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ABSTRACT

Heterogeneity in Migration Responses to Climate Shocks: Evidence from Madagascar*

We analyze the impact of climate events on migration among a cohort of young adults residing in rural Madagascar. We find a strong negative impact of drought on the decision of youth to migrate in the year after the adverse weather shock. Household assets and access to savings institutions attenuate this impact, consistent with the notion that wealth and savings cushion the blow of the shock on the resources required to finance migration. We also find that households that report more social connections outside their villages are more likely to have their young adult members migrate. Our findings suggest that the liquidity constraints from climate shocks that prevent youth migration are more binding for young women who migrate largely for reasons of marriage and education. Males, in contrast, are more likely to migrate in search of employment, which often has higher economic returns than migration motivated by marriage and education. These factors likely explain why drought deters migration of young women, but not so for young men who still choose to migrate in search of a job.

JEL Classification: O15, J13, N3, N57

Keywords: youth migration, Madagascar, climate shocks, internal migration

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1 Introduction

The increasing number of extreme climate events such as droughts, floods and tropical storms that result from global warming have particularly serious implications for developing countries where mitigation efforts and coping strategies are less available. Large climate shocks often cause the destruction of schools and physical and social infrastructure, and contribute to environmental degradation, such as soil depletion, deforestation, and the destruction of fragile ecosystems. One mechanism to deal with the loss of livelihoods from climate change is migration away from affected zones (Rigaud et al., 2018).[1] While some of this migration may be to other countries, much of it is expected to be internal to urban areas or less affected rural areas, where the costs are lower and challenges are less formidable (Mastrorillo et al., 2016, Dallmann and Millock, 2017 and IOM, 2018). This is especially true in an island, poor, country like Madagascar, which is the focus of our study. However, even internal migration is a challenge for most poor households, because of the lack of access to credit or insurance markets, limited assets, uncertain or absent land property titling, and lack of collateral that are needed to cover monetary cost of migration. The absence of social networks can magnify the implicit cost of migration (McKenzie & Rapoport, 2010). Under these conditions, poor households may face formidable obstacles in their quest to migrate, especially as they are further impoverished by adverse weather events (Azzarri & Signorelli, 2020). Additionally, there may be other obstacles to migration, especially for women because of cultural barriers and social norms that limit their mobility and thus ability to respond to negative weather events (Gray & Mueller, 2012).

In this paper we study how slow-onset and fast-onset climate events affect internal population movements of young individuals who resided in rural areas before the shock. In addition, we investigate the mechanisms that relate income shocks to migration, and explain the extent of heterogeneity in the response to these weather events across individuals. To do so, we use a national longitudinal dataset from Madagascar that tracks a cohort of young adults and their households. The first round of the survey was conducted in 2004 when the cohort members were between 13 and 16 years old, and the

[1] This study provides a discussion on the role of climate change in pushing populations from sub-Sahara Africa, Latin America and South Asia to move internally to escape the impacts of climate change

second round of the survey was in 2012 when they were young adults. Controlling for fixed effects to account for unobserved individual and geographic heterogeneity, we estimate the effects of drought episodes and cyclones on the probability of internal migration from rural areas during this critical time of life.

The rural-to-urban migration has often been studied by the economics literature interested to the urbanization process. In this context, Barrios et al. (2006) provide evidence that shortages in rainfall have contributed to increase the movement from rural to urban areas in Sub-Saharan Africa. Marchiori et al. (2012) extend their conclusions showing that this is particularly true for those countries that are highly dependent on agriculture, and that the effect is mainly explained through a decrease of rural wages. While Marchiori et al. (2012) indicate that weather induced rural-to-urban migration subsequently generates international migration, Beine and Parsons (2015) as well as Burzynski et al. (2019) rather find that the connection between extreme weather events and international migration is weak. The positive effect of warming trends on internal migration is questioned by Cattaneo and Peri (2016), who show that high temperatures increase the probability of migration to urban areas and outside the country in medium-income countries but that they have the opposite effect in poor countries.[2] Other caveats are introduced by Henderson et al. (2017) who find that negative weather shocks induce rural-to-urban migration only in districts where tradable manufacturing sector is well developed and is thus able to absorb the excess of labor from rural areas. Black et al. (2012) remark that vulnerability to climatic events decreases with assets endowment while the inverse is true for the ability to move. Vulnerable population can be thus trapped in their origin locality (Beine & Jeusette, 2018). Under this framework, adverse climate events could even reduce human mobility, as is observed by Herren (1991) for Kenya and by Koubi et al. (2016) for five developing countries, in response of a drought. Mueller et al. (2020) find that weather anomalies cause a decrease in migration from urban areas in Eastern Africa, while they have no effect on rural to urban migration. Other country-based studies rather find a positive effect of negative weather shocks on the probability to migrate out from rural areas (see among others Nawrotzki et al., 2017, Defrance et al., 2020, Giannelli and Canessa, 2021). Heterogeneous effects across gender or across reasons to migrate are evidenced by some authors. Gray and Mueller (2012) show, for instance,

[2] Madagascar is included in this study and classified as a poor country.

that drought pushes men to migrate for employment reasons while it reduces marriage-related migration for women. Dillon et al. (2011) also found that warming only induces male migration. According to Beine and Jeusette (2018), the heterogeneity in the results that we observe in both macroeconomic and microeconomic literature can be explained by the fact that the propensity to move strongly depends on the context. It thus remains an empirical question to determine which is the (internal) migration response to climate shock.

We contribute to the literature on the internal migration response to climate change in Africa. In our case, we focus on the extremely poor island nation of Madagascar with its fragile ecosystem where there is a high frequency of weather shocks. And differently from the existing evidence, our focus is on climate-induced migration choices during the years individuals are transitioning from their teenage years to young adulthood. This is a critical period of the life course when individuals not only migrate in search of a job, but also for reasons related to schooling, marriage, and even to get access services and amenities that are concentrated in urban centers.

We take advantage of the longitudinal character of the survey data to track the movements of the cohort members over time, including information on their place of original residence and the timing of movements to new regions. Individual data are matched with satellite-based rainfall and temperature, as well as with a data set on the occurrence of cyclones, relying on the GPS coordinates that we collected at the localities where the cohort members resided. Hence, our weather variables are matched precisely with the relevant individuals' locality. In accordance with the distinction presented in Cattaneo et al. (2019), we use two sets of extreme weather events: droughts and temperature increase (slow-onset events), and cyclones (fast-onset event) [3], that have the biggest impact on population, as shown by Deschênes and Moretti (2009). Following the previous literature (Jayachandran, 2006; Shah and Steinberg, 2017; Kaur, 2019), we define a drought event as a situation when the standardised rainfall deviation observed during the agricultural season (November to April) in a given year between 2004 and 2011 falls in the 20th percentile of the historical distribution in a given locality. Temperature events are

[3]Flood, another fast-onset event, is not used because it has not been a recurrent event in Madagascar during the period of study.

likewise defined in terms of the standardised deviation from their historical average, and a cyclone is a binary variable equal to one if a wind speed of at least 119 km/h occurred in a given year between 2004 and 2011.

The reliance on exogenous weather data guarantees the estimation of a causal effect of drought on migration; however, there might still be two potential threats to identification which relate to the possible anticipation of climate shocks by individuals and to the temporary or permanent nature of the effect we identify. On the first point, if people anticipate the occurrence of climate shocks, the relationship between the shock and the decision to migrate would not be causal. We address this identification issue by a falsification test to see if individuals adjust their decision to migrate based on expectations for a future draught by regressing the probability of migration on $t + 1$ of our adverse climate event. On the second point, it is also possible that drought has only a temporary displacement effect on migration: it could anticipate or postpone a migration episode that would have occurred anyway, even in absence of the shock. We address the second issue by regressing migration on various lagged climate shocks. In both tests, our results add confidence that our findings of the relationship between weather events and migration are indeed causal.

We find that the occurrence of a drought induces a decrease in rural migration, whereas cyclones do not affect the migration decision. The effect induced by droughts is not immediate, but is delayed for about one year after the drought event. We claim that the driving mechanism of this effect is the income reduction due to the drop in productivity caused by the drought. In a poor country like Madagascar, dominated by rainfed agriculture, a drop in income would make the cost of migration less affordable for rural households (Cai et al., 2016, Bazzi, 2017). Since we do not observe household income directly, we proved this mechanism through various indirect tests. First, we interact a household asset index observed at the beginning of the period by the drought variable, and find that people living in wealthier households buffer the negative effect of the shock on their migration decision. Second, for those individuals whose households have access to some sort of savings institutions the occurrence of drought does not affect their choice of migration. Third, we stratify our estimations by farm and non-farm households, and find that drought affects the migration decision only for farm households. As a last test, we interact drought by a network variable. In line with the literature pointing to the role of network in cutting down the costs of migration (e.g., McKenzie and Rapoport, 2007, Alam et al., 2016), we found that having a network elsewhere in the country generally helps individuals to fully cope with the negative effect of drought on their decision of migration.

We also find significant heterogeneity by the gender of cohort member in the sample and by the destination of migration. Young women are affected by the climate shock in their decision to migrate, while the effect is not significant for young men under conventional confidence levels. This could indicate that traditional gender norms in Madagascar restrict mobility more for young women then for young men when households faces liquidity constraints. Also, our results indicate that drought has a negative impact on rural to rural movements and on migrations across short distances, which are the type of migration often experienced by poorest households.

The remainder of our paper is structured as follows. In section 2 we present the context of study, discuss the data and present descriptive statistics on the main variables. The discussion of the empirical strategy follows in section 3, and we present the results of the different models estimated in section 4. We conclude and discuss the implications of the findings in section 5.

2 Context, data and identification

2.1 Data and context

Madagascar, one of the poorest countries in Africa, has been characterised by slow economic growth over the past two decades. There was considerable volatility in terms of the rate of economic growth during the period covered by our analysis. Following the political instability during the early 2000s, when the GDP per capita growth dropped up to -15% in 2002, the average economic growth accelerated in Madagascar between 2003 and 2008, averaging 3.2% per year (The World Bank, 2020). This period was followed by the global financial crisis, that hit the country hard; in 2009, growth in GDP per capita was -6%. The poverty rate on the island was 77.6% in 2012 and slightly decreased to 74.1% in 2019 (The World Bank, 2020). This small decline in poverty lagged far behind that experience in most other countries in the region.

Madagascar also remains one of the most agriculture-dependent countries in Africa. Nearly 50 percent of total African population rely on agriculture as their main source of employment (Blein et al., 2013), and this number is actually even higher in Madagascar. Indeed, in Madagascar, depending on the region and year, about 50 to 90 percent of total household income comes from agriculture, which is the main sector of employment for the poorest 80 percent of the population in the country (The World Bank, 2016) and 80.5% of the active population in 2010 was employed in the agricultural sector (IOM, 2014). This high level of dependence on agriculture as a source of livelihoods, as well as the sector's large share of GDP and exports (Beegle et al., 2016), implies that the country is very sensitive to climatic variations affecting the agricultural sector.

Madagascar's limited natural resources and ecological fragility is a challenge shared with many other countries in the region. But the role of climate is heightened in Madagascar where evidence points to the country being one of the 10 most vulnerable to climate change (USAID, 2019). This in part reflects the lack of irrigation and the fact that inhabitants rely largely on rainfed agriculture as their main source of income. Consequently, the Malagasy people are very vulnerable to climatic shocks, especially those that involve rainfall deviating significantly from average levels, which cause floods and droughts that affect crop yields. Cyclones are particularly perilous since they directly damage crops. Such weather events also contribute to long-term ecological damage such as soil erosion and deforestation, while concurrently destroying crucial economic and social infrastructure (Rakotobe et al., 2016). All these adverse climatic events are exacerbated not just by the loss of household incomes, already critically low even in good years, but because household coping mechanisms are limited. This inability to absorb the blow from climate shocks is in part due to the virtual absence of a government safety net. Weak physical productive infrastructure, including the absence of significant progress in increasing the land under irrigation, and access to insurance and credit, means that climate events result in a large loss of incomes. [4]. Subsequently, there are often long term implications of current shocks that may contribute to a downward spiral of increased impoverishment and poverty traps. Our paper is intended to test whether that migration can represent one of the few options available to rural households affected by an adverse climatic event in Madagascar. In fact, while migration to urban areas or other, possibly more fertile, rural zones may represent a copying mechanism during "normal" times, such an option might not be affordable after a climate shock.

Our study is limited to tracking migration internally, due to Madagascar's geographical situation, where international migration is unusually low for an African country [5]. In fact, in 2000, only 78.6 thousands people emigrated overseas, comprising less than 1 percent of all migrations. International migration for Malagasy people is mostly motivated by work and between 2006 and 2012, and about 11 000 exit visas were issued to workers and domestic servants, mostly represented by women (IOM, 2014). The rate of internal migration rate, in contrast, is quite high (IOM, 2019). Estimates are that more than 100,000 people move every year from rural areas to the capital city, Antananarivo, (IOM, 2014) and, according to the *Enquête Périodique auprès des Ménages* (EPM), migration from rural to urban, and from rural to rural areas, is of the same magnitude among young adults (IOM, 2014). According to IOM (2014), internal migration is mainly motivated by a search for employment; another important reason for rural migrants is the research of more fertile lands in the country. Younger women (between 15 to 34 years old) have higher mobility than men for marriage reasons (IOM, 2014).

The empirical section of this paper aims to estimate the migration response to climate shocks in Madagascar among our cohort members, who are in transition between adolescence and young adulthood between 2004 and 2011, a particularly important period in their life course. We limit our study to the impact of climate events on migration from rural areas where agriculture represents the main source of livelihoods for about 80 percent of the population (IOM, 2019) and as such, climate shocks such as drought are expected to be of great importance. The data set we use are the Progression through School and Aca-

[4] A similar argument is provided in Alam et al. (2016) for the case of rural farmers in Bangladesh, where only farmers with access to institutions and credit facilities could buffer adverse climate shocks by diversifying crops and tree plantation

[5] Source: https://www.oecd.org/migration/46561284.pdf

demic Performance in Madagascar Survey (EPSPAM) and the Madagascar Life Course Transition of Young Adults Survey, which were respectively conducted in 2004 and 2011. We are able to construct a perfectly balanced individual yearly panel dataset over this long time span. Individuals were between 13 and 16 years old in 2004 and between 20 and 23 in 2011. The panel data contains information on their place of residence during the course of those years, as well as information on the cohort members, their household, and the communities where they reside. Individual level data includes detailed information on education and schooling, as well as employment and labor market activities, and the presence of friends or relatives elsewhere in the country (regardless of whether they were migrants). Household level data include information on the demographic make-up of the household, the employment and schooling characteristics of household members, access to credit, and asset ownership which is used to create a wealth index. From the GPS and other geographical details of the cohort member, we used complementary data sources to construct climate events, as we describe below. Summary statistics of key individual, household and community variables are presented in Table 1 in the annex and are used to form control variables in the models that we estimate.

2.2 Defining Migration

The dependent variable, whether or not a cohort member is a migrant, equals 1 if the individual migrated during a given year and 0 otherwise. Out of the 1,148 individuals who were resident in rural areas in 2004, 307 (or 26.8%) migrated between then and 2011. A nearly equal number of migrations were to other rural and urban areas, with an average migration rate of about 2.5% a year. As expected, given the age of the cohort members, migration episodes become more frequent starting from 2009, when individuals were aged 18-21; during these years, the migration rate increases to about 6% per year. Most of migrants (42%) moved within the same district, 38 per cent between districts of the same province, and 20 per cent between provinces. Figure 1 shows the distribution of migration episodes in our rural sample areas across the study period.

2.3 Defining climate shock

The first measure of climate shock used in this study is that of a drought given the expectation that a negative rainfall shock will have a direct impact on crop yields and output. Our measure of drought captures low rainfall occurrences between November and April. This is the rainy season in Madagascar, which also defines the planting and growing seasons. More specifically, we link the data on the GPS coordinates of the location of the cohort members with secondary data sources on climate – rainfall and temperature. Satellite Rainfall data is provided by the National Oceanic and Atmospheric Administration (NOAA) which measures average daily rainfall in Madagascar from 1983 to 2011 with a spatial resolution of 0.1 degrees (around 10 km^2). We thus have information on daily rainfall for grid cells of about 10 squared kilometers. This allows us to calculate, for each grid or satellite based unit (SBU), the amount of rain that has fallen during the agricultural season from November and April each year, as well as enables us to calculate the mean and standard deviation over the period 1991-2011. To define the drought indicator, we follow the existing literature (e.g., Jayachandran, 2006; Shah and Steinberg, 2017; Kaur, 2019) where a drought in a given year is defined as the standardized rainfall deviation in a Satellite-based unit (SBU) falling below the 20th percentile. This standardised measure then allows us to compare weather events across different localities and climatic zones in the country. The 20th percentile is recognized as a reasonable low rainfall intensity threshold by the *American Meteorological Society* (see Bergemann et al., 2015), and is widely used in the economics literature (e.g., Jayachandran, 2006; Shah and Steinberg, 2017; Kaur, 2019). Climate events can have immediate as well as delayed effects. We therefore also create a lagged climate variable to account for any cumulative and displacement effects. Figure 2 shows the distribution of lagged drought in Madagascar across our study period.

In addition to drought, we use climate data on tropical storms to define the cyclone variable which represents the strength of cyclones during agricultural season each year. This variable equals 1 if the wind speed, according to the the Saffir–Simpson hurricane wind scale (SSHWS), reached strength 1 (from 119 to 153 km/h) or higher in a given year, and zero otherwise. Data on cyclones are taken from the Tropical Cyclones Windspeed Buffers 1970–2015, provided by the Global Risk Data Platform. Finally, based on

Climatic Research Unit (CRU) data for each grid, we define the temperature variable as the deviation from the local, long-term mean, as we did for precipitation.

3 Empirical strategy to identify migration response to climate variation

3.1 Econometric specification

We estimate the causal effect of a climate shock on migration for individuals residing in rural areas, where the dependence on rainfed agriculture as a source of livelihood, and the extent of vulnerability to climate shocks, is highest.

The outcome variable of interest is migration, denoted as $M_{i,s,t}$, an indicator function equal to 1 if a CM i residing in SBU s migrated at time t, and 0 otherwise. Using a linear probability model (LPM) with robust standard errors and individual fixed effects, we estimate the following specification:

$$M_{i,s,t} = \sum_{l=1}^{2} \beta_l^o CS_{s,t-l}^o + \gamma_1 X_{i,t} + \omega_1 \theta_{i,t} + \omega_2 \mu_i + \omega_3 \sigma_t + \varepsilon_{i,t}, \quad (1)$$

where the term $CS_{s,t-l}^o$ identifies the climate shock event of type o in SBU s occurred at time $t-l$, with $l = 1, 2$ representing the number of lagged years and o identifies the slow-onset (i.e., drought and temperature increase) and the fast-onset (i.e., cyclones) events. In the case of cyclones, given their nature, l equals 1 only, thus capturing the immediate effects of the acute destruction of crops and infrastructure that is likely to occur. β_l^o represents our coefficient of interest, that is the effect of a climate shock o on the decision of migration. $X_{i,t}$ includes individual and household time varying characteristics. We are aware that some of these controls may be endogenous; however, we opted to include them to be conservative. We have estimated the models without these endogenous controls, and our results do not change qualitatively, therefore indicating that their inclusion does not drive our results. The summary statistics of the control variables are reported in Table 1. The term ω_1 captures the age effect, while the terms ω_2 and ω_3 capture the individual and temporal fixed effects, respectively. Individual fixed effects allow us to control for all unobservable time invariant characteristics, at individual, household and village level, that might affect migration decision. Given the plausibly exogenous nature of a climate shock in a given locality and year, and that we control for any potential time invariant unobservables which may potentially interfere on the relationship between a climate event and the decision of migration, we can assume that β_l^o measures the causal effect of a climate shock on migration. As in Shah and Steinberg (2017), standard errors are clustered at climatic zones level to account for potential serial correlation of droughts in station-based units (SBU). Following Jayachandran (2006) and Kaur (2019), in separate specifications (not shown here but available upon request), we also clustered standard errors by climatic zone-year for potential correlations of droughts across station-based unit (SBU) in a given year. Results are robust.

3.2 Identification challenges

The baseline specification presented above assumes that individuals do not anticipate future climate variations or shocks and that current and past weather events are not correlated with future events. If this assumption does not hold, β_l^o would be biased. To test whether our baseline assumption is true, we estimate the following specification:

$$M_{i,s,t} = \beta_{t+1}^o CS_{s,l+1}^o + \gamma_1 X_{i,t} + \omega_1 \theta_{i,t} + \omega_2 \mu_i + \omega_3 \sigma_t + \varepsilon_{i,t}, \quad (2)$$

The coefficient of interest for this test is β_{t+1}^o, which measures the effect of a climate shock that occurred in $t+1$. If β_{t+1}^o is not statistically significant we can conclude that our baseline results are not biased by "anticipation" effects.

Another potential identification threat is the displacement of the effect of a climate event on migration (Deschênes & Moretti, 2009). A climate shock could indeed simply anticipate or postpone the decision to migrate. In such a scenario, the causal effect of a climate shock would not be permanent. To test whether the causal effect estimated in (1) is permanent, we add various lags of the climate shock variable to the baseline specification, as follows:

$$M_{i,s,t} = \sum_{l=1}^{4} \beta_l^o CS_{s,l-1}^o + \gamma_1 X_{i,t} + \omega_1 \theta_{i,t} + \omega_2 \mu_i + \omega_3 \sigma_t + \varepsilon_{i,t}, \quad (3)$$

Given the young age of the individuals in our sample, a reasonable number of lags can be 4. If β_ls are statistically significant and show opposite signs, we would conclude that the effect is not permanent, otherwise we can assert that the effect is long-term.

4 Estimation results

4.1 Migration response to climate shocks

Table 3 reports the baseline results of the causal effect of a climate shock on the decision to migrate. We distinguish between fast-onset climate events like cyclones and slow-onset events like droughts. Column (1) shows the results for the overall sample. The occurrence of a cyclone in Madagascar does not increase the likelihood of migration. Similarly, a drought does not have a contemporaneous effect on the migration decision. However, a drought which occurred in the previous year decreases the probability of current migration by 2.2 percentage points. This delayed effect is expected to the extent that migration reduces the availability of financial resources to migrate, whether it be for employment or schooling. In contrast, a contemporaneous effect on migration would be less likely since the process always involves some degree of planning and is not expected to be immediately affected by a climate shock, as would be the case for an outcome like dropping out of school or changes in employment (see, *e.g.*, Marchetta et al., 2019). The results also suggest that economic stress from a climate shock plays a strong role in reducing the resources to enable migration, at least in the current period. This effect is stronger than any possible increased inducement to migrate as a short-term coping mechanism (see the discussion in Cattaneo et al., 2019). Thus, we can conclude that, at least for young adults in Madagascar, drought seems to discourage migration as it reduces resources to finance migration.

As a robustness exercise, we leave current drought out of the specification (Column (2)) and find that the effect of lagged drought is unchanged, proving that serial correlation of drought in our data is not a concern. In addition, we control for the standardised deviation of temperature (Column (3)). While we do not find any significant effect of temperature, these results are encouraging as the effect of drought could be correlated with temperature's variation.

4.2 Falsification tests results

As discussed earlier, the results shown in Table 3 may suffer of various identification challenges. To ensure they are not biased as a result, we start by testing whether the results are affected by a temporal displacement of drought-induced migrations. Drought in $t-1$ could in fact induce a reduction in migration in t and at the same time an increase in migration in the following years if migration is just temporally displaced because of the negative weather event. Results reported in column (1) of Table 4 discard this threat, as the lagged drought coefficient is not cancelled out by any lagged drought variables and the latter are never significant.

The second falsification test is with respect to the issue of individuals' expectation of future drought. If this is the case, people may adjust today's decision migration accordingly. Table 4, column (2), shows that the occurrence of future drought does not have a statistically significant effect on migration. Henceforth, we can fairly confidently conclude that our baseline results measure a causal effect of drought on the migration decision.

4.3 Mechanism

What drives the negative effect of drought on the decision of migration? The hypothesis we want to test is whether a drop in the available household income induced by the occurrence of a drought is the reason why rural youth are less likely to migrate after a climate shock. Following a drought, households living in rural areas would have less money to cover the costs of migration. Since our survey do not measure household income, we test our hypothesis by using various income-related variables.

First, we interact the lagged drought variable by an asset index that measures the wealth of the household at the beginning of the study period, i.e. in 2004.[6] By including this interaction, we directly test whether wealthier households are more able to afford the costs of migration, despite the decline in income induced by a drought. If this is the case, we should observe a positive coefficient on the interaction term between drought and wealth index, indicating that wealth attenuates the negative effect of drought on the probability of migration. Results reported in Table 5, column (1) show such a positive coefficient.

Second, one of the most important reasons why rural households are vulnerable to climate shocks is the lack of access to credit or saving institutions. Simply, when a drought occurs, the availability of savings or credits would allow people to cover the costs of migration, despite the unanticipated loss in their income. Column (2) in Table 5 indicates that CMs living in households with financial deposits in a savings institution in 2004 are able to use those resources to compensate for the negative effect of drought on migration.

Third, we separate cohort members into 2 groups: (1) those living in farm and non-farm households. Since drought is expected to affect farm households only (at least in the immediate to short-term), if loss of income from a climate shock is a driving mechanism that discourages migration, we should find that migration is negatively affected for those cohort members living in farm households, but not for those in non-farm households. As shown in Table 5 in columns (3) and (4), the occurrence of a drought reduces migration only among CMs living in farm households before migrating. This is consistent with the hypothesis that the income of non-farm households is not affected by a drought in the short terms.

[6]The asset index was obtained through the principal component analysis approach, as suggested by Filmer and Pritchett (2001). The indicators included in the index are: ownership of durable goods (i.e., radio, refrigerator, TV, bicycle, motorbike, car) and dwelling characteristics (i.e., availability of electricity, type of toilet, type of water provision, quality of walls, type of cooking practice, number of rooms per person).

Finally, having friends or relatives elsewhere in the country should facilitate migration by reducing its costs. This is what is predicted by the literature on social network effects in the migration literature (e.g., McKenzie and Rapoport, 2007). If the costs of migration are reduced because of the network effect, then we expect that such connections would facilitate a move even when a climate shock occurs because it would again attenuate the impact of an income loss induced by a drought. In order to measure social networks, we use an information that was collected on all CMs in 2012, who were asked whether they had a relative or a friend residing in another region. The expectation is that individuals having friends or relatives residing in another region of the country have a wider social network (Bertoli & Ruyssen, 2018), both outside and within their region of residence. [7] The interaction between drought and having a network is thus expected to be positive, and like wealth, represents a "compensation" effect with respect to a loss of current income. Table 5, column (5), shows that the negative effect of the income shock induced by a drought is fully compensated in the case of CMs with friends or relatives elsewhere in the country.

The results of the extension of our core model strongly suggest that liquidity constraints that occur after the income shocks prevent youth migration. Poor people, in particular, are "trapped" in affected areas and cannot move even if they might have done so in the absence of these adverse climate events. Interventions that helps mitigate the shock, as well as efforts to encourage and promote diversifying income with non-farm activities would increase the resilience of people at higher risk of climate shocks.

4.4 Heterogeneous effects

In this section we investigate possible heterogeneity in the baseline results shown earlier. We start by exploring the effect of the occurrence of drought by the gender of the CM. Differences in the reasons of migration as well as the existence of cultural barriers which favor boys may result in migration decisions after an economic shock which differ by

[7] The problem in using this question is that CMs having migrated *across regions* could reply affirmatively because they indeed have relatives and friends in their origin region. This is why we believe that this question can not be used as a measure of the social network for CMs who experienced long distance migration, i.e. *between provinces*

gender. Indeed, as shown by Table 2, girls mostly migrate for education and marriage reasons[8] (28.2 and 27.6 percent respectively), while boys move to other localities mostly for education and job searching (36.8 and 20.5 percent respectively). In addition, to the extent that liquidity constraints reduce the likelihood of migration, these may be more binding for young women then for men, especially among ethnic groups with strong patriarchal social norms like the Antambahoaka and Antandroy. Moreover, the gendered nature of division of labor and resource entitlements may compromise women's capacity to resort to specific adaptation or resilience strategies, such as migration. In rural settings, gendered norms tend to prevent women from pursuing off-farm activities and limit their options in terms of transiting out of agricultural activities into other sectors of employment (Doss, 2018). This may discourage migration in search of new economic opportunities. We thus present in Table 6 how the occurrence of a drought in the previous year affects the probability of migration disaggregated by gender. We can see that such a climate event decreases the probability of migration for women, but not by men. [9]

We next look at the differences in the effect of drought on the migration decision, distinguishing those who migrate to an urban or another more proximal rural destination. Table 7 shows that drought decreases the probability of closer movements like migration within the district of origin, between the same district and to other rural areas (columns (1), (2) and (5) respectively), but not that of longer distance migrations, specifically to another province or to urban areas (columns (3) and (4)). This is consistent with the evidence that CMs who migrate to another province and to urban areas are on average wealthier than the migrants moving to closer destinations.[10] As discussed above, wealthier households would be able to buffer the income shock associated with drought, and CMs from better off household would not witness any effect of such events on migration.

[8] Differently from most of other sub-Saharan African countries, in Madagascar paying a bride price is not a dominant marriage practice (Corno et al., 2020). Therefore, we do not expect that an income shock such as that induced by a drought would push parents to marry off their daughter. The occurrence of a drought, then, is not expected to increase girls' migration for marriage reasons.

[9] Although the effect is not significant for boys at the conventional confidence levels, it is significant at 12.5 per cent. Moreover, further estimates by gender show that under some circumstances boys are affected as well: for example, boys are negatively affected by the drought occurrence if they live in a community that does not have access to irrigation facilities. However, we take these results with some caution because of the important reduction in the number of migrants when we split the sample by gender.

[10] The average asset index in 2004 for migrants moving towards urban areas stands at 36.74 vs 29.68 for rural areas. Migrants moving between districts have an average asset index in 2004 of 41.24, vs. an average of 28.0 for migrants moving within and between districts of the same provinces.

Finally, we present the result of the effect of drought, but run separate models where we split the sample by reason of migration, that is, whether the individual migrants in search of a job, or for reasons related to education and marriage (see Table 8). The results indicate that, regardless of the motivation to migrate, the likelihood is reduced subsequent to the occurrence of a drought.

5 Conclusion and implications

The expectation about the sign of the impact of climate shocks on migration decisions is ambiguous. On the one hand, the economic stress associated with adverse weather events, and related possible destruction of economic infrastructure and related outcomes such as degradation of soils and fragile ecologies, increase the challenges of sustaining rural livelihoods. This could be expected to encourage migration. On the other hand, households have fewer resources to finance a move, which is costly, especially to the extent that migration involves an expensive job search and related costs of living accommodations.

Our findings indicate that drought events, lagged one year, decrease the probability of internal migration originated from rural areas, whereas cyclones do not have such an affect. The role of droughts in terms of reducing migration is not immediate, but instead lagged by one year subsequent to the adverse climate situation.

We validate our (causal) results by conducting a series of robustness checks that address the concern of possible weakness of our identification strategy. It is likely that potential migrants anticipate future climate variations or shocks and that drought has only a temporary displacement effect on migration. Our falsification tests, suggest that our results are causal and that climate shocks indeed impact the migration decision.

Our baseline results would suggest that the loss of income occurs owing to an induced decline in productivity, making migration less affordable for rural households (Cai et al., 2016) and (Bazzi, 2017). To test this mechanism further we interacted a household asset index with the drought variable, and indeed found that wealthier household are able to buffer the negative effect the shock on their migration decision. Similarly, among households with access to savings institutions, drought also does not affect their choice of migration. The fact that drought also only impacts the migration decision among rural households who depend on agriculture for their livelihoods, adds further support for the interpretation of our findings. Another interesting result of our analysis is the evidence of the role of networks in reducing the costs, and thus mitigating the negative effect of drought on migration. This is shown by the significant interaction of the network variable, defined in terms of knowing and having access to family and friends in communities outside the current region of residence, with the drought variable.

Our paper also explores heterogeneity in the findings by gender, which we in fact observe. More specifically, while the impact of drought on young women's migration decision is strong and robust, this is not the case for young men. We interpret this finding as being a result of gender norms and related to the reason for migration - women tend to migrate more frequently for reasons related to marriage and schooling. Mobility of women is likely to be less and more restricted in periods of economic stress that results from drought and the lack of liquidity to finance migration. It is possible that young women are perceived to have lower returns from migration. and as such, when there is a negative weather shock that would reduce household incomes, they may be discouraged to migrate. . In contrast, households may still continue to finance boys' migration even when hit by adverse income shocks. Another source of heterogeneity in the findings is that drought has a negative impact on rural to rural and on migrations across short distances, which are the type of migration often experienced by poorest households.

All in all, our results suggest that liquidity constraints that occur after the income shocks prevent youth migration in rural Madagascar. Poor people, in particular, are "trapped" in affected areas and cannot move even if they might have done so in the absence of these adverse climate events. Interventions that helps mitigate the shock, as well as efforts to encourage and promote diversifying income with non-farm activities would increase the resilience of people at higher risk of climate shocks.

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Table 1: *Descriptive statistics*

Time-varying characteristics	Boys		Girls	
	Mean (2004) (SD)	Mean (2011) (SD)	Mean (2004) (SD)	Mean (2011) (SD)
Age (years)	14.72	21.67	14.75	21.74
	(0.90)	(0.90)	(0.92)	(0.91)
Migrant	0.90	5.83	0.84	5.99
	(0.09)	(0.23)	(0.09)	(0.24)
Married	0.18	15.73	1.36	31.47
	(0.04)	(0.36)	(0.12)	(0.46)
Household owns a land	48.11	81.39	35.75	80.27
	(0.50)	(0.40)	(0.48)	(0.40)
Parent	0.90	17.49	3.37	51.88
	(0.09)	(0.38)	(0.18)	(0.50)
Father's shock	7.75	19.28	8.09	18.40
	(0.27)	(0.39)	(0.27)	(0.39)
Mother's shock	7.21	13.45	3.88	12.20
	(0.26)	(0.34)	(0.19)	(0.33)
School	91.71	20.85	89.04	14.86
	(0.28)	(0.41)	(0.31)	(0.36)
Work	20.90	83.86	22.92	81.82
	(0.41)	(0.37)	(0.41)	(0.39)
Non agricultural household	9.73	4.71	11.13	6.43
	(0.30)	(0.21)	(0.31)	(0.25)

Time-invariant characteristics	Boys	Girls
	Mean (SD)	Mean (SD)
Household assets in 2004 (number)	20.14	19.50
	(15.89)	(16.55)
Savings in 2004	58.72	57.82
	(0.49)	(0.49)
Network in 2012	6.66	4.55
	(0.25)	(0.21)
Ethnicity Antakarana	26.69	22.66
	(0.44)	(0.42)
Ethnicity Antambahoaka	17.30	17.73
	(0.38)	(0.38)
Ethnicity Antandroy	9.85	10.22
	(0.30)	(0.30)
Ethnicity Antanosy	46.16	49.40
	(0.50)	(0.50)
Number of observations	555	593

Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.
Note : Variables are expressed in percentages unless differently specified. Father and mother shocks happen if the parent is sick or passed away.

Table 2: *Descriptive statistics for migrations*

	Boys	**Girls**
Main reasons of migration		
Looking for work	21.05	8.02
	(0.41)	(0.27)
Education	36.84	27.78
	(0.48)	(0.45)
Marriage	3.76	28.40
	(0.19)	(0.45)
Migration destination		
Rural to urban	46.32	37.43
	(0.50)	(0.49)
Rural to rural	44.85	51.46
	(0.50)	(0.50)
Within districts	39.71	42.11
	(0.49)	(0.50)
Between districts	41.91	38.60
	(0.50)	(0.49)
Between provinces	18.38	19.30
	(0.39)	(0.40)

Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.
Note : Variables are expressed in mean percentages with standard deviation in parentheses underneath. The sum of "rural to urban" and "rural to rural" migration is not 100 because for a few observations we were not able to determine if the destination locality was in a rural or urban area.

Table 3: ***Baseline regression of the effect of a climate shock on migration***

	(1)	(2)	(3)
Cyclones	-0.000	-0.000	-0.002
	(0.009)	(0.009)	(0.009)
Drought	-0.001		
	(0.009)		
Drought in t-1	-0.024**	-0.023**	-0.023**
	(0.011)	(0.010)	(0.010)
Temperature deviation in t-1			0.012
			(0.010)
Additional controls	yes	yes	yes
Age Dummies	yes	yes	yes
Year Dummies	yes	yes	yes
Individual fixed effects	yes	yes	yes
Observations	7,226	7,226	7,226
R-squared	0.310	0.310	0.310

Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.
Note : *** p<0.01, ** p<0.05, * p<0.1 . Robust standard errors in parentheses. All specifications control for CM (individual) fixed effects and standard errors are clustered at the SBU level. Additional controls include: whether the CM was in school in $t-1$, at work in $t-1$, got married in $t-1$, gave birth in $t-1$, his/her father (mother) got sick or died in $t-1$, CM's household had access to land in t.

Table 4: ***Falsification tests of the effect of a climate shock on migration***

	(1)	(2)
Drought	-0.003	
	(0.009)	
Drought in t-1	-0.025**	
	(0.012)	
Drought in t-2	-0.022	
	(0.015)	
Drought in t-3	0.005	
	(0.018)	
Drought in t-4	0.003	
	(0.016)	
Drought in t+1		0.001
		(0.010)
Additional controls	yes	yes
Age Dummies	yes	yes
Year Dummies	yes	yes
Individual fixed effects	yes	yes
Observations	7,226	7,226
R-squared	0.310	0.309

Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.
Note : *** p<0.01, ** p<0.05, * p<0.1 . Robust standard errors in parentheses. All specifications control for CM (individual) fixed effects and standard errors are clustered at the SBU level. Additional controls include: whether the CM was in school in $t-1$, at work in $t-1$, got married in $t-1$, gave birth in $t-1$, his/her father (mother) got sick or died in $t-1$, CM's household had access to land in t.

Table 5: ***Role of income and networks on migration in the case of a climate shock***

	(1) Assets	(2) Savings	(3) Non farmer	(4) Farmer	(5) Network
Drought in t-1	-0.037***	-0.029***	-0.032	-0.023***	-0.037***
	(0.010)	(0.010)	(0.071)	(0.008)	(0.007)
Drought in t-1 × Savings		0.121*			
		(0.063)			
Drought in t-1 × Assets	0.001*				
	(0.000)				
Drought in t-1 ×Network					0.032**
					(0.013)
Additional controls	yes	yes	yes	yes	yes
Age Dummies	yes	yes	yes	yes	yes
Year Dummies	yes	yes	yes	yes	yes
Individual fixed effects	yes	yes	yes	yes	yes
Observations	7,199	7,226	625	6,601	6,889
R-squared	0.310	0.311	0.375	0.308	0.312

Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.
Note : *** p<0.01, ** p<0.05, * p<0.1 . Robust standard errors in parentheses. All specifications control for CM (individual) fixed effects and standard errors are clustered at the SBU level. Additional controls include: whether the CM was in school in $t-1$, at work in $t-1$, got married in $t-1$, gave birth in $t-1$, his/her father (mother) got sick or died in $t-1$, CM's household had access to land in t. In column (5), we excluded CMs who migrated between provinces.

Table 6: ***Heterogeneity of the effect of climate shock on migration, by gender***

	(1)	(2)
	Boys	Girls
Drought in t-1	-0.020	-0.028**
	(0.013)	(0.012)
Additional controls	yes	yes
Age Dummies	yes	yes
Year Dummies	yes	yes
Individual fixed effects	yes	yes
Observations	3,561	3,665
R-squared	0.284	0.335

Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.
Note : *** p<0.01, ** p<0.05, * p<0.1 . Robust standard errors in parentheses. All specifications control for CM (individual) fixed effects and standard errors are clustered at the SBU level. Additional controls include: whether the CM was in school in $t-1$, at work in $t-1$, got married in $t-1$, gave birth in $t-1$, his/her father (mother) got sick or died in $t-1$, CM's household had access to land in t.

Table 7: ***Heterogeneity of the effect of climate shock on migration, by destination***

	(1) Within district	(2) Between districts	(3) Between provinces	(4) To urban	(5) To rural
Drought in t-1	-0.012*	-0.011*	-0.004	-0.009	-0.015**
	(0.007)	(0.006)	(0.004)	(0.008)	(0.007)
Additional controls	yes	yes	yes	yes	yes
Age Dummies	yes	yes	yes	yes	yes
Year Dummies	yes	yes	yes	yes	yes
Individual fixed effects	yes	yes	yes	yes	yes
Observations	6,451	6,372	6,149	7,084	7,107
R-squared	0.287	0.324	0.277	0.295	0.307

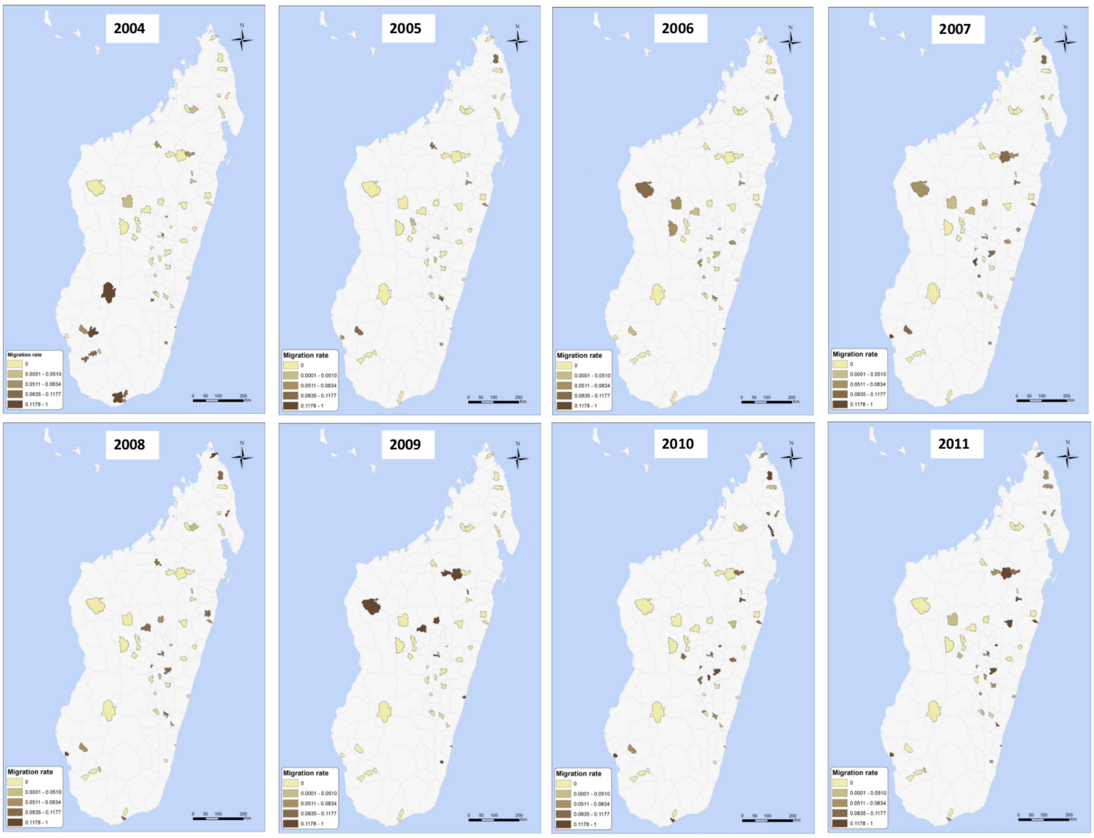
Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.
Note : *** p<0.01, ** p<0.05, * p<0.1 . Robust standard errors in parentheses. All specifications control for CM (individual) fixed effects and standard errors are clustered at the SBU level. Additional controls include: whether the CM was in school in $t-1$, at work in $t-1$, got married in $t-1$, gave birth in $t-1$, his/her father (mother) got sick or died in $t-1$, CM's household had access to land in t.

Table 8: ***Heterogeneity of the effect of climate shock on migration, by reason of migration***

	(1) For work	(2) For education	(3) For marriage
Drought in t-1	-0.009*	-0.014*	-0.007**
	(0.005)	(0.007)	(0.003)
Additional controls	yes	yes	yes
Age Dummies	yes	yes	yes
Year Dummies	yes	yes	yes
Individual fixed effects	yes	yes	yes
Observations	6,105	6,301	6,112
R-squared	0.233	0.295	0.326

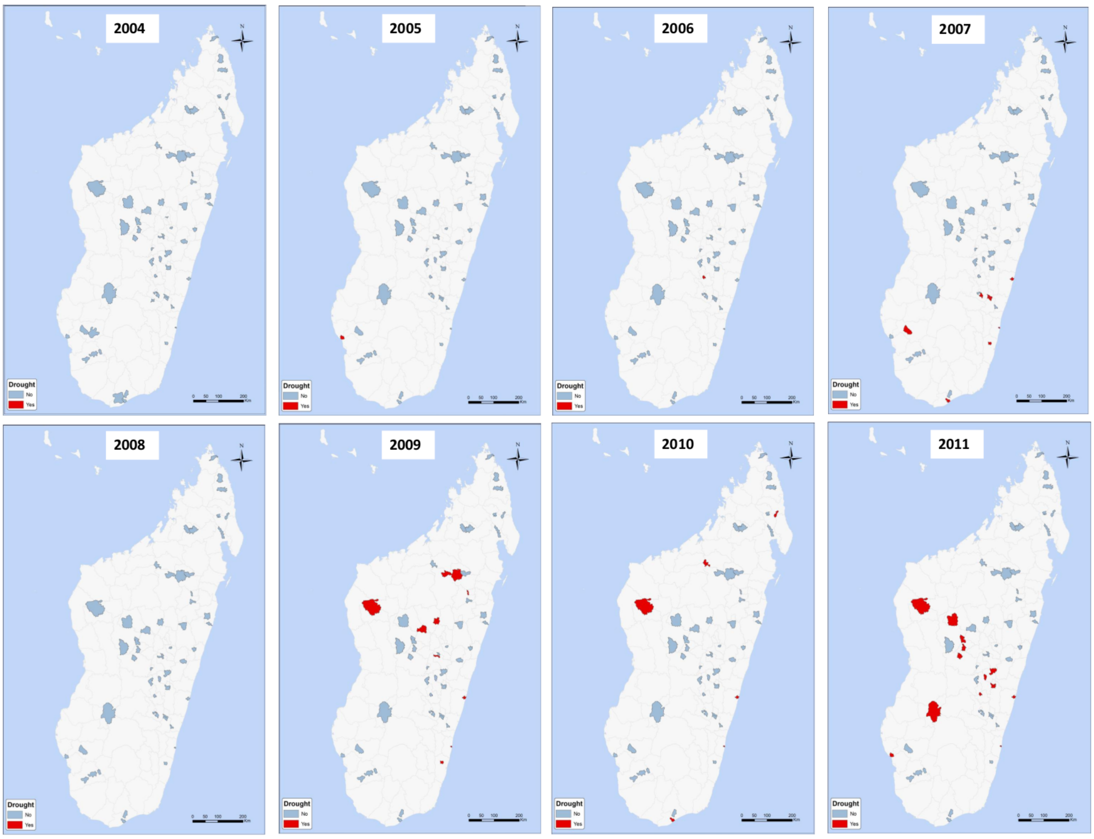
Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*. *Note* : *** p<0.01, ** p<0.05, * p<0.1 . Robust standard errors in parentheses. All specifications control for CM (individual) fixed effects and standard errors are clustered at the SBU level. Additional controls include: whether the CM was in school in $t-1$, at work in $t-1$, got married in $t-1$, gave birth in $t-1$, his/her father (mother) got sick or died in $t-1$, CM's household had access to land in t.

Figure 1: *Distribution of Migration among youth in Madagascar, by year*



Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.

Figure 2: *Distribution of lagged drought in Madagascar, by year*



Source: Authors' elaboration from *Madagascar Young Adult Survey* and *EPSPAM*.