all household members. Our results in Table A5 prove both that households react to droughts with an increased probability of migration, even if the droughts happened 4 or 5 years before, and also that the precise effect on migration decisions is very dependent on other individual-level characteristics.

In Tables A6 and A7 in the Appendix, we present evidence showing that the nonlinear definition of droughts is not driving the results presented above. We define two drought variables, level 2 and level 3 droughts, corresponding to droughts of different severity, where level 2 droughts refer to negative rainfall anomalies at least 1 standard deviation lower than the long term mean, and level 3 droughts refer to negative rainfall anomalies at least 1.5 standard deviations lower than the long term mean. Instead of the baseline specification where we simultaneously included (cumulative) severe and extreme droughts in our specifications, we estimate the effect of (cumulative) level 2 and 3 droughts in separate regressions. Similarly to the results before, we see that droughts of higher severity have a larger migration-increasing effect (2.1% for level 2 droughts in comparison with 2.4% for level 3 droughts). Additionally, if households experienced one more level 2 or level 3 drought in the past 4 or 5 years, their migration response is almost as large as it would be to a drought that was experienced in the year directly preceding the migration. This supports the notion that the validity of our results does not depend on the specific definition. All droughts in the past 5 years with a sufficiently large disruptive effect on agriculture have a persistent adverse effect on households, and lead to an increase in the probability of migration in our sample.

As mentioned before, our dataset does not provide a perfect way to distinguish between permanent and temporary migration. While temporary, seasonal or circular migration is a wide-spread phenomenon in sub-Saharan Africa (Mueller et al. 2020), it is unlikely to contribute to long-term urbanization. Therefore, in our estimates presented before, we exclude all migrants who have returned to the household in our sample period. However, for individuals who have left the household towards the end of our sample period (in the last wave or visit for a certain country), there is no way to observe whether they will have returned in the future, which might bias our estimates. In Table A8, we show an alternative set of results with the inclusion of all migrants we observe in the sample. In this estimation, the significance and sign of the coefficients

**Table 3** Probit regression results with Mundlak–Chamberlain device *Source*: Authors' calculations based on WB LSMS household data climate data and EM-DAT CRED disaster data. Notes: Probit regressions with household-level Mundlak-Chamberlain device included. Coefficients in the table are marginal effects. Regressions include the following controls: sex, age, marital status, relationship to the household head, education, employment status, household size, non-agricultural income and enterprises. Standard errors are clustered at the community level

| Variables | (1) Left the HH | (2) Left the HH | (3) Left the HH | (4) Left the HH | (5) Left the HH |
|---|---|---|---|---|---|
| Severe drought | 0.010*** | | | | |
| | (0.004) | | | | |
| Extreme drought | 0.036*** | | | | |
| | (0.005) | | | | |
| Severe drought cumulative 2 years | | −0.002 | | | |
| | | (0.003) | | | |
| Extreme drought cumulative 2 years | | 0.012*** | | | |
| | | (0.004) | | | |
| Severe drought cumulative 3 years | | | −0.002 | | |
| | | | (0.003) | | |
| Extreme drought cumulative 3 years | | | 0.006 | | |
| | | | (0.005) | | |
| Severe drought cumulative 4 years | | | | 0.008*** | |
| | | | | (0.002) | |
| Extreme drought cumulative 4 years | | | | 0.025*** | |
| | | | | (0.004) | |
| Severe drought cumulative 5 years | | | | | 0.007*** |
| | | | | | (0.002) |
| Extreme drought cumulative 5 years | | | | | 0.022*** |
| | | | | | (0.003) |
| Constant | | | | | |
| | 139,906 | 139,906 | 139,906 | 139,906 | 139,906 |
| Controls | Yes | Yes | Yes | Yes | Yes |
| Mundlak–Chamberlain device | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

is broadly in line with our baseline results, with the slight decrease in the magnitude. Extreme droughts increase migration probabilities by 1.7% in the next year, and 1.7% (1.4%) even if they happened 4 years (5 years) before the move. For severe droughts, the effect is smaller, an additional severe drought in the past 4 years increases migration by 0.6%. These results again prove that the effects of droughts do not significantly diminish or fade over time but continue to increase individual migration for year after they are experienced by rural households.

Our main findings are robust to choosing different levels of clustering, or different estimation techniques. As shown in Table A9, clustering standard errors at the household level, that accounts for household-level correlation in the error terms does not change the conclusions. In Table 3, we demonstrate that our results are also consistent if we use a probit model with a Mundlak-Chamberlain device correction. The impact of droughts and cumulative droughts is negative and significant, with a slightly increased magnitude.

Our results build on current research and advance our understanding of the determinants of the decision to migrate by showing to what extent repeated shocks which cumulate in the medium and long-term can affect households' behavior. These findings emphasize the contribution of droughts to urbanization, especially in case of repeated exposure to droughts in short periods, which is in line with the findings of macro-level cross-country studies about sub-Saharan African urbanization (e.g., Barrios et al 2006; Henderson et al 2017). Our new approach sheds light on why looking at contemporaneous or 1-year lagged effects of single climate shocks on migration can only provide a lower bound estimate of the effects of climate change on migration. At the same time, our estimations also emphasize the importance of using micro-level data including individual and household characteristics that often have a larger explanatory power in migration decisions (including migration for employment, marriage, or other reasons) than weather shocks themselves.

## 4 Robustness Check

In the previous section, 'Results', we present the regression output from our main specification (Eq. 1) in Table 2, and the Mundlak-Chamberlain Probit regression in Table 3. We capture changes in household size to explain the effect of 'leaving home'. However, some critics might argue that our specification may have concerns of measurement error that might lead to endogeneity in our target variable, the dependent variable: the likelihood of leaving the household and not return ($M_{i,t}$). Having said that, classical measurement error in the dependent variable is more innocuous than measurement error in the independent variable, and does not bias the estimates, but acts just by affecting the standard errors negatively. Nevertheless, we run a robustness check on the same specification by using standard heteroskedasticity-based IV, following the Lewbel estimation method. The instruments used are natural ($DN_{c,t}$) and non-natural disasters ($DO_{c,t}$). Since the disaster variables are at time $t$, we keep the contemporaneous results only as part of the robustness check. The results are outlined in Table 4. We establish that even though we find no significant outcome for severe droughts with an instrument, we have a positive and significant effect for extreme droughts, which reinforces our main results. The output for the cumulative years can be found in the appendix in Table A10.

## 5 Conclusion

Characterized by high dependence on agriculture, the rural population in sub-Saharan Africa is at a high risk of experiencing adverse effects of climate change. As both the margins for adaptation and the possibilities of insurance are limited, many households use migration to other areas as an income-diversification strategy either through new employment, or through marriage (decrease in household size). In this paper we examine the effect of different type of weather shocks on the decision to migrate for individuals living in rural households by relying on a newly-constructed multi-country household panel for five sub-Saharan African countries.

First, we show that severe and extreme droughts have a small, but significant immediate impact on decisions to leave the household. Households who experienced a severe drought or an extreme drought last year are 1.1% or 2.8% are more likely to migrate in the current year. We find a larger effect for extreme droughts that suggests that household adaptation is more difficult in case of a more extreme climate shock.

Second, we contribute to the literature by challenging the assumption that droughts only influence migration in the year immediately after they occur. We argue that if rainfall shortages gradually erode households' adaptation capabilities, then their effect are likely to persist for more than one year and they are going to have a larger impact on out-migration from rural areas in the long term. We show that both severe and extreme droughts have a long-lasting impact, increasing migration for at least 5 years after they occur. Moreover, this impact does not significantly fade or diminish over time. That is, the average impact of experiencing an additional severe or extreme drought any time in the past five years (0.7% and 1.9% respectively) is comparable in magnitude to the impact of experiencing a severe or extreme drought in the previous year (1.1% and 2.8% respectively). Consequently, the overall combined impact of a severe or extreme drought on migration in the next five years is given in the following, cumulative way: a severe (extreme) drought that happens in 2009 will increase migration by 0.7% (1.9%) in 2010 (1 year later), 2011 (2 years later), 2012 (3 years later), 2013 (4 years later) and 2014 (5 years later), each and every year in the next 5 years. Compared to the model customarily used by previous literature, that analyzed the effect of climate shocks on leaving the household including only droughts that happened one or two years before, our augmented specification estimates that droughts can have an almost five times larger migration-inducing impact, more specifically an impact over a longer period of time (5 years) which will amount to an increase of 3.5% for severe and 9.5% for extreme droughts.

Additionally, because of their persistence, the effect of multiple recently experienced droughts accumulates over time. All severe and extreme droughts that households experienced in the past 5 years have an impact on the contemporaneous probability of migration, hence resulting in a much higher number of migrants than we would expect based on the effect of last year's droughts only. This means that the size of the impact on migration could range from 0.7% (experiencing one severe drought) to 9.5% (experiencing five extreme droughts).

To give a better sense of the magnitude of the effects, when considering to be both persistent and cumulative, let us extrapolate the effect of the most extreme scenario that we observe in the sample, that is a household experiencing 1 severe and 3 extreme droughts during 5 consecutive years, to the entire population of these 5 countries. For a household that observed these four droughts, the probability of members leaving the household increased by 6.4% compared to case with no severe or extreme droughts in a particular year, all four droughts affecting the household for 5 years. If all rural households in these five countries experienced these 4 droughts, the migration impact could range to approximately 224 thousand more migrants in that particular year. However, the combined cumulative impact over 9 years (from the first year after the first drought to the 5th year after the last one) would amount to five times the yearly impact, reaching altogether up to 1.1 million additional rural out-migrants. This evidence underlines why it is important to consider longer time periods affecting household decision-making. As an increasing frequency of droughts damages the climate resilience of households, it can lead to persistently higher migration likelihood.

While our results are robust to changes in the definition of our main variables or in our estimation methods, some caveats remain due to the unavailability of more detailed data

**Table 4** Standard IV Regression Results for contemporaneous time period

| Variables | (1)<br>Left the HH |
|---|---|
| Severe drought | −0.0390 |
| | (0.033) |
| Extreme drought | 0.109*** |
| | (0.027) |
| Non-natural disasters | 0.000*** |
| | (0.000) |
| Natural disasters | 0.000*** |
| | (0.000) |
| Constant | 0.0322*** |
| | (0.008) |
| Observations | 140,162 |
| R-squared | 0.054 |
| Country-household FE | Yes |
| Controls | Yes |
| INSTRUMENTS | |
| Non-natural disasters | Yes |
| Natural disasters | Yes |

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

on migration. With an increase in the quality and quantity of household data from sub-Saharan African countries, further research should be directed at differentiating between the impact of climate change on migration for labor and family reasons, and domestic and international migration.

These findings have some relevant implications. They show that focusing only on the effect of weather shocks in the short-term may lead to an underestimation of the impact of climate change on long-term migration. In this regard, they point to the importance of examining the cumulative impact of climate change and other shocks over time in order to advance our understanding of the determinants of migratory flows and their impact on individuals themselves, and on both sending and receiving economies.

## Appendix

See Tables A5, A6, A7, A8, A9, and A10

**Table A5** Regression results with severe and extreme drought and interactions *Source*: Authors' calculations based on WB LSMS household data climate data and EM-DAT CRED disaster data

| Variables | (1)<br>Left the HH | (2)<br>Left the HH | (3)<br>Left the HH | (4)<br>Left the HH | (5)<br>Left the HH |
|---|---|---|---|---|---|
| Severe drought | 0.034*** | | | | |
| | (0.010) | | | | |
| Extreme drought | 0.047*** | | | | |
| | (0.011) | | | | |
| Female | 0.013*** | 0.013*** | 0.013*** | 0.013*** | 0.013*** |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Age | 0.001*** | 0.001*** | 0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Married | 0.047*** | 0.045*** | 0.045*** | 0.046*** | 0.046*** |
| | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Severe drought × married | −0.019*** | −0.014** | −0.014** | −0.015*** | −0.014** |
| | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Extreme drought × married | 0.019*** | 0.025*** | 0.025*** | 0.023*** | 0.024*** |
| | (0.006) | (0.005) | (0.005) | (0.005) | (0.005) |
| Size of the household | 0.002** | −0.000 | 0.000 | −0.000 | −0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Severe drought × household size | −0.003** | 0.001 | 0.001 | −0.000 | −0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Extreme drought × household size | −0.002* | 0.003*** | 0.003*** | 0.002*** | 0.002*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Household head or spouse | −0.189*** | −0.189*** | −0.189*** | −0.189*** | −0.189*** |
| | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| Child of household head | −0.061*** | −0.061*** | −0.061*** | −0.061*** | −0.061*** |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Any post-primary education | 0.036*** | 0.035*** | 0.035*** | 0.036*** | 0.036*** |

**Table A5** (continued)

| Variables | (1)<br>Left the HH | (2)<br>Left the HH | (3)<br>Left the HH | (4)<br>Left the HH | (5)<br>Left the HH |
|---|---|---|---|---|---|
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| Severe drought × post-primary educ | 0.009 | 0.011 | 0.010 | 0.011 | 0.011 |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) |
| Extreme drought × post-primary educ | −0.010* | −0.007 | −0.006 | −0.006 | −0.006 |
| | (0.006) | (0.006) | (0.006) | (0.005) | (0.006) |
| Employed | 0.010*** | 0.008*** | 0.008*** | 0.009*** | 0.009*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Severe drought × employed | 0.022*** | 0.024*** | 0.023*** | 0.023*** | 0.022*** |
| | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Extreme drought × employed | −0.016*** | −0.010** | −0.011** | −0.011** | −0.011** |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| Any household enterprises | 0.015*** | 0.015*** | 0.015*** | 0.013*** | 0.013*** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Sum of all other income received (thousand euros) | −0.006 | −0.006 | −0.006 | −0.006 | −0.006 |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Natural disaster, affected per ten thousand | 0.000 | 0.000* | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Non-natural disaster, affected per ten thousand | 0.000 | −0.000* | −0.000 | 0.000 | −0.000** |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Severe drought cumulative 2 years | | −0.009* | | | |
| | | (0.005) | | | |
| Extreme drought cumulative 2 years | | −0.005 | | | |
| | | (0.006) | | | |
| Severe drought cumulative 3 years | | | −0.004 | | |

**Table A5** (continued)

| Variables | (1)<br>Left the HH | (2)<br>Left the HH | (3)<br>Left the HH | (4)<br>Left the HH | (5)<br>Left the HH |
|---|---|---|---|---|---|
| | | | (0.004) | | |
| Extreme drought cumulative 3 years | | | −0.003 | | |
| | | | (0.005) | | |
| Severe drought cumulative 4 years | | | | 0.008*** | |
| | | | | (0.003) | |
| Extreme drought cumulative 4 years | | | | 0.017*** | |
| | | | | (0.004) | |
| Severe drought cumulative 5 years | | | | | 0.008*** |
| | | | | | (0.002) |
| Extreme drought cumulative 5 years | | | | | 0.013*** |
| | | | | | (0.003) |
| Constant | 0.080*** | 0.104*** | 0.102*** | 0.093*** | 0.092*** |
| | (0.009) | (0.008) | (0.008) | (0.008) | (0.008) |
| Observations | 139,906 | 139,906 | 139,906 | 139,906 | 139,906 |
| R-squared | 0.256 | 0.255 | 0.255 | 0.255 | 0.255 |
| Country-household FE | Yes | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Regressions include the following controls: sex, age, marital status, relationship to the household head, education, employment status, household size, non-agricultural income and enterprises. Standard errors are clustered at the community level

**Table A6** Regression results with drought level 2 *Source*: Authors' calculations based on WB LSMS household data, CRU TS climate data and EM-DAT CRED disaster data. Notes: Regressions include the following controls: sex, age, marital status, relationship to the household head, education, employment status, household size, non-agricultural income and enterprises. Standard errors are clustered at the community level. We propose level 2 drought as an alternative measure of severely dry growing seasons, where level 2 drought is defined as an occurrence of a negative rainfall anomaly at least 1 standard deviation lower than the mean. Cumulative level 2 droughts are calculated in a similar way as in our main specification, a cumulative 2 year drought refers to the number of level 2 drought events in the 2 years preceding the migration

| Variables | (1) Left the HH | (2) Left the HH | (3) Left the HH | (4) Left the HH | (5) Left the HH |
|---|---|---|---|---|---|
| Level 2 drought | 0.021*** | | | | |
| | (0.003) | | | | |
| Level 2 drought, cumulative 2 years | | 0.002 | | | |
| | | (0.003) | | | |
| Level 2 drought, cumulative 3 years | | | −0.003 | | |
| | | | (0.004) | | |
| Level 2 drought, cumulative 4 years | | | | 0.014*** | |
| | | | | (0.003) | |
| Level 2 drought, cumulative 5 years | | | | | 0.012*** |
| | | | | | (0.002) |
| Constant | 0.092*** | 0.102*** | 0.105*** | 0.099*** | 0.098*** |
| | (0.008) | (0.008) | (0.008) | (0.007) | (0.007) |
| Observations | 139,906 | 139,906 | 139,906 | 139,906 | 139,906 |
| R-squared | 0.255 | 0.254 | 0.254 | 0.254 | 0.255 |
| Country-household FE | Yes | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

**Table A7** Regression results with drought level 3 *Source*: Authors' calculations based on WB LSMS household data, CRU TS climate data and EM-DAT CRED disaster data. Notes: Regressions include the following controls: sex, age, marital status, relationship to the household head, education, employment status, household size, non-agricultural income and enterprises. Standard errors are clustered at the community level. We propose level 3 drought as an alternative measure of extremely dry growing seasons, where level 3 drought is defined as an occurrence of a negative rainfall anomaly at least 1.5 standard deviations lower than the mean. Cumulative level 3 droughts are calculated in a similar way as in our main specification, a cumulative 3 year drought refers to the number of level 3 drought events in the 3 years preceding the migration

| Variables | (1) Left the HH | (2) Left the HH | (3) Left the HH | (4) Left the HH | (5) Left the HH |
|---|---|---|---|---|---|
| Level 3 drought | 0.024*** | | | | |
| | (0.004) | | | | |
| Level 3 drought, cumulative 2 years | | 0.012*** | | | |
| | | (0.004) | | | |
| Level 3 drought, cumulative 3 years | | | 0.007 | | |
| | | | (0.004) | | |
| Level 3 drought, cumulative 4 years | | | | 0.019*** | |
| | | | | (0.004) | |
| Level 3 drought, cumulative 5 years | | | | | 0.016*** |
| | | | | | (0.003) |
| Constant | 0.094*** | 0.099*** | 0.103*** | 0.102*** | 0.100*** |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) |
| Observations | 139,906 | 139,906 | 139,906 | 139,906 | 139,906 |
| R-squared | 0.255 | 0.254 | 0.254 | 0.254 | 0.255 |
| Country-household FE | Yes | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

**Table A8** Regression results with migration including return migrants *Source*: Authors' calculations based on WB LSMS household data climate data and EM-DAT CRED disaster data

| Variables | (1) Left the HH (including returned) | (2) Left the HH (including returned) | (3) Left the HH (including returned) | (4) Left the HH (including returned) | (5) Left the HH (including returned) |
|---|---|---|---|---|---|
| Severe drought | 0.006 | | | | |
| | (0.004) | | | | |
| Extreme drought | 0.017*** | | | | |
| | (0.004) | | | | |
| Severe drought cumulative 2 years | | -0.003 | | | |
| | | (0.003) | | | |
| Extreme drought cumulative 2 years | | 0.008* | | | |
| | | (0.005) | | | |
| Severe drought cumulative 3 years | | | -0.001 | | |
| | | | (0.003) | | |
| Extreme drought cumulative 3 years | | | 0.004 | | |
| | | | (0.005) | | |
| Severe drought cumulative 4 years | | | | 0.006** | |
| | | | | (0.003) | |
| Extreme drought cumulative 4 years | | | | 0.017*** | |
| | | | | (0.004) | |
| Severe drought cumulative 5 years | | | | | 0.008*** |
| | | | | | (0.002) |
| Extreme drought cumulative 5 years | | | | | 0.014*** |
| | | | | | (0.003) |
| Constant | 0.111*** | 0.118*** | 0.120*** | 0.113*** | 0.109*** |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) |
| Observations | 139,906 | 139,906 | 139,906 | 139,906 | 139,906 |

Table A8 (continued)

| Variables | (1)<br>Left the HH (including returned) | (2)<br>Left the HH (including returned) | (3)<br>Left the HH (including returned) | (4)<br>Left the HH (including returned) | (5)<br>Left the HH (including returned) |
|---|---|---|---|---|---|
| R-squared | 0.256 | 0.256 | 0.256 | 0.256 | 0.256 |
| Country-household FE | Yes | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Regressions include the following controls: sex, age, marital status, relationship to the household head, education, employment status, household size, non-agricultural income and enterprises. Standard errors are clustered at the community level

**Table A9** Regression results with household-level clustering *Source*: Authors' calculations based on WB LSMS household data climate data and EM-DAT CRED disaster data

| Variables | (1)<br>Left the HH | (2)<br>Left the HH | (3)<br>Left the HH | (4)<br>Left the HH | (5)<br>Left the HH |
|---|---|---|---|---|---|
| Severe drought | 0.011*** | | | | |
| | (0.003) | | | | |
| Extreme drought | 0.028*** | | | | |
| | (0.003) | | | | |
| Severe drought cumulative 2 years | | −0.003 | | | |
| | | (0.002) | | | |
| Extreme drought cumulative 2 years | | 0.010*** | | | |
| | | (0.003) | | | |
| Severe drought cumulative 3 years | | | −0.003 | | |
| | | | (0.002) | | |
| Extreme drought cumulative 3 years | | | 0.005* | | |
| | | | (0.003) | | |
| Severe drought cumulative 4 years | | | | 0.008*** | |
| | | | | (0.002) | |
| Extreme drought cumulative 4 years | | | | 0.024*** | |
| | | | | (0.003) | |
| Severe drought cumulative 5 years | | | | | 0.007*** |
| | | | | | (0.001) |
| Extreme drought cumulative 5 years | | | | | 0.019*** |
| | | | | | (0.002) |
| Constant | 0.089*** | 0.101*** | 0.104*** | 0.094*** | 0.093*** |
| | (0.007) | (0.006) | (0.006) | (0.006) | (0.006) |
| Observations | 139,906 | 139,906 | 139,906 | 139,906 | 139,906 |
| R-squared | 0.255 | 0.254 | 0.254 | 0.255 | 0.255 |
| Country-household FE | Yes | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Regressions include the following controls: sex, age, marital status, relationship to the household head, education, employment status, household size, non-agricultural income and enterprises. Standard errors are clustered at the household level

**Table A10** Standard IV Regression results for cumulative years

| Variables | (1)<br>Left the HH | (2)<br>Left the HH | (3)<br>Left the HH | (4)<br>Left the HH |
|---|---|---|---|---|
| Severe drought cumulative 2 years | 0.021 | | | |
| | (0.053) | | | |
| Extreme drought cumulative 2 years | 0.073*** | | | |
| | (0.014) | | | |
| Severe drought cumulative 3 years | | −0.220*** | | |
| | | (0.067) | | |
| Extreme drought cumulative 3 years | | −0.000 | | |
| | | (0.026) | | |
| Severe drought cumulative 4 years | | | 0.589*** | |
| | | | (0.199) | |
| Extreme drought cumulative 4 years | | | 0.062 | |
| | | | (0.069) | |
| Severe drought cumulative 5 years | | | | 0.235*** |
| | | | | (0.067) |
| Extreme drought cumulative 5 years | | | | 0.059*** |
| | | | | (0.023) |
| Non-natural disasters | 0.000 | −0.001*** | −0.001 | −0.002*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Natural disasters | 0.000*** | 0.000*** | 0.000* | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Constant | 0.017 | 0.175*** | −0.532*** | −0.225*** |
| | (0.026) | (0.046) | (0.190) | (0.073) |
| Observations | 140,162 | 140,162 | 140,162 | 140,162 |
| R-squared | 0.073 | −0.200 | −3.101 | −0.505 |
| Country-household FE | Yes | Yes | Yes | Yes |
| Controls | Yes | Yes | Yes | Yes |
| Instruments | | | | |
| Non-natural disasters | Yes | Yes | Yes | Yes |
| Natural disasters | Yes | Yes | Yes | Yes |

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

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