

Environmental refugees: The impact of climate change on emigration¹

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Abstract

Scholars increasingly argue that one of the links between climate change and conflict is likely to be migration, particularly at the *domestic, intrastate* level. Raises in temperature and precipitation may force people to leave their homes and, predominantly *within a country*, settle elsewhere. While country-specific studies provide evidence for this pattern, the literature offers little guidance, both theoretically and empirically, on whether climate-induced migration also occurs *between* countries, i.e., internationally. Examining this issue seems crucial as finding evidence for transnational environmental migration pushes the significance of this issue from a domestic to an international, global scale. This research addresses this shortcoming by studying whether people leave their home and migrate to other countries due to climate change. Empirically, the theoretical arguments are analyzed with recently compiled time-series cross-section emigration data since the 1960s. The results suggest that increases in temperature are strongly associated with emigration. Controlling for unobserved influences via country and year fixed effects, changes in the estimator, and other robustness checks further increase our confidence in this finding. This research substantially improves our understanding of how climate change forces individuals leaving countries and emphasizes that climate-induced migration is, in fact, a global phenomenon.

Keywords: Climate change; international migration; quantitative analysis

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Introduction

Migration pertains to people leaving their home (“origin”) to live elsewhere. In general, scholars have focused on push factors to explain this phenomenon. Among the socio-political factors (i.e., unemployment, war, or human rights violations), the literature increasingly acknowledges the importance of climatic reasons (i.e., droughts, floods and high temperatures) that drive people to leave their homes and move away. These people migrating for the latter reason are known as “climate refugees” and they belong to a larger group of immigrants known as “environmental refugees.” Environmental refugees consist of migrants forced to flee due to natural disasters, such as volcanoes or tsunamis (and other environmental disasters). To illustrate the substance of this phenomenon, the International Red Cross estimates that there are more environmental refugees than political refugees fleeing from wars and other conflicts: more than 36 million people were displaced by natural disasters in 2009 (United Nations High Commissioner for Refugees (UNHCR)).

Given the large scale of this phenomenon, and because climate change is likely to have a profound effect on agriculture, natural disasters, diseases, and economic activity more generally, it is not surprising that scholars have been and continue examining not only the economic and political determinants of migration, but also environmental reasons (e.g., Anthoff et al. 2006; Reuveny 2007; Laczko and Aghazarm 2009). The argument about the connection between climate change and migration boils down to individuals’ life satisfaction (see also, Luechinger and Raschky 2009). In general, migration is driven by people’s capability and opportunity to migrate (Hunter et al. 2015). Arguably, people look for life satisfaction in suitable and safe areas (Luechinger and Raschky 2009). But if the living conditions in one area become intolerable, the individual will eventually *have* to move away, i.e.,

willingness and opportunity are both affected by environmental change. But where does an individual then go to? While existing work shed light on migration flows due to variability in the weather and climatic shocks (see, e.g., Reuveny 2007; McLeman 2014), the focus – so far – has been on the mobility *within the state*. Implicitly, previous studies thus suggest that migration flows associated with environmental factors are merely internal (Adger et al. 2015; Hunter et al. 2015; Adamo and Izazola 2010; Raleigh et al. 2008). Hence, for example, if the sea level rises in the South of state A, people will be moving to the North of the same country.

Hartman (2010) refers to the degradation narrative and explains that scholars and practitioners are often ill informed about the real roots of problems. For instance, it is common to blame farmers for land degradation. Evidently the one does not exclude the latter. Along these lines existing literature links the Syrian uprising to a series of social, economic and political factors. Nevertheless, De Châtel (2014) explains how the 2006-2010 droughts in Syria led to the uprising and the following increase of emigrants. She particularly argues that it was not the drought per se that generated the uprising that followed by a conflict and millions of refugees but the government's failure to respond to humanitarian needs affected by environmental reasons (see also, Kelley et al. 2015).

I therefore posit that if the environment has a major impact and state capacity is unlikely to facilitate adaptation, climate change will influence the state as whole. In this case, it seems equally plausible that people are forced to flee out of their home countries and therefore, *migrate to another country*. In order to address the neglect of this issue in previous work, I stress the phenomenon of emigration² with regards to

² Throughout the manuscript, I use the terms emigration, transnational migration, and international migration interchangeably to describe people's mobilization from their home country to another.

climate change and examine whether climatic change factors actually force *people out of their country*. Considering the consequences of emigration (e.g., economic instability, diseases, etc.), finding evidence for international environmental migrants will highlight that climate-induced migration is, in fact, a global phenomenon – and not limited within-country movements.

Country-specific studies have shown that people move *within states* looking for better and safer conditions (Massey et al. 2010; Black et al. 2011; McLeman 2014; Adger et al. 2015; Hunter et al. 2015). But are people also forced to *transnationally migrate* because of climate change? I offer the first study on this issue, providing evidence on climate variability and emigration. To this end, I contribute to the literatures on the environment and conflict, transnational diffusion, and migration. Empirically, the corresponding arguments are analyzed with time-series cross-section data from 1960 to 2000.³ I focus on how climate-change variables, i.e., temperature and precipitation patterns, affect emigration levels for capturing the conditions that force people to leave their country. The results do indeed suggest that high levels of temperature make people to emigrate from their countries, which is likely to have crucial implications globally – and not only within specific countries.

The next section reviews the existing literature on transnational migration. This not only allows me to highlight most alternative determinants of emigration, but also to stress that environmental factors have not been considered so far here.⁴ In turn, I will develop an argument for climate-induced international migration, i.e., emigration. The following section describes the research design, while I then present and discuss the

³ The availability of data limits the period under study. I will return to this in the research design section.

⁴ As discussed above, this differs from the previous research on the climate-migration nexus, which has a focus on the domestic level only.

findings. The last section concludes and discusses potential avenues for further research.

Transnational migration: Causes and consequences

The causes of migration are complex and, to a large degree, context-specific (Hartman 2010). People choose to migrate only as a last resort as costs are associated with migration as well (Black et al. 2013; Penning-Rowsell et al. 2013). Hence, migration might be driven by a series of factors that are usually intertwined and generate intolerable living conditions. As a result, people are forced to leave their homes, looking for a new place to live. The literature usually focuses on push factors, distinguishing between willingness and opportunity aspects. First, several factors pertain to the opportunities for migration. After the end of World War II, for example, several countries liberalized their immigration admission policies, thus increasing immigration from a larger set of countries. Furthermore, with the creation of the European Union in 1992, the freedom of movement began within the union. Similarly, as the Cold War waned, the West experienced large migrant inflows from former Eastern bloc countries (Zlotnik 1999). Asia, on the other hand, encompasses the labour migration system revolving around the oil-producing countries of Western Asia. Parallel to these changes, commercial air travel has made transportation faster and cheaper than ever before (Zlotnik 1999; Castles 2002). In general, globalization processes induce higher cross-border mobility. It is in fact the case that international migration has increased significantly only due to these opportunity factors. In addition, willingness factors influence an individual's opinion to emigrate (Most and Starr 1989). Literature refers to the willingness factors as "stressors", reasons that affect people's living satisfaction and could potentially impact on their willing to

migrate (Speare 1974; Knapp and Graves 1989; Lilleør and Van den Broeck 2011; Adger et al. 2015; Hunter et al. 2015).

Against this background, the literature focuses on more specific determinants of emigration that pertain to both willingness and opportunity, i.e., economic and political drivers (which are, of course, also highly interrelated). Economic reasons of emigration are primarily about “labour emigration.” Existing studies argue that declining economic growth, low business activity, high levels of unemployment, and poverty are all (interlinked) determinants that push people to flee out of their countries looking for employment and better living standards in other states (Vanderkamp 1971; Vidal 1998; Gibson and Mckenzie 2011). As a consequence, highly trained and qualified people might leave their home country looking for higher life standards in another state, i.e., we observe the so-called “brain drain” (Portes 1976; Beine et al. 2008; Gibson and Mckenzie 2011). Roncoli et al. (2001) demonstrate that a large number of Burkinabe people migrated to Ivory Coast for economic reasons (see also, Cordell et al. 1996).

With regard to the political determinants of emigration, research mostly focused on conflicts and human rights violations. And, in fact, one of the devastating consequences of war for societies is the massive dislocation of populations (Davenport et al. 2003; Moore and Shellman 2004; Salehyan and Gleditsch 2006; Raleigh 2011). This is a result of conflict, ethnically, religiously, or ideologically motivated, disputes over land and property rights, or guerrilla warfare, including low-intensity conflict. Conflict circumstances, in general, create unstable and unfavourable conditions for survival. In particular the breakdown of the social nets, family loss, the disruption of daily life, lack of shelter and food shortages, the lack of basic services, and the destruction of the local infrastructure contribute to extreme

forms of life dissatisfaction. In the last decades, for instance, countries affected by conflict like Liberia, the Central African Republic, or Cambodia have experienced internal and external displacements (Barnett 2000; Raleigh 2011) For example, estimates in 2010 place the total internal displaced population (IDP) at 27 million (Raleigh 2011).

These factors are known to mobilize, at first, within a state. Nevertheless, when these factors become intense and affect a country as a whole, e.g., wars or financial crises, people become more and more inclined to move to another country. In light of this, when examining thoroughly the potential reasons of transnational migration, we can see that only events that affect a country as a whole are likely to induce international emigration. If a phenomenon is not spread across the whole country, people still opt for alternatives within the state of their origin, as migration across countries is presumably more costly. Along these lines, I examine in the next section the effect of climate change on transnational migration. While some forms of climate change may only affect specific regions of a country (i.e., coastal areas), there are also more widespread climatic changes that potentially can affect larger geographical areas and thus, a country as a whole. If finding evidence for this claim, international climate-induced migration is a global-scale problem that will require more direct and immanent policy responses than domestic-level migration.

Climate change: How is it linked to transnational migration?

Changes in the atmospheric composition occur from anthropogenic emissions of greenhouse gases, such as carbon dioxide that results from the burning of fossil fuels and methane, and nitrous oxide from multiple human activities (e.g., Karl and Trenberth 2003). While there is consensus that climate change occurs, and is driven

by mankind to a large degree, there is less consensus about its consequences, particularly in the security sector. Climate change is a highly complex and long-term phenomenon, which is hard to grasp for “ordinary” citizens. Not everybody is affected by climate change equally, and its consequences are not easily observed from one day to another. That said, one stream in the literature known as neo-Malthusian posits that climate change is a direct threat to international security (e.g., Homer-Dixon 1999). On the other hand, scholars known as Cornucopians argue that humanity will be able to adapt to the challenges of climate change through technological innovation (e.g., Lomborg 2001).

An observable implication of climate change is climate variability, i.e., higher temperatures and precipitation. Higher temperatures melt the ice and, thus, raise sea levels. Moreover, higher temperature increases the likelihood of droughts and leads to shortages of water both portable and for agricultural use. Hence, increases in temperature and precipitation change the living conditions and generate survival issues at a large scale (Henry et al. 2004). The literature then has focused on climate-induced migration, albeit at a domestic level within countries and defines environmental migrants as follows:

“Environmental refugees are these people who can no longer gain a secure living in their traditional homelands because of environmental factors of unusual scope, notably drought, desertification, soil erosion, water shortages and *climate change* (emphasis added), also natural disaster such as cyclones, storm surges and floods In face of these environmental threats people feel they have no alternative but to seek sustenance elsewhere, whether within their own countries or beyond

and whether on a semi-permanent or permanent basis” (Myers 1995: 18).

As discussed in the previous section, although existing studies have pointed out that migration occurs due to climate change, the main focus of this work lies at the domestic level (Mathieu 1994; Ezra 2001; Henry et al. 2004). The decision to migrate is based on several factors. Voluntary migrants have a variety of motives, and among the most common ones is the desire for economic improvement. That being said, people affected by climate change are unlikely to voluntarily emigrate, because they are pushed away from their home by external forces (climate change). And this is precisely the reason why these people are called refugees, and not migrants (Bates 2002).

Human settlement patterns have been changing throughout history. And environmental migration is not a new phenomenon as human settlement choices have been driven by climatic conditions. Already Aristotle wrote that “the lands beyond the tropics are uninhabitable,” implying that only temperate areas were habitable (Isenberg 2014: 180). In addition, in the 1930s, an estimated 2.5 million North Americans have left the Great Plains because of droughts and dust storms (Reuveny 2007; see also McLeman 2006, 2014), while, in 2005, Hurricane Katrina resulted in 1.5 million people being displaced temporarily and about 500,000 permanently (McLeman 2014; Fussell et al. 2009; Grier 2005). Again, however, most of these patterns pertain to domestic, within-country migration, and the existing literature has focused on this accordingly. A systematic analysis of transnational migration is missing so far.

My main argument focuses on the impact of climate change in total on a country. That is, climate change is a global threat, affecting countries directly at large. It is

usually not the case that only a few, remote areas within a nation experience the impact of an altered climate (Nordås and Gleditsch 2007). When the climate changes, this in turn directly affects the country as a whole. Climate change also influences multiple political and economic characteristics of a state. Climatic change might affect both economic (e.g., unemployment) and political (e.g., violence) drivers of emigration that could influence a country in total, thereby creating an indirect path to emigration as well. Both mechanisms, a direct and an indirect one, could eventually lead to more migration and ultimately increase transnational migration as a country is affected by climate change in its entirety.

Note that the existing literature suggests that climate change will exacerbate resource scarcity, create mass population dislocation, and, ultimately, fuel violent conflicts (Salehyan and Gleditsch 2006; Salehyan 2008). In other words, climate change can be considered a source factor of human catastrophes (Salehyan 2008). When subscribing to these effects, and further arguing that resource scarcity, mass population dislocations, and violent conflicts may not necessarily affect only remote, isolated areas of a state, but affect the country as a whole (Nordås and Gleditsch 2007) migration should not only be seen within countries, but across states. Environmental emigration induced by climate change is thus a global phenomenon.

Along the lines of existing theoretical framework on the push factors of migration, “opportunity” and “willingness”⁵ defines people’s decision of moving elsewhere (Vanderkamp 1971; Most and Star 1989; Vidal 1998; Gibson and McKenzie 2011). People do not only consider the necessity of moving away (usually defined by the current living conditions), but they also take into account the conditions that they will face in the new environment Hence, people move within a country to areas where

⁵ Morrissey (2008) similarly notes that people’s decisions to migrate are affected by both structural and individual factors.

there is some potential for better living conditions. However, what if a country is affected at a larger scale, perhaps suffering from a negative externality countrywide? Climate change could be such a variable as it affects states at a larger scale and potentially as a whole. For instance, McAdam and Loughry (2009) focus on migration in the small islands of Kiribati and Tuvalu and claim that climatic change along other socio-economic has forced people to migrate. In recent years these islands have been reported in the media as the “shrinking islands”. The authors claim “the islands will be uninhabitable by the middle of this century whilst their people will be the world’s first climate refugees” (McAdam and Loughry 2009). The total surface of Kiribati (all islets included) is 811 km². Given that the sea levels in the pacific have risen,⁶ it is very well known that all islands are affected, forcing people not only to domestically migrate from one area to another, but also to look for another nation, a non-island state, to emigrate to. Eventually, the expectation in light of this discussion is that transnational migration is also possible due to climate change, and I thus seek to test the following hypothesis:

Hypothesis: Climate change leads to transnational migration (i.e., emigration).

Research design

Data and dependent variable

For the empirical test of my hypotheses, I use time-series cross-sectional data. The unit of analysis is country year between 1960 and 2000. Data on migrants are taken from the World Bank and refer to the total amount of migrants leaving one country in

⁶ At the United Nations Framework convention for Climate Change (UNFCCC) annual conference of the parties (COP) was reported that sea levels have risen by 20cm in the last century (FAO 2015). Available at www.fao.org/climate-change/international-fora/major-events/unfccc-cop-21/en/.

a given year (transnational migrants). The World Bank estimates are derived from over 1,100 national individual census and population register records for more than 230 destination countries and territories over the last five decades (i.e., 1960-2000) (Özden et al. 2011). As each census round was conducted during a 10-year window, I linearly interpolated all missing data between two consecutive rounds. The variable of emigrants is also logged transformed. For example, in 2000, 566,091 people left Honduras moving to another country.

Given a continuous dependent variable – the number of emigrants, – I employ ordinary least squares (OLS) regression models to empirically test my hypothesis. Next to the main determinants of climate change that I want to focus on, I also control for relevant alternative influences, i.e. “exogenous-external conditions or common shocks” (Franzese and Hays 2007: 142) by including a temporally lagged dependent variable that captures a country’s emigration in the previous year, country-fixed effects, and year-fixed effects.

Thus, I allow for the potential influence of country’s past emigration patterns on their current emigration rates. While including a temporally lagged dependent variable captures time dependencies more generally,⁷ year-fixed effects control for temporal shocks that are common for all states in a given year (e.g., economic crises, EU accession rounds). Country-fixed effects capture any time-invariant unit-level (domestic) influences.

Explanatory variables

Temperature

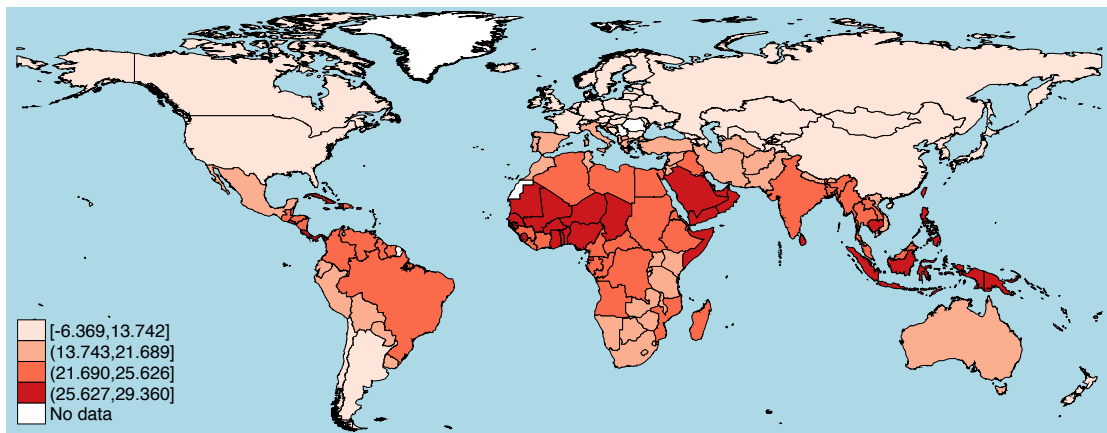
⁷ Given the structure of the data, serially correlated errors within countries might be possible; the temporally lagged dependent variable addresses this (Beck 2001).

Existing research suggests that climate change will lead to more climate variability, including an increasing global temperature (Steinbruner et al. 2013). For the temperature data, I follow Landis (2014) and use the data from NOAA's NCEP/NCAR Reanalysis Monthly Means Dataset 1948-2011 (in degrees Celsius) (Kalnay et al. 1996). These data provide surface or near surface air temperatures (at a 0.995 sigma level) with spatial coverage of a 2.5*2.5 degree longitude native resolution (144*72).

“Temperature mean” is measured as the monthly mean temperature for country i in month t in year z . This temperature shock measure uses the monthly deviation from a country's long-term monthly mean, indicated by $(X_{itz} - X_{it-\bar{t}})/a_{it}$ where X_{itz} is the mean temperature of country i in month t in year z , and $X_{it-\bar{t}}$ is the panel mean of country i 's long-term monthly ($t-\bar{t}$) mean temperature for the period 1948-2011, and a_{it} is the standard deviation of that panel (Landis 2014). According to Landis (2014), this approach is adopted from Hendrix and Salehyan's (2012: 41) measure of rainfall deviation, as the latter study argues that deviations from the panel mean are an optimal operationalization of the “eco-shock” mechanism. For the purposes of this analysis, I employ the *yearly* average temperature for each country.

Landis (2014) also suggests that a deviational measure like this is preferable to other measures of climate variability, because its construction acknowledges that climate is different from weather as the climate does in fact change over decades. The weather, though, can change on a daily basis. Moreover, this measure is standardized, allowing for meaningful comparisons of deviational differences between countries. Figure 1 illustrates the temperature rates in the world between 1960 and 2000. The temperatures pertain to yearly average temperature levels in each country between 1960 and 2000, measured in Celsius.

Figure 1: World map for yearly average temperatures

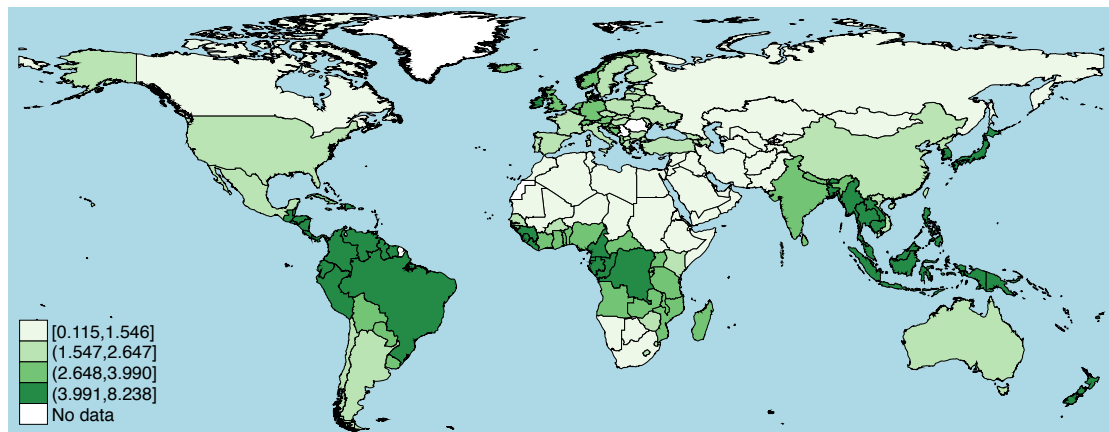


Note: to facilitate the illustration of the temperatures I employed four different temperature categories where light red colour refers to low temperatures and dark red colour to high temperatures.

Precipitation

Temperature changes affect precipitation patterns. Countries affected by low levels of precipitation suffer from various extreme conditions, including droughts. These phenomena are consequences of climate change that make former habitable land inhabitable. Hence, I use precipitation as another climate-change indicator that may affect transnational migration patterns. Along the lines of Landis (2014), I aggregate monthly levels of precipitation and precipitation deviations using monthly precipitation data (mm/month) from the Global Precipitation Climatology Project Version 2.2. These data have a spatial coverage of 2.5*2.5 degrees with a longitude resolution (144*72) for 1979-2011 (Adler et al., 2003). Figure 2 illustrates precipitation rates in the world between 1979 and 1999. Precipitation pertains to yearly average precipitation levels in each country between 1979 and 1999, measured in millimetres (mm).

Figure 2: World map for yearly average precipitation



Note: to facilitate the illustration of the temperatures I employed four different precipitation categories. Dark green pertains to high levels of precipitation, while lighter greens pertain to lower levels of precipitation.

In terms of the control variables, I consider a set of indicators that *can* influence the willingness and opportunity drivers for translational migration. I refer to the interested reader to the previous literature that discusses these factors in depth, e.g., Gray and Mueller (2012b); Van der Land and Hummel (2013); Hunter et al. (2015). In order to address issues of simultaneity bias, all explanatory variables are lagged by one year.

A variable for a state's (i.e., the state sending migrants, which is the unit of analysis) regime illustrates whether people's choice of leaving their country is also affected by domestic politics in the source country (e.g., human rights violations). For measuring democracy, I include the polity2 item taken from the Polity IV data set, which covers basically all countries in my sample over the entire period (Marshall and Jaggers, 2010). Polity2 measure ranges from -10 to 10.

High unemployment might also push people to leave their countries looking for better life conditions, and I thus include an indicator for unemployment from the World Bank Development Indicators. The measure for unemployment refers to the share of the labor force that is without work but available for and seeking

employment. For example, in 2000, Greece was affected by 11.1% of unemployment. The original variable of unemployment suffers from missing values in 79% of the sample cases. To address this issue, I linearly interpolate these missing values.

I also control for population size and GDP per capita using data from Gleditsch (2002). These measures are logged to reduce their distributions' skewness, because some countries are much wealthier and larger than other countries.

Table 1 summarizes the descriptive statistics of all variables discussed so far as well as the variation inflation factors (VIFs) of the explanatory factors. According to the VIFs, multicollinearity is unlikely to be a major issue, since all VIFs are well below the common threshold value of 5. Variables with a value over 5 would indicate high multicollinearity (O'Brian 2007). The appendix presents a correlation matrix for all variables included in this analysis (Table 1 in the appendix).

Table 1: Descriptive statistics and VIF

Variable	Obs.	Mean	Std. Dev.	Min	Max	VIF
Emigrants \ln	7,680	11.77	2.23	0	16.40	
Emigrants \ln (lag)	7,872	11.75	2.24	0	16.40	
Temperature (lag)	6,015	19.69	7.45	-8.42	30.73	1.39
Precipitation (lag)	3,635	3.07	1.93	0.07	10.40	1.21
Democracy (lag)	5,467	-0.24	7.55	-10	10	1.48
Unemployment (lag)	5,405	10.58	7.80	0	39.03	1.03
GDP per capita \ln (lag)	5,995	8.24	1.12	5.14	11.34	1.42
Population \ln (lag)	6,015	8.55	1.92	2.81	14.05	1.08

Empirical analysis

How does climate change affect transnational migration? To answer this question, I provide a time-series cross-section analysis that moves beyond the conventional examination of climate-induced migration at the domestic, within-country level. This approach will allow me to draw inferences for an overall assessment on whether and how environmental events, on average, drive emigration.

As indicated above, all models are based on OLS regression, which include year- and country-fixed effects and a lagged dependent variable, and I employ robust standard errors clustered on country to address potential problems of intra-group correlation and heteroskedasticity. Table 2 presents all models on climate's impact on emigration. I start with a baseline model, which omits control variables as they may actually increase the bias instead of diminishing it (Clarke 2005). Model 2 constitutes my full model, i.e., all control variables are included. Finally, Model 3 omits the year- and country-fixed effects: models including these items make the estimation of slow-moving, largely time-invariant variable inefficient. Model 3 thus demonstrates that my core results are not dependent on whether or not I include the fixed effects.

Table 2: The impact of climate change on emigration

	(Model 1)	(Model 2)	(Model 3)
Emigrants_{ln} (lag)	0.999*** (0.00)	0.989** (0.00)	0.999*** (0.00)
Temperature (lag)	0.001*** (0.00)	0.003** (0.00)	0.001*** (0.00)
Precipitation (lag)	0.003*** (0.00)	0.002 (0.00)	0.003*** (0.00)
Democracy (lag)		-0.001 (0.00)	-0.001 (0.00)
Unemployment (lag)		0.001* (0.00)	-0.001 (0.00)
GDP per capita_{ln} (lag)		-0.016 (0.01)	0.001 (0.00)
Population_{ln} (lag)		-0.016 (0.02)	-0.001 (0.00)
N	3,448	2,740	2,740
Country fixed effects	No	Yes	No
Year fixed effects	No	Yes	No
R2	0.9997	0.9999	0.9996
RMSE	0.03657	0.01963	0.03193

Notes: table entries are coefficients; standard errors in parentheses; year- and country-fixed effects included in all models, but omitted from presentation. The results capture the period between 1979 and 1999 because of the limited data availability for the precipitation variable. Omitting the precipitation item, however, does virtually not change the main findings. Please refer to the appendix in Table 4.

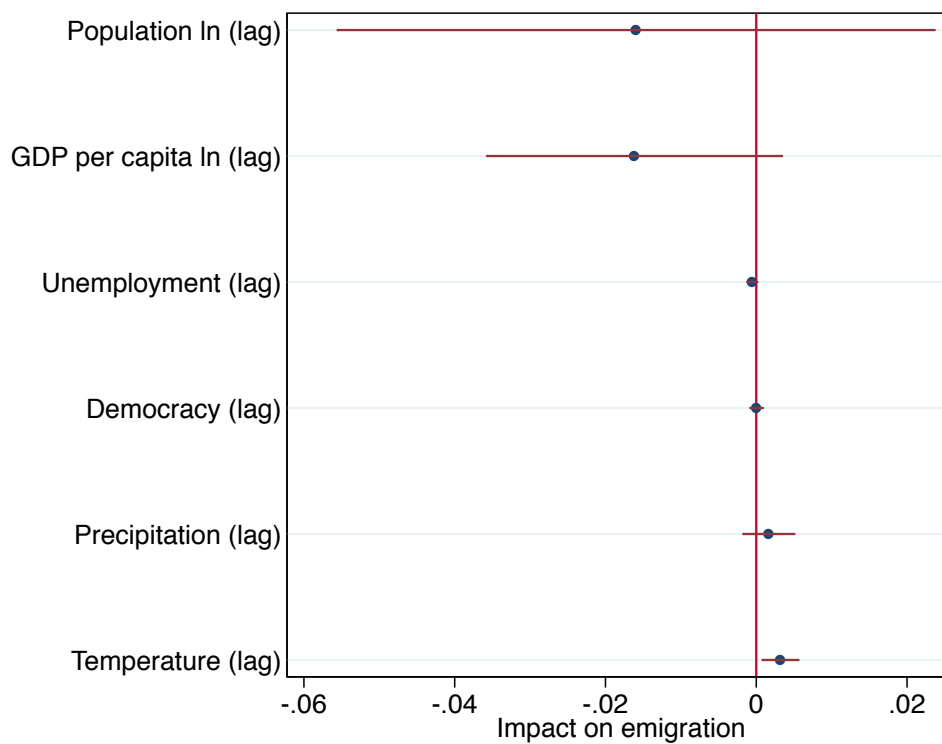
* p<0.10; ** p<0.05; *** p<0.01

Due to the temporally lagged dependent variable, the coefficient estimates of all other explanatory variables only reflect the short-term effect, i.e., the impact in a current year (Figure 2). In order to estimate the asymptotic, long-term impact of the independent variables, I re-estimate the individual coefficients by taking into account the coefficient of the lagged dependent variable (Plümper et al. 2005: 336), “where β_0 is the estimated coefficient of the lagged dependent variable.”

$$y_t(\alpha, \nu) = \alpha \sum_{n=0}^T \beta_0^n + \sum_{n=0}^T \theta_t \beta_0^{(t-n)}, n = [0, T] \quad (1)$$

Equation 1 illustrates how the intercept, the lagged dependent variable, and the period dummies commonly capture much of the time series variance in panel data structure. Accordingly, I estimate asymptotic long-term effects (in addition to short-term effects) for the explanatory variables of Model 2 and summarize them in Figure 3.⁸

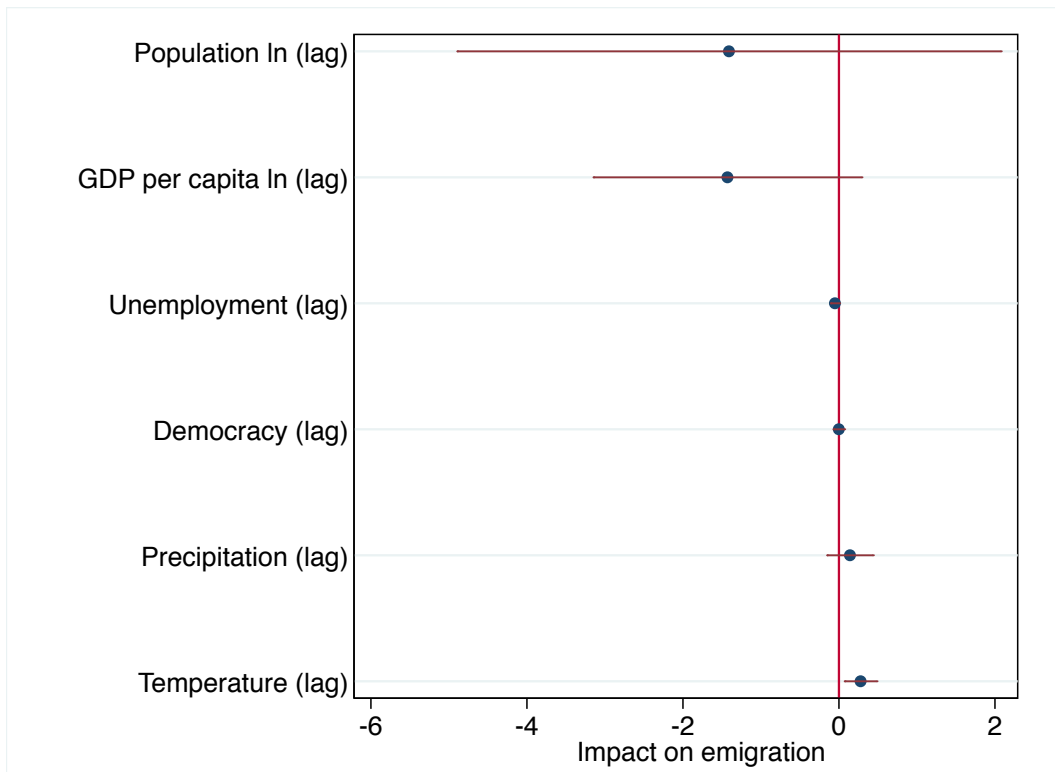
Figure 2: Short-term effects on emigration (Model 2)



Note: the horizontal bars are 90 percent confidence intervals and the vertical red line represents a marginal effect of 0. Estimates are based on models in Table 3, Model 2.

⁸ The results of Figures 2 and 3 are also presented in tables in the appendix for a better illustration of the coefficients and confidence intervals.

Figure 3: Asymptotic long-term effects on emigration (Model 2)



Note: the horizontal bars are 90 percent confidence intervals and the vertical red line represents a marginal effect of 0. Estimates are based on models in Table 3, Model 2.

The coefficient estimate of *Temperature* is 0.003 (Model 2). Given that the outcome variable is log-transformed, the substantive short-term effect of *Temperature* is $\exp(0.003)$, i.e., for a two-unit increase in temperature (2 degree Celsius)⁹, the geometric mean of emigrants increases by 0.06 percent. That is, the mean of logged emigrants variable (11.77) translates into 129,314.15 emigrants. A share of 0.06 percent of that figure pertains to an additional 776 people leaving the country. The asymptotic long-term effect is 0.25, which is calculated using Equation 1 described above. In substantive terms, we obtain $\exp(0.25)$, i.e., 1.28. That is, although the short-term effect is in fact rather small, the substantive long-term impact of

⁹ UNFCCC global temperature target increases are limited to below 2 degrees Celsius. (see also, www.unfccc.int/key_steps/cancun_agreements/items/6132.php).

temperature highlights that an increase in temperature by two units (2 degree Celsius) leads to an increase of emigration by about 72,416 people. This is about seven times the population of the Republic of Nauru. These estimates, 0.003 and 0.25 are statistically significant, at least at the 5 percent level. Given that I control for a large set of alternative explanations, including year- and country-fixed effects, there is strong confidence in the validity of my findings.

With regards to the indicator of precipitation, the results indicate statistically significant impact on transnational migration only when not applying country and year fixed effects (Models 1 and 3 in Table 2). However, when I control for country and year fixed effect the impact of precipitation on transnational migration withdraws.

The results for democracy do not indicate a significant impact on transnational migration in any of the presented models. The indicator for unemployment is positive and statistically significant when applying country and year fixed effects while there is statistically significant relationship on emigration without the country and year fixed effects. The predictors for GDP per capita and population do not have a significant impact emigration.

In order to demonstrate how predictions of climatic change (temperature and precipitation) impact on transnational migration I examine the predictive power of the explanatory variables via in-sample predictions. Following the approach of in-sample prediction, I examine how accurate are the “conditional statements about a phenomenon for which the researcher actually has data, i.e., the outcome variable has been observed?” (Bechtel and Leuffen 2010: 311). Böhmelt and Bove (2014: 3) explain that “Theil’s U is the square root of the ratio between the sum of squared prediction errors of the baseline model¹⁰ and the sum of squared prediction errors of a

¹⁰ i.e., Model 3 in Table 2 in this analysis.

naïve model, that is, a no-change prediction. The closer the MPSE is to 0, the more accurate is the model in making predictions. Moreover, if Theil's U is larger than 1, the model actually performs worse than the *naïve* model; values for Theil's U smaller than 1 indicate that the "theoretically informed model" performs better than the *naïve* specification." For my baseline model, the MPSE is 0.0010, while the Theil's U is at 0.7717. Table 3 gives an overview of the baseline model's in-sample forecasting power and the individual contribution each of the variables variable employed in Model 3 (Table 2) makes. The contributions of each variable is measured by calculating the difference between the average value of the baseline model's MSPE or Theil's U values on one hand and, on the other hand, the corresponding average goodness-of-fit measure's value calculated for a model that discards that particular item. For example, excluding *Temperature* from the baseline model leads to an increase in Theil's U from 0.7717 to 0.7883. Therefore, *Temperature* does contribute to the model's overall prediction and forecasting power by 0.0166 units according to Theil's U. Similarly, leaving out this variable induces an increase of 0.0000 in terms of the MSPE. The contribution of *Temperature* to the model's forecasting power is therefore given, yet is small in substance, and this mirrors the findings for most other predictors. Finally, note that none of these predictors included in Model 3 diminishes the predictive power. In other words, neither Theil's U nor the MSPE decrease when leaving out an item from the model specification. Ultimately, the specifications used in Model 3 in Table 2 perform well in predicting emigration.

Table 3: In-sample forecasting power (based on Model 3 in Table 2)

Excluded variables	Mean U	Mean MSPE	ΔU	$\Delta MSPE$
None (baseline model)	0.7717	0.0010	-	-
Temperature (lag)	0.7883	0.0011	0.0166	0.0000
Precipitation (lag)	0.7842	0.0014	0.0125	0.0004
Democracy (lag)	0.7965	0.0012	0.0248	0.0001
Unemployment (lag)	0.7833	0.0012	0.0115	0.0001
GDP per capita _{ln} (lag)	0.7728	0.0010	0.0010	0.0000
Population _{ln} (lag)	0.7718	0.0010	0.0000	0.0000

Conclusion

There are a few empirical examinations of the relationship between environmental change and migration, particularly at the domestic, within-country level (e.g., Henry et al. 2004). In this study, I took a different approach by focusing on migration as a global-scale phenomenon, i.e., I examined how climate-change related variables affect transnational migration.

The results strongly and robustly suggest that if temperature continues to rise at the current rate, migration is not only to occur at the domestic level, but across countries. The findings further highlight a significant difference between the short- and long-term effects of temperature on emigration. Given the consequences of migration at larger scales, many countries will face problems, and as my results suggest indirectly due to climate change as well. Existing studies suggest that transnational migration mainly occurs due to economic reasons, but there was no study yet analysing whether climate change influences international migration patterns. I sought to fill this gap.

Internal migration for social, economic, and political reasons is strongly linked to people's return, whilst transnational migration is frequently associated with lower rates of return (Henry et al. 2004). In terms of climate-induced migration, the conditions of return might look even more different. A country affected by unemployment or violence might still be able to recover after decades or even years, providing opportunities to its former citizens to return. A country, however, that is affected by climatic changes will not be able to recover due to the severity of the climate change consequences (i.e., shrinking islands). That is, further research could move beyond the consequences of climate-induced *internal migration* and examine further the climate-induced *transnational migration* and its consequences. Another potential pathway to further research is to examine in depth where environmental refugees go to; do they strategically look for an environmentally safe country or do they choose along other country characteristics (i.e., economic, cultural)? This could provide scholars with implications on the importance of climate change and adaptability for people affected by climate change.

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Appendix

Table 1: Correlation matrix

	Temperature (lag)	Precipitation (lag)	Democracy (lag)	Unemployment (lag)	GDP per capita _{ln} (lag)	Population _{ln} (lag)
Temperature (lag)	1.00					
Precipitation (lag)	0.24*** (0.00)	1.00				
Democracy (lag)	-0.36*** (0.0000)	0.18*** (0.00)	1.00			
Unemployment (lag)	-0.01 (0.36)	-0.14*** (0.00)	0.05 (0.00)	1.00		
GDP per capita_{ln} (lag)	-0.37*** (0.00)	-0.10*** (0.00)	0.45*** (0.00)	0.07*** (0.00)	1.00	
Population_{ln} (lag)	-0.28*** (0.00)	-0.09*** (0.00)	0.10*** (0.00)	-0.03 (0.07)	-0.12*** (0.00)	1.00

Table 2: Short-term effects of climate change

	Marginal effect estimate	Lower bound	Upper bound
Temperature (lag)	0.003	0.001	0.005
Precipitation (lag)	0.002	-0.002	0.005
Democracy (lag)	-0.001	-0.001	0.001
Unemployment (lag)	-0.001	0.001	0.000
GDP per capita \ln (lag)	-0.016	-0.036	0.003
Population \ln (lag)	-0.016	-0.055	0.023

Table 3: Asymptotic long-term effects of climate change

	Marginal effect estimate	Lower bound	Upper bound
Temperature (lag)	0.278	0.073	0.482
Precipitation (lag)	0.142	-0.152	0.435
Democracy (lag)	-0.002	-0.070	0.068
Unemployment (lag)	-0.051	-0.105	0.003
GDP per capita \ln (lag)	-1.429	-3.147	0.290
Population \ln (lag)	-1.409	-4.893	2.074

Table 4: The impact of climate change on emigration (omitting precipitation)

	(Model 1)
Emigrants _{ln} (lag)	0.996*** (0.00)
Temperature (lag)	0.001*** (0.00)
Democracy (lag)	-0.000 (0.00)
Unemployment (lag)	-0.000 (0.00)
GDP per capita _{ln} (lag)	0.002 (0.00)
Population _{ln} (lag)	0.002 (0.00)
N	4,094
Country fixed effects	No
Year fixed effects	No
R ²	0.9995
RMSE	0.03777

* p<0.10; ** p<0.05; *** p<0.01