Extreme Weather Events and Internal Migration: Causal Evidence from Global Micro-level Data

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Abstract

Migration has long served as an adaptive response to environmental change. Numerous empirical studies have highlighted the significant impact of environmental stress on migration, particularly within national borders and from rural to urban areas. However, environmental factors are rarely the sole driver of mobility. Rather, they interact with complex socio-economic, political, and demographic factors that influence the decision to migrate. By employing harmonized georeferenced IPUMS micro-level data (covering 21 countries across different world regions between 1971 and 2019, both at the household and individual levels), coupled with rasterized information on extreme climate conditions (proxied via the Standardized Precipitation–Evapotranspiration Index (SPEI), this study aims to assess the impact of environmental stressors on the probability that a household undertakes internal migration. Our preliminary results show that exposure to climatic anomalies in the region of origin (both very wet conditions and severe droughts) positively associate with a higher probability of undertaking internal migration. The large sample size and the great heterogeneity of our sample not only allow us to empirically test a set of channels behind this effect (e.g., agricultural dependency, income levels, and population structure), but also to establish causal effects by adopting a staggered difference-in-differences identification strategy.

1. Introduction and literature background

A recent and expanding stream of empirical literature has explored the impact of climate change on several demographic outcomes, including human mobility (Abel, Muttarak and Stephany, 2022; Beine and Jeusette, 2021; Helbling et al., 2023; Hoffmann et al., 2022; Hoffmann et al., 2024; Thiede et al., 2016). Migration has been historically employed as an adaptation strategy to environmental change (McLeman & Smit, 2006). In this regard, severe weather anomalies have been identified as a major cause of both international movements (Daoust & Selby, 2024), as well as internal migration. Several empirical findings consistently show that climate-induced migration occurs predominantly over short distances, and it often remains within national borders (Hoffmann et al., 2024), particularly consisting of flows from rural to urban areas (Thiede et al., 2016; Henderson et al., 2017).

Admittedly, climate and enviromental factors are rarely the sole driver of human mobility, but they interact with complex socio-economic, political, and demographic factors (Black et al., 2013; Cattaneo et al., 2019). That is, the impact of weather anomalies on migration is highly dependent on the socioeconomic and demographic factors of the region of origin, including the level of agricultural dependency, income levels, and population structure. Indeed, when *in situ* adaptation options fail, households may choose or they may be forced to migrate from the affected area (Black et al., 2011). However, because migration is a costly process (Kleemans, 2015), being affected by adverse climatic conditions, such as severe drought or floods, can itself erode household income, making it impossible for the most vulnerable to afford the costs of migration. This can lead to the phenomenon of "trapped populations", which are less able to undertake migration despite the detrimental effects caused by exposure to climate disasters (Black et al., 2013). Recent empirical evidence supports this mechanism; for example, negative rainfall shocks tend to suppress outmigration, especially in low-income countries (Abel et al., 2022). Similarly, while positive rainfall shocks (e.g., above-average rainfall patterns) could increase agricultural production, and thus generate the necessary disposable income to finance movement (Marchiori et al., 2017), in the event of floods, households' livelihoods are disrupted (Oskorouchi and Sousa-Poza, 2021) and the probability of migration increases (Freihardt 2025). Not surprisingly, probably for their greater levels of vulnerability, households living in rural and predominantly agricultural areas are more likely to enact internal migration responses, often with movements stemming from poorer regions towards the wealthier ones (Hoffmann et al., 2024).

This study investigates the effect of climatic factors on the probability of a household undertaking internal migration using georeferenced micro-level census data from IPUMS. This data includes both household- and individual-level information[1], as well as geo-identification on the current and previous (one year before the census) first administrative unit of residence. The dataset covers 21 countries across multiple regions of the world over the period 1971–2019. A major contribution of the present study to the existing stream of literature (e.g., Hoffmann et al. 2024 and Abel, Muttarak and Stephany 2022) is its ability to test a series of mechanisms and transmission channels of the climate-migration nexus by employing a staggered difference-in-differences (DiD) quasi-experimental identification strategy (see section "Further Developments" below for details). Unveiling such causal and heterogeneous effects provides the opportunity to isolate the contribution of climate change, regardless of the effect of other confounding factors such as poverty levels, human-made disasters, or political factors. Such analysis could contribute to the current policy-relevant debate on the involuntary nature of climate-driven migration. In fact, empirically demonstrating a causal impact of climate shocks strengthens the argument that such migration is, at least in part, involuntary.

2. Data and methodology

We employ harmonized census microdata from IPUMS international database, which provides integrated population data from national censuses across countries, ensuring comparability over time and space. This data includes information on 21 countries over the period 1971-2019, which are all those for which information on the household and individual levels previous region of residence is available. The ability to geographically identify the current and previous region of residence (one year before the census) allows us to couple the micro-level data with rasterized information on extreme adverse events as measured by the Standardized Precipitation-Evapotranspiration Index (SPEI).

For this preliminary version of our study, we run a series of ordinary least squares (OLS) regressions where the dependent variable is a dichotomous indicator of realized internal migration, which takes a value equal to one if the current region of residence differs from the one recorded for the year before the census date, and zero otherwise. The key explanatory variables capture exposure

[1] Preliminary results (see section below) are based solely on household-level regressions due to the substantial computational demands associated with analyzing several hundred million observations. The final version of the study will present analyses at both the household and individual levels.

to climatic anomalies in the region of origin, operationalized through the SPEI measured over a 12-month period. Weekly global SPEI raster data are from the global drought crops monitoring dataset (Vicente-Serrano et al., 2023), providing weekly SPEI values since January 1979, at a 0.5° spatial resolution. These data are spatially matched to first-level administrative regions. For each region, we compute the number of grid cells within its boundaries that experienced severe drought (SPEI-12 < –1.5) or excess rainfall (SPEI-12 > +1.5) one year before the census enumeration month. These counts are divided by the region's land area in square kilometers to account for size differences and subsequently standardized (z-scores) across all regions and countries. Following established thresholds in the climate literature (cf. Vicente-Serrano et al., 2010), positive climatic anomalies reflect abnormally wet conditions and negative anomalies severe to extreme droughts. To estimate the assossiation of climatic anomalies with the probability of internal migration, we estimate three OLS models with the following specification:

Model 1 (baseline):

$$Migration_{\,i} = \beta_1 * SPEI\_Wet_r + \beta_2 * SPEI\_Dry_r + \epsilon_i$$

Model 2 (with fixed effects):

$$Migration_{\,i} = \beta_1 * SPEI\_Wet_r + \beta_2 * SPEI\_Dry_r + \gamma_c + \delta_t + \epsilon_i$$

Model 3 (full specification):

$$Migration_{\,i} = \beta_1 * SPEI\_Wet_r + \beta_2 * SPEI\_Dry_r + X_i'\theta + \gamma_c + \delta_t + \epsilon_i$$

Where *i* indexes individuals, *r* are regions, *c* countries, and *t* years. γ_c and δ_t represent country and year fixed effects, respectively, to account for unobserved heterogeneity and temporal trends. X_i is a vector of individual-level controls, including current household size and urban/rural residence status. The coefficients of interest, β_1 and β_2, measure the influence of extreme wet and dry conditions on the probability of internal migration, holding other factors constant.

It should be noted that destination-area characteristics are observed at time t+1, that is after the migration event. Ideally, these variables should be measured before migration to avoid mediator bias. Due to data limitations, pre-migration information is not available. Therefore, we treat these variables as proxies for the typical features of the destination area, assuming they are relatively stable and largely reflect the conditions households consider when choosing a destination. Although their inclusion in the model may introduce some degree of bias in the estimation of the coefficients of the control variables, it is unlikely to produce severe distortions in the estimation of the SPEI coefficients. Indeed, their inclusion could remove part of the causal pathway and therefore underestimates the total effect of climate shocks on migration. The sensitivity analyses presented in this long abstract, which exclude these destination-area controls, confirm the overall robustness of our results.

3. Preliminary results

The preliminary results presented in Table 1 indicate a positive and statistically significant association between both wet and dry climatic anomalies and internal migration. The estimated effects are small in absolute terms but meaningful given the scale of the phenomenon: a one-standarddeviation increase in the share of territory exposed to abnormally wet conditions is associated with roughly a 4.6 percentage-point higher probability of household migration, while an equivalent increase in the share of territory affected by drought corresponds to a 2.8 percentage-points increase (see Model 3). The magnitude of the coefficients increases notably in the full specification, suggesting that once controlling for household and contextual characteristics, extreme climatic conditions, particularly wet anomalies, are strongly associated with higher internal mobility. This pattern supports the hypothesis that climatic shocks, whether due to excessive or insufficient precipitation, act as relevant push factors shaping migration decisions.

Table 1 – Severe wet and extreme drought events on the probability of internal migration (OLS)

	Model 1	**Model 2**	**Model 3**
SPEI Wet (z)	0.016***	0.015***	0.046***
	(0.000)	(0.000)	(0.000)
SPEI Dry (z)	0.003***	0.001***	0.028***
	(0.000)	(0.000)	(0.000)
Country FE	**No**	**Yes**	**Yes**
Year FE	**No**	**Yes**	**Yes**
Controls	**No**	**No**	**Yes**
Observations	47,018,279	47,018,279	40,457,190
Adjusted R^2	0.008	0.338	0.106
F-stat	178,931.9	630,989.4	159,203.1
F-stat (p-value)	0.000	0.000	0.000

4. Futher developments

We aim to estimate the causal effect of climate shocks on the probability of internal migration by employing a staggered DiD identification strategy. This approach enables the isolation of causal effects under the assumption that the parallel trends condition holds. The staggered DiD design is particularly suitable for repeated cross-sectional data encompassing multiple groups and treatment periods, as it compares treated units with those not yet treated while simultaneously controlling for country and year fixed effects. A key advantage of this estimator lies in its capacity to mitigate bias arising from omitted confounding factors, particularly those related to individual or household characteristics measured prior to the migration event, variables that are typically unavailable in large-scale, globally harmonized micro-datasets containing georeferenced migration information. To address this limitation, we will also directly control for characteristics of the first administrative unit in the year preceding the census, merging the microdata with rasterized global datasets on GDP (or night-time lights), agricultural suitability, population density, and the regional share of the rural population. Finally, the large sample size enables us to examine the potential mediating mechanisms through which climate shocks influence migration decisions. Specifically, we will test whether the effects operate through channels such as agricultural dependency, income levels, conflict, and demographic structure.

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