Climate Change, Desertification, and Internal Migration: Evidence from Global Census Data

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Short Abstract

The role played by climate change as a migration driver has received widespread public attention in the past years. Yet, especially for internal migration, comparable data are missing, challenging the empirical estimation of climatic impacts. Here, we use a novel census-based dataset to estimate the impacts of long-term desertification and drying trends on internal migration worldwide. The longitudinal data are based on IPUMS International microdata for 68 countries, covering the period 1960-2015. We use information on the current and previous residence of census participants to calculate 98000 bilateral internal migration flows between 1600 subnational regions of origin and destination. Combining the migration with environmental data, we find evidence for a substantial impact of drying on human mobility. The impact is strongest in already arid areas, in particular in Africa and Asia, highlighting the role of desertification trends. Agricultural dependence as well as low development levels further exacerbate the climatic effects.

Extended Abstract

That climate change will trigger large-scale human migration has been predicted by many scholars and UN agencies since the 1980s (Myers 2002; Stern 2006; Piguet 2012). A warmer future climate is likely to aggravate both the frequency and intensity of extreme weather events and graduate processes of environmental degradation which pose serious threats to food security, health and water availability. The increase in livelihood insecurity can in turn trigger human migration as an adaptation and coping strategy (Hunter et al. 2015; McLeman & Smit 2006).

Due to increasing temperatures and changing rainfall patterns, drying and desertification trends are observable in many parts of the word, putting a significant strain on the livelihoods of affected populations. Already today, drylands comprise more than 40% of the global terrestrial area and are home to around 2.5 billion people or one third of the global population. They are ecosystems characterized by high temporal and spatial rainfall variability and aridity (FAO 2019). Climate change is expected to have major impacts on these areas with increasing levels of water stress, land degradation, and a continued loss of biodiversity. By the end of this century, drylands are projected to further expand by 11% under a medium (RCP4.5) and up to 23% under a high (RCP8.5) greenhouse gas emission scenario relative to a 1961–1990 baseline (Huang et al. 2016)

Despite an increase in public interest in climate-induced migration, empirical evidence on the relationship between climate conditions and migration remains inconclusive (Hunter et al. 2015). This is due to the fact that most studies are localized, with a focus on one community or one country and methodologies used vary considerably (Hoffmann et al. 2020; Hoffmann et al. 2021). Comparable data, in particular for internal migration, is missing, challenging the estimation of climatic impacts which are expected to be particularly important for mobility within countries' borders (Rigaud et al. 2018). Previous analyses were either based on micro samples or relied on proxies to estimate internal migration flows, such as urbanization trends across countries (Henderson et al. 2017; Barrios et al. 2006).

In this paper, we use a novel census-based internal migration dataset to provide a comparative analysis of climate-induced internal migration across 68 countries (Appendix Figure A1). The data are based on the microdata supplied by the Integrated Public Use Microdata Series (IPUMS) International over the period 1960-2015. Using the data from 188 censuses, we construct a unique longitudinal database at the sub-national regional level (Geo 1 census regions) with information on bilateral migration flows between regions of origin and destination (Appendix Figure A2). Migration is estimated based on information on the current and previous residence of the census participants five or ten years prior to the respective census date (Garcia et al. 2015), allowing us to calculate how many people have migrated from region A to region B, and vice versa. In total, we derive information on internal migration from 1600 census regions, estimating approximately 98000 bilateral migration flows over time (Appendix Figure A3).

Gravity-type fixed effects models (Poisson Pseudo Maximum Likelihood estimation) are used to analyze internal migration flows induced by drying and desertification processes (Beine & Parsons 2017). In the measurement of our climatic indicators, we consider broad time windows of 10 year intervals reflecting long-term changes in the aridity of the considered subnational regions. This distinguishes our analyses from previous studies that considered the impact of short-term changes, climatic variations, and anomalies (e.g., Gray & Wise 2016; Marchiori et al. 2012; Cai et al. 2016).

We use three key variables to measure drying and desertification trends, which are substantive in some regions (Appendix Figure A4). The aridity index (AI) measures the dryness as the ratio between precipitation and the potential evapotranspiration, the Normalized Difference Vegetation Index (NDVI) is a remote sensing measure showing the amount of green vegetation, and the Standardized Precipitation Evapotraspiration Index (SPEI) measures the water balance in a region based on both the local precipitation and potential evapotranspiration. All three indicators are similarly scaled with smaller values indicating drier and larger values indicating more humid conditions. This has important implications for the interpretation of our model coefficients as negative coefficients indicate a positive relationship between dryer conditions and migration.

As main outcome, we consider migration flows between origin and destination regions, which are normalized using the population in origin areas as offset variable (Appendix Figure A5). In our models, unobserved heterogeneities as well as common time trends are controlled for via the use of region of origin and destination as well as time fixed effects. These allow us to derive a causal estimate of within regional changes in environmental conditions on migration. We use heterogeneity analyses to explore differential effects by ecological and socioeconomic conditions, considering both regions of origin and destination. A particular advantage of our census-based data is that they do not only allow to estimate the extent of migration flows, but to also explore who is migrating based on the migrants' characteristics and where they are going based on information about destination regions.

Our preliminary findings show a substantial impact of drying trends on migration. According to our baseline models (Appendix Table A1), a reduction of the aridity index by 0.1, indicating drier conditions, leads to an estimated increase in migration of 0.027 percentage points. Similar changes in the NDVI and SPEI are estimated to result in a 0.021 and 0.011 percentage point increase in migration, respectively. The results highlight the important role of long-term environmental deterioration in shaping migration outcomes.

Further distinguishing the effects by world regions and ecological zones, we find substantive heterogeneity in the findings (Appendix Figure A6). Stronger migration impacts of drying are observable for regions in Africa and East Asia and the Pacific, as well as for already dry hyper-arid and arid regions. The latter finding highlights the important role of desertification trends in already arid areas, which can lead to land degradation and a loss in biodiversity, putting pressure on the already difficult livelihoods of local populations. The effects are further moderated by local agricultural and socioeconomic conditions (Appendix Figure A7). Both agricultural dependence as well as low development levels exacerbate the climatic effects.

In additional models (Appendix Table A2), we also consider the impact of short-term climatic events in comparison to those of long-term changes. We find a sizeable impact of negative precipitation anomalies, as well as weaker but significant impacts of heat anomalies and droughts on migration. Our findings furthermore suggest that also climatic conditions in destination regions influence migration flows to those regions.

As next steps, we plan to extend our analysis to study not only whether and where climate-induced migration occurs, but also to better understand who migrates, under which conditions, and to which locations. For this, we will use rich information collected in the censuses about the socioeconomic and demographic characteristics of migrants as well as complementary data on the conditions in the origin as well as prospective destination regions. The results of our study have important implications in the context of global policy discussions and highlight the role of contextual differences in shaping migration responses to climate change.

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Appendix

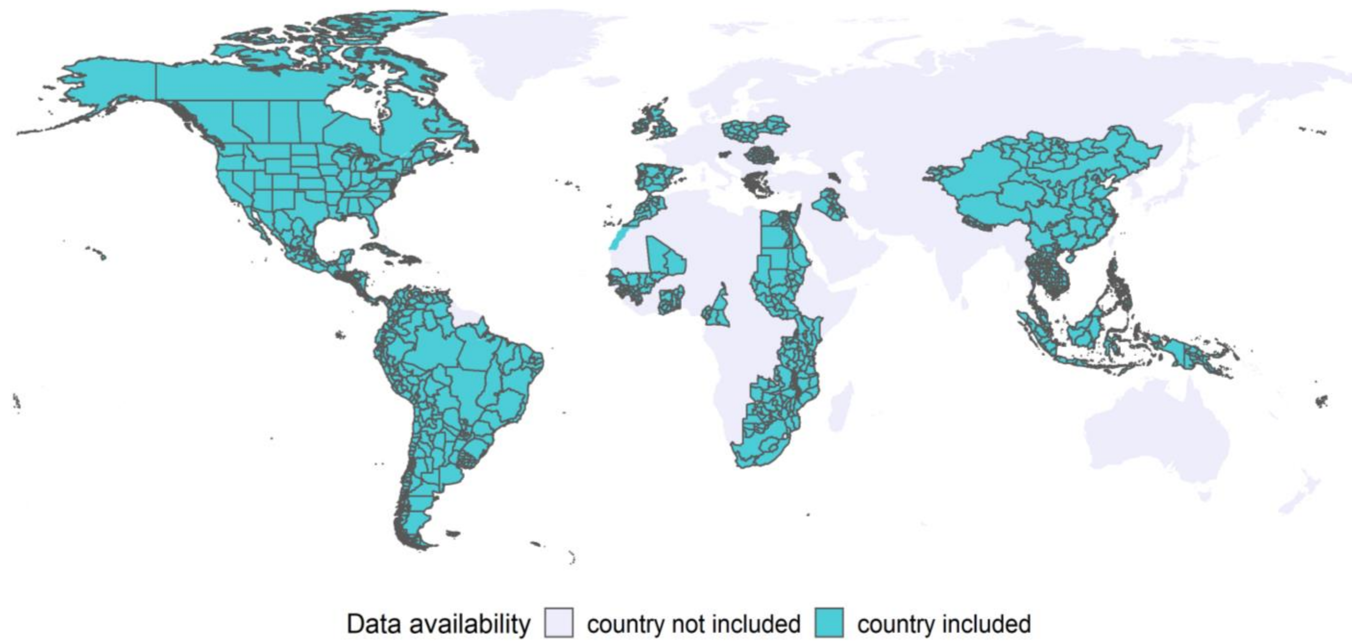

Figure A1 – Countries covered by the census-based migration data. The dataset include 68 countries in North America, Latin America and the Caribbean, Europe, Africa, and East and Southeast Asia

Figure A2 – Illustration of the bilateral migration flow estimation for an example of two subnational regions in China. As part of our data, we observe migration flows in the past 5 or 10 years from a region A to a region B, and vice versa. In total, we obtain information for about 98000 internal migration flows in different countries over time

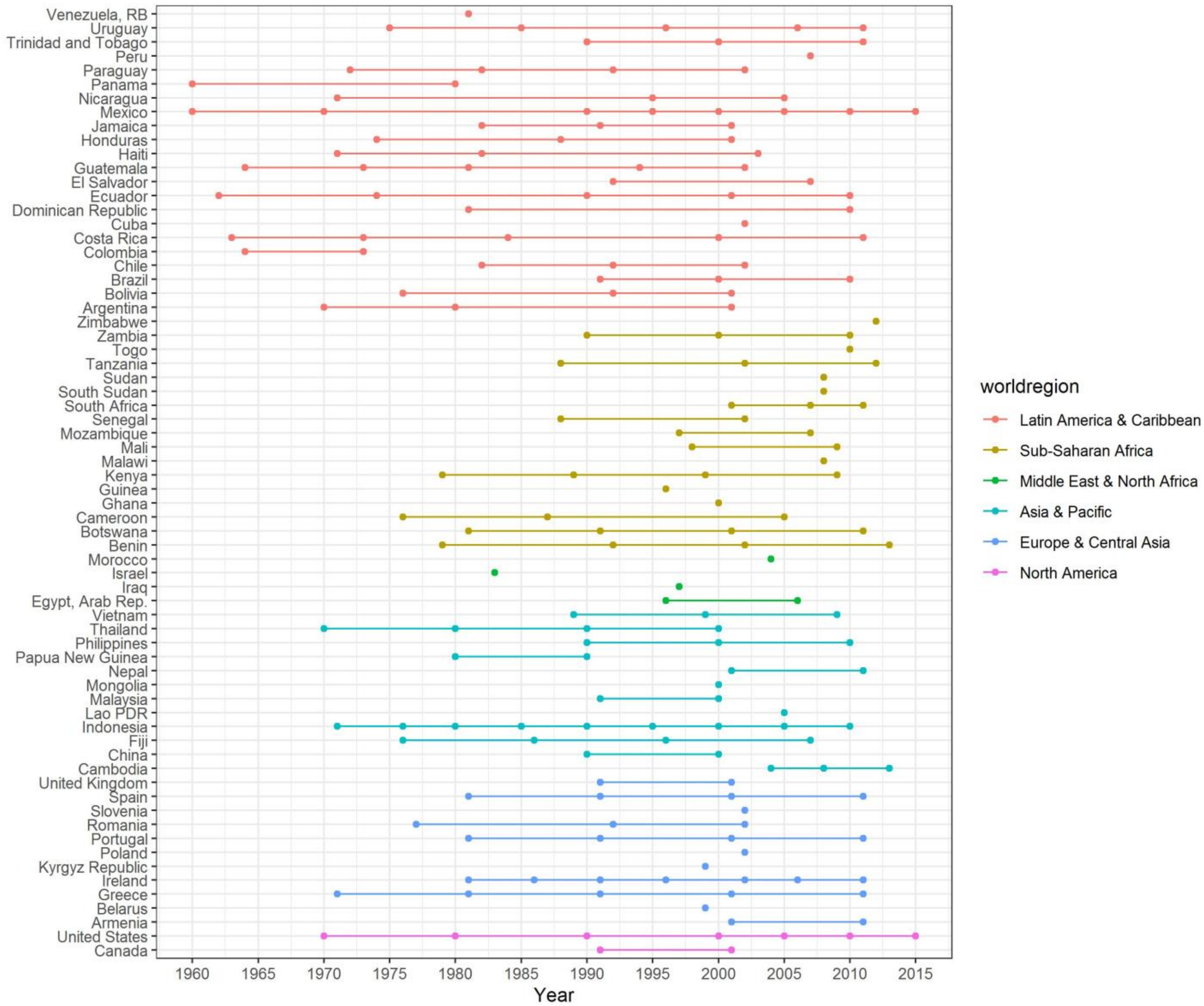

Figure A3 - Timing of censuses across countries and world regions covered in the census-based migration dataset. The unbalanced longitudinal data contains information from 1960 to 2015.

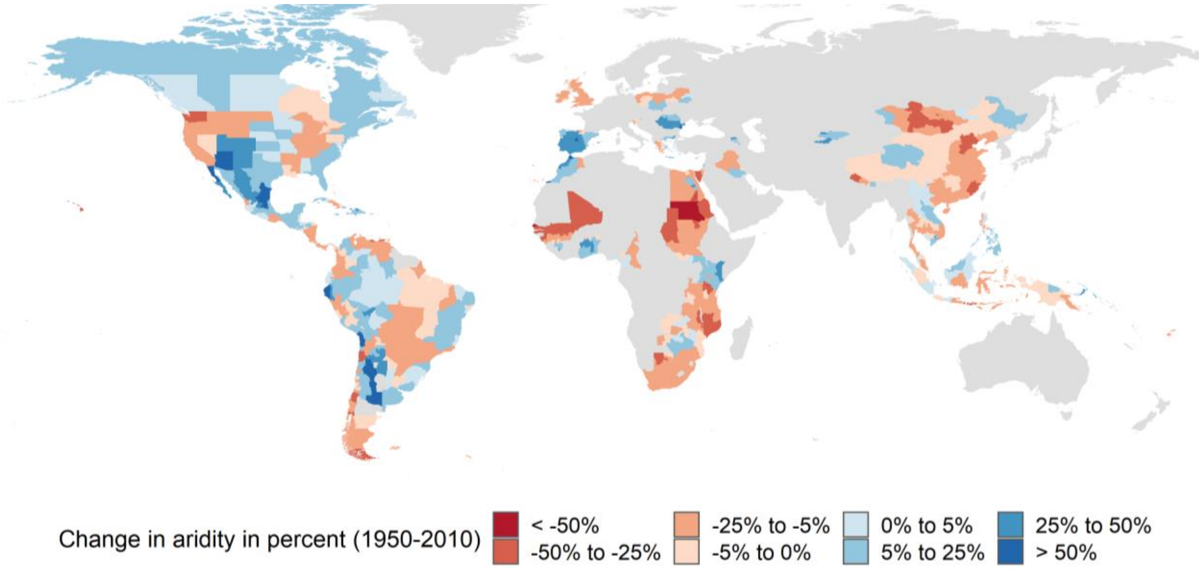

Figure A4 – Drying trends measured as changes in aridity from 1950 – 2010 in the regions covered by the census-based migration data. The aridity index captures the degree of dryness in a region. It is calculated as the ratio between precipitation and evapotranspiration. Higher values on the index indicate more humid conditions and lower values drier conditions. Accordingly, drying and desertification trends are reflected in a decrease of the index.

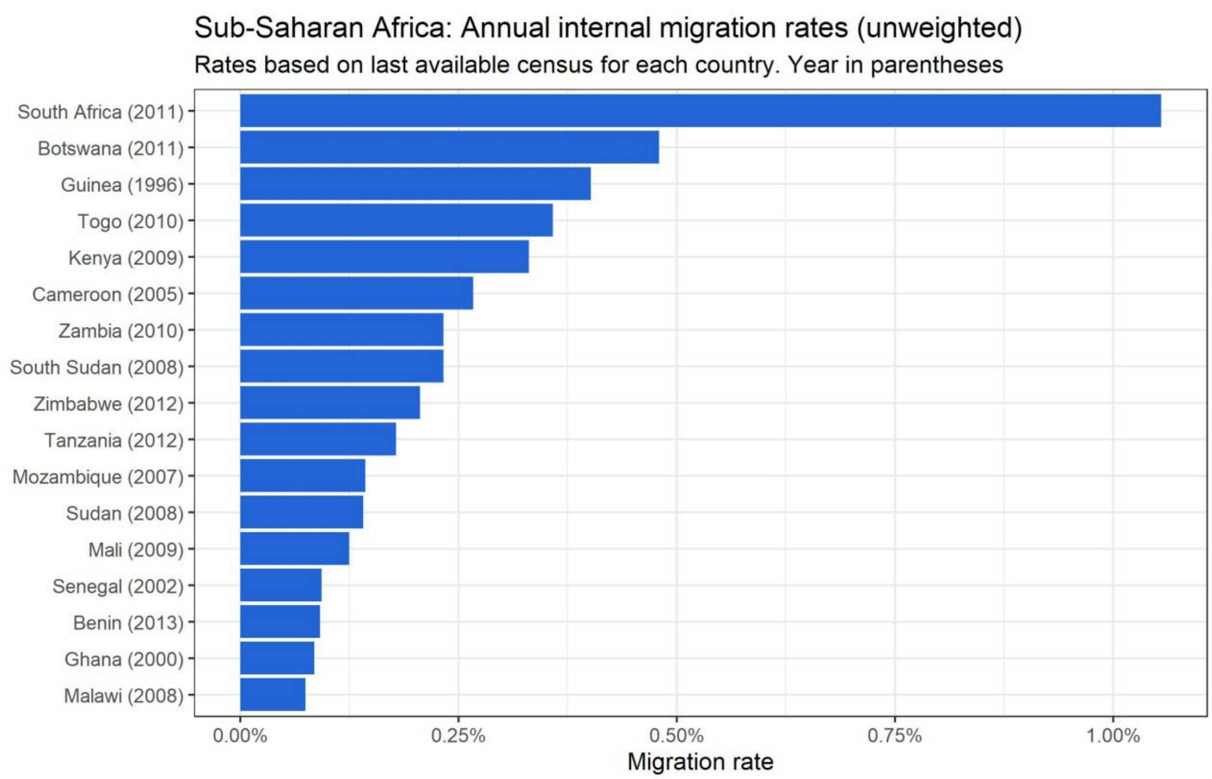

Figure A5 – Yearly internal migration rates for countries in sub-Saharan Africa based on the most recent census. The year of the census is provided in parentheses behind the country names.

Table A1 – Baseline models estimating drying impacts on migration

	Outcome: Annual out-migration rate			
	(1)	(2)	(3)	(4)
AI (mean past 10y)		-0.2688*** (0.0872)		
NDVI (mean past 10y)			-0.2111*** (0.0361)	
SPEI (mean past 10y)				-0.1084*** (0.0281)
log(population origin)	-0.8263*** (0.0697)	-0.8356*** (0.0728)	-0.5834*** (0.0700)	-0.8315*** (0.0707)
log(population destin)	0.1783*** (0.0580)	0.1859*** (0.0605)	-0.2317*** (0.0684)	0.1799*** (0.0584)
census interval	-0.1123*** (0.0097)	-0.1135*** (0.0103)	-0.2585*** (0.0173)	-0.1087*** (0.0098)
# origin regions	-0.0021 (0.0023)	-0.0016 (0.0023)	0.0285*** (0.0051)	-0.0017 (0.0022)
Time FE	Yes	Yes	Yes	Yes
Origin FE	Yes	Yes	Yes	Yes
Destination FE	Yes	Yes	Yes	Yes
S.E.: Clustered	by: origin	by: origin	by: origin	by: origin
Observations	98,868	95,276	42,563	98,850
Pseudo R2	0.19516	0.19501	0.20676	0.19523
BIC	32,415.70	31,511.60	22,479.20	32,414.60

Note: PPML fixed effects gravity models. Poisson regression coefficients with cluster robust standard errors in parentheses. Clustering of standard errors at origin region level. Input variables: Aridity index (AI), Normalized Difference Vegetation Index (NDVI), Standardized Precipitation Evapotraspiration Index (SPEI). For all main climatic input variables, smaller values indicate drier conditions. Accordingly, negative relationship coefficients indicate an increase in migration with drier conditions. The outcome variable is the net outmigration rate. P-values: * 0.1 ** 0.05 *** 0.01

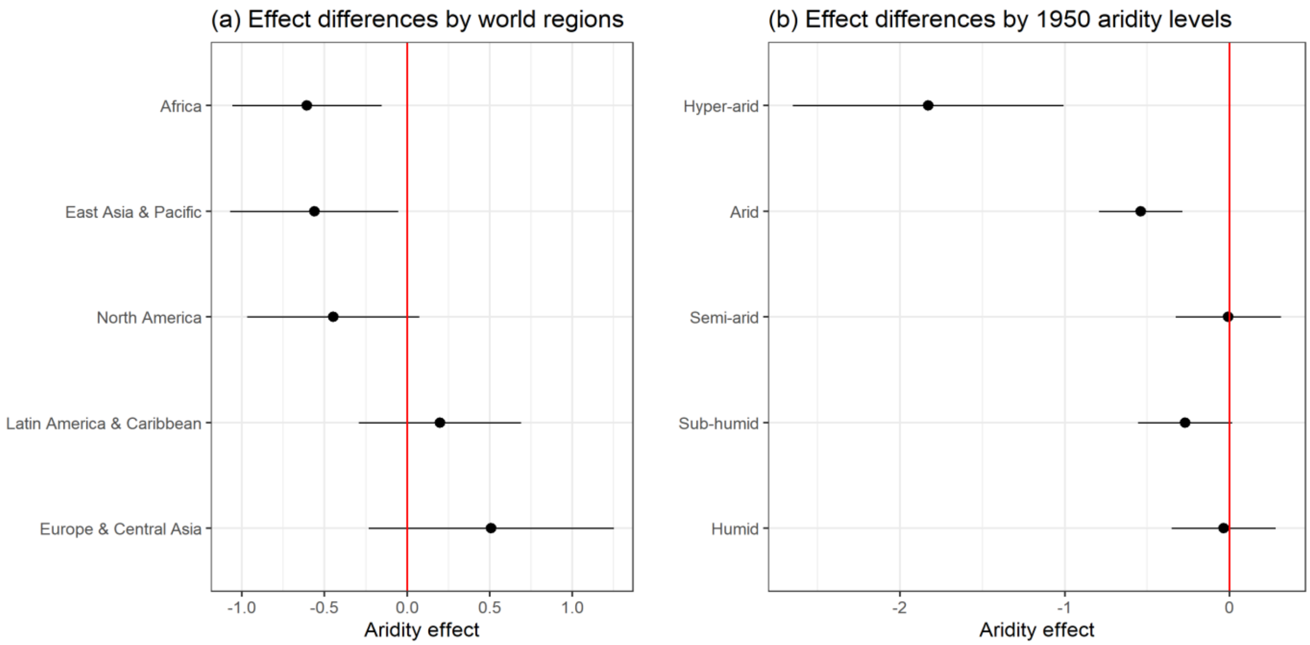

Figure A6 – Heterogeneities in the effects of drying on migration. The panels show coefficient dot whisker plots (based on baseline model 2) showing differences in the effects of changes in aridity for (a) different world regions and (b) different ecosystems. Negative effects indicate an increase in migration with increasing aridity. Stronger effects of drying on migration are observable for regions in Africa and East Asia and the Pacific, and for hyper-arid and arid regions.

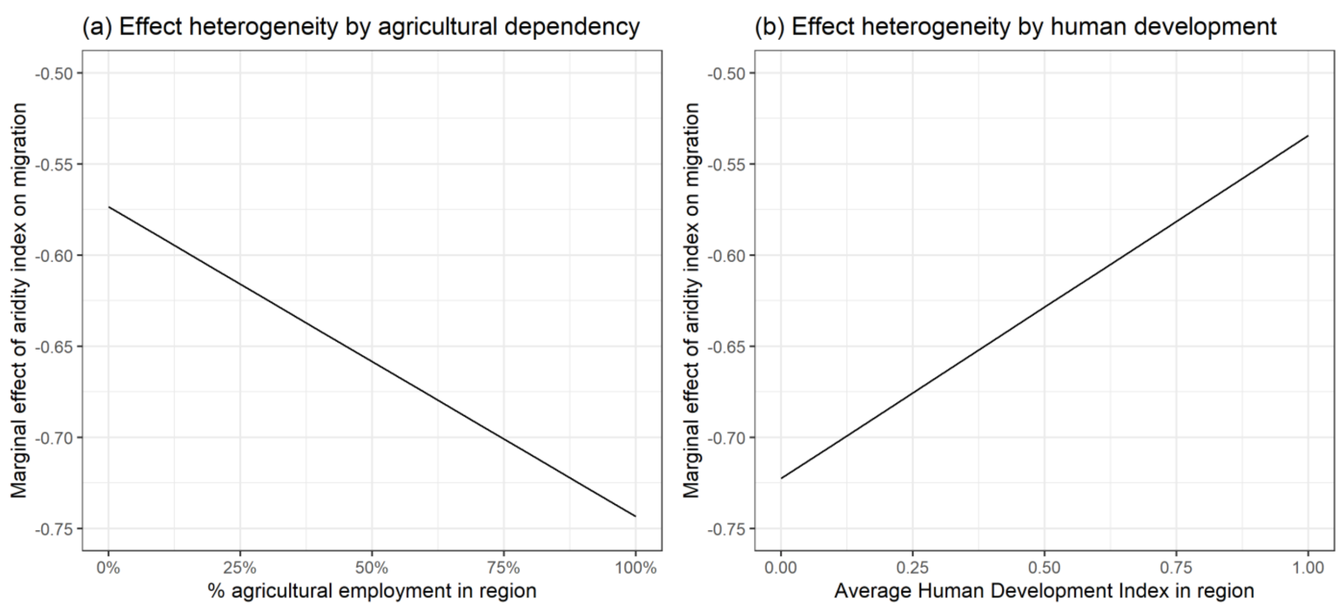

Figure A7 – Heterogeneities in the effects of drying by socioeconomic characteristics of census regions. The graph shows changes in marginal effects of the aridity index on migration with (a) increasing agricultural employment in a region and (b) with an increasing human development index (HDI) in a region. Stronger negative effect sizes indicate a stronger impact of drying on migration. Migration impacts of drying are estimated to be stronger in more agriculturally dependent and less developed regions in the sample.

Table A2 – Extended models estimating the impacts of climate anomalies on internal migration rates

	Outcome: Annual outmigration rate						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Climate							
Origin: % months past 10y with precipitation anomaly (<1SD)		0.01972***					0.01445*
		(0.005777)					(0.008525)
Destin: % months past 10y with precipitation anomaly (<1SD)		-0.003887					-0.006337
		(0.004246)					(0.004246)
Origin: % months past 10y with precipitation anomaly (>1SD)			0.008022				
			(0.006211)				
Destin: % months past 10y with precipitation anomaly (>1SD)			-0.003233				
			(0.00489)				
Origin: % months past 10y with temperature anomaly (>1SD)				0.00776*			0.006645*
				(0.004004)			(0.00392)
Destin: % months past 10y with temperature anomaly (>1SD)				-0.006496**			-0.005875**
				(0.003042)			(0.002972)
Origin: % months past 10y with temperature anomaly (<1SD)					-0.01403**		
					(0.00662)		
Destin: % months past 10y with temperature anomaly (<1SD)					0.01357***		
					(0.004668)		
Origin: % months past 10y with drought (SPEI<1SD)						0.005132**	0.001952
						(0.002332)	(0.003603)
Destin: % months past 10y with drought (SPEI<1SD)						0.002564	0.004777
						(0.002442)	(0.003209)
Controls							
Log origin population	-0.9092***	-0.9186***	-0.9113***	-0.9133***	-0.9124***	-0.9135***	-0.9214***
	(0.03206)	(0.0317)	(0.03179)	(0.03163)	(0.03137)	(0.03214)	(0.03119)
Log destination population	0.276***	0.2797***	0.2745***	0.2781***	0.2748***	0.2791***	0.2808***
	(0.0276)	(0.02747)	(0.02755)	(0.02746)	(0.02727)	(0.02773)	(0.02733)
# origin regions	-0.005052**	-0.003605	-9.6E-06	-9.8E-06	-0.005683**	-0.005683**	-0.00294
	(0.002362)	(0.002312)			(0.002308)	(0.002308)	(0.002278)
Log distance	-0.8264***	-0.8269***	-0.8267***	-0.8272***	-0.8271***	-0.8263***	-0.8277***
	(0.02418)	(0.02417)	(0.02417)	(0.02426)	(0.02423)	(0.02418)	(0.02425)
Migration interval (5 vs 10 y)	0.2069***	0.2126***	0.2088***	0.2018***	0.2059***	0.2095***	0.2073***
	(0.01132)	(0.01162)	(0.01124)	(0.01064)	(0.01086)	(0.01148)	(0.01102)
Fixed effects							
Origin	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Destination	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year (5 Year Intervals)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S.E. type: Clustered	by: origin	by: origin	by: origin	by: origin	by: origin	by: origin	by: origin
Observations	98,868	98,868	98,868	98,868	98,868	98,868	98,868
Squared Corr.	0.665	0.666	0.666	0.666	0.667	0.665	0.667
Pseudo R2	0.24009	0.24023	0.24015	0.24025	0.24027	0.24014	0.24037
BIC	37,560.60	37,582.17	37,583.02	37,581.94	37,581.75	37,583.11	37,626.70

Note: PPML fixed effects gravity models. Poisson regression coefficients with cluster robust standard errors in parentheses. Clustering of standard errors at origin region level. The outcome variable is the net outmigration rate. P-values: * 0.1 ** 0.05 *** 0.01